CLIMATE-SMART AGRICULTURE
Sourcebook

CLIMATE-SMART AGRICULTURE
Sourcebook

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
2013

ISBN 978-92-5-107720-7 (print)
E-ISBN 978-92-5-107721-4 (PDF)

Table of contents

MODULE 6: Conservation and sustainable use of genetic resources for food and agriculture

MODULE 7: Climate-smart crop production system

MODULE 8: Climate-smart Livestock

MODULE 9: Climate-smart forestry

MODULE 10: Climate-smart fisheries and aquaculture

MODULE 11: Developing sustainable and inclusive food value chains for Climate-smart agriculture

MODULE 12: Local institutions

MODULE 13: Mainstreaming Climate-smart agriculture into National Policies and Programmes

MODULE 14: Financing Climate-smart agriculture

MODULE 15: Disaster Risk Reduction: Strengthening Livelihood Resilience

MODULE 16: Making Climate-smart agriculture a work for the most vulnerable: the role of safety nets

MODULE 17: Capacity development for climate-smart agriculture

MODULE 18: Assessment, monitoring and evaluation

Acknowledgements

The drafting of this Sourcebook on Climate-Smart Agriculture, Forestry and Fisheries has been a collaborative effort involving professionals from within several departments of FAO and a variety of partner organizations. Many individuals played a leading role as main authors and coordinators in the preparation of the modules, while others made written contributions to the Modules' boxes and case studies.

The conceptualization and production of this sourcebook was coordinated by Lucia Palombi and Reuben Sessa, under the overall supervision of the Director of the Climate, Energy and Tenure Division of FAO Xiangjun Yao and the Senior Natural Resources Officer Tiina Vähänen. Editorial support was provided by Denise Martínez Breto, Kaisa Karttunen, Gordon Ramsay and Alessandra Bresnan while the graphic design was elaborated by Maria Guardia and Fabrizio Puzzilli.

Module 1 on why climate-smart agriculture, forestry and fisheries was written by Alexandre Meybeck (FAO) and Vincent Gitz (FAO) with contributions from Richie Ahuja (EDF–India), Kevern Cochrane (FAO), Anette Engelund Friis (World Farmers Organization), Elwyn Grainger-Jones (IFAD), Hsin Huang (OECD), Chang-Gil Kim (KREI-South Korea), Atta-Krah Kwesi (Bioversity International), James Lomax (UNEP), Dr B. Mantlana (South Africa), Hayden Montgomery (New Zealand), Lucia Perugini (University of Perugia) and Dipti Thapa (World Bank). The module was reviewed by Shivaji Pandey and Wilfrid Legg.

Module 2 on managing landscapes for climate-smart agricultural ecosystems was written by Marja-Liisa Tapio-Bistrom (FAO), Anne Bogdanski (FAO) and Lisen Runsten (FAO) with contributions from Anni Arial (FAO); Nadine Azzu (FAO); Sally Bunning (FAO); Christina Seeberg-Elverfeldt (FAO); David Coates (CBD secretariat); Zhijun Chen (FAO); Cassandra De Young (FAO); Paolo Groppo (FAO); Marc Dumas Johansen (FAO); Damiano Luchetti (FAO); Sheila Mwanundu (IFAD); Matthias Reiche (FAO); Janie Rioux (FAO); Reuben Sessa (FAO); Kim-Anh Tempelman (FAO); Stephen Twomlow (IFAD); and Tiina Vahanen (FAO). Box 2.4 was written by Maria Nuutinen (FAO). Case Study 2.1 was written by Richard Hatfield (Natural Capital East Africa). Case Study 2.2 was written by David Boerma (FAO). Case study 2.3 was written by Doris Soto (FAO). Case Study 2.4 was written by Lisen Runsten (FAO) and Manuela Vollbrecht (FAO). Case Study 2.5 was written by Pieter Van Lierop (FAO) and Petteri Vuorinen (FAO). Case Study 2.6 was written by Wu Ning (ICIMOD) and Hans Joosten (University of Greifswald). Case Study 2.7 was written by Sally Bunning (FAO) and Monica Petri (FAO). Case Study 2.8 was written by Tomas Lindemann (FAO), Paola Palestini (FAO) and Daniela Morra (FAO).

Module 3 on water management was written Jean-Marc Faurès (FAO) with contributions from Devin Bartley (FAO), Mohamed Bazza (FAO), Jacob Burke (FAO), Jippe Hoogeveen (FAO), Doris Soto (FAO) and Pasquale Steduto (FAO).

Module 4 on soils and their management for CSA was written by Sally Bunning (FAO), Sandra Corsi (FAO) and Ronald Vargas (FAO).

Module 5 on energy was written by Olivier Dubois (FAO), Alessandro Flammini (FAO), Anne Bogdanski (FAO) and Jonathan Reeves (FAO).

Module 6 on conservation and sustainable use for genetic resources for food and agriculture was written by Damiano Luchetti, Ehsan Dulloo, Anna Asfaw and Linda Collette (FAO) with contributions by Devin Bartley, Cassandra De Young, Mary Jane Dela Cruz, Matthias Halwart, Kathrin Hett, Irene Hoffmann, Mario Marino, Albert Nikiema, Dafydd Pilling, Beate Scherf, Doris Soto, Kim-Anh Tempelman and Álvaro Toledo (FAO) in coordination with the Secretariat of the Commission on Genetic Resources for Food and Agriculture and FAO's inter-departmental working group on biodiversity.

Module 7 on crop production systems was written by Nadine Azzu (FAO) and Suzanne Redfern (FAO) with contributions from Theodor Friedrich (FAO), Gualbert Gbehounou (FAO), Amir Kassam (FAO), Chikelu Mba (FAO) and Cornelis VanDuijvendijk (FAO).

Module 8 livestock was written by Pierre Gerber (FAO) with contributions from Benjamin Henderson (FAO) and Carolyn Opio (FAO). Case study 8.2 was written by Muhammad Ibrahim (IICA-Belize), Cristóbal Villanueva (CATIE), Claudia Sepúlveda (CATIE), Diego Tobar (CATIE-Costa Rica), Guillermo Chuncho (CATIE).

The key messages for Module 9 on climate-smart forestry were written by Susan Bratz (FAO).

Module 10 on climate-smart fisheries and aquaculture was written by Cassandra De Young (FAO), Doris Soto (FAO) and James Muir (FAO consultant) with contributions by Randall Brummett (World Bank) and Matthias Halwart (FAO) and in coordination with the Global Partnership for Climate, Fisheries and Aquaculture (PaCFA). Box 10.6 on climate-smart tuna fishing was written by Johann Bell (SPC). Box 10.7 on culture based fisheries was written by Sena De Silva (Deakin University) and Doris Soto (FAO). Box 10.8 on fuelwood saving fish processing technology was written by Yvette DieiOuadi (FAO). Box 10.9 on LIFE fishing was written by Petri Suuronen (FAO) and James Muir (FAO consultant). Box 10.10 on the role of trade was written by Victoria Chomo (FAO) and Cassandra De Young (FAO). Case study 10.1 on catfish farming was written by Sena De Silva (Deakin University) and Doris Soto (FAO). Case study 10.2 on integrated multitrophic aquaculture was written by Changbo Zhu (South China Sea Fisheries Research Institute) and Joao Ferreira (Universidade Nova de Lisboa). Case study 10.3 on mussel farming was written by Ana Farias (Universidad Austral), Jose Luis Rodriguez (Instituto Gallego de Formación en Acuicultura), Doris Soto (FAO) and Iker Uriarte (Universidad Austral).

Module 11 on sustainable and inclusive food value chains was written by Tamara van't Wout (FAO) and Reuben Sessa (FAO) with contributions from Martin Hilmi (FAO), David Neven (FAO), Robert van Otterdijk (FAO), Camelia Bucatariu (FAO), Danilo Meja (FAO), Jogeir Toppe (FAO), Lucio Olivero (FAO), Sandra Corsi (FAO) and Alashiya Gordes (FAO).

Module 12 on local Institutions was written by Patti Kristjanson (CCAFS/CGIAR), Alashiya Gordes (FAO) and Reuben Sessa (FAO) with contributions from Ademola Braimoh (WB) and Sonja Vermeulen (CCAFS/CGIAR).

Module 13 on national policies and programs was written by Majory-Anne Bromhead (World Bank), and Reuben Sessa (FAO) with contributions from Savis Joze Sadeghian (FAO). The module was reviewed by Leslie Lipper (FAO).

Module 14 on financing climate-smart agriculture was written by Leslie Lipper (FAO) and Bjorn Conrad (FAO) with contributions from World Bank made by Ademola Braimoh, David Treguer and Marco Van der Linden. The module was reviewed by Elisabeth Barsk-Rundquist, Camilla Nordheim-Larsen and Siv Oystese at the Global Mechanism of the UNCCD. Additional contributions were also made by Luis Bockel (FAO), Uwe Grewer (FAO) and Savis Joze Sadeghian (FAO).

Module 15 on disaster risk reduction was written by Monica Trujillo (FAO) with contributions from Stephan Baas (FAO) and reviewed by Jim Hancock (FAO) and Kennedy Igbokwe (FAO).

Module 16 on safety nets was written by Catherine Zanev (WFP) and Carlo Scaramella (WFP) with contributions from Ugo Gentilini (WFP) and was reviewed by Niels Balzer (WFP), Volli Carucci (WFP), Alexandra Guyetsky (FAO), Nyasha Tirivayi (FAO) and Tamara van't Wout (FAO).

Module 17 on capacity development was written by Claudia Hiepe (FAO) and Patrick Kalas (FAO) with contributions by Federica Matteoli (FAO), Katrin Nichterlein (FAO), Sibyl Nelson (FAO) and Janie Rioux (FAO). Box 17.1 was written by Janie Rioux (FAO). Box 17.5 was written by Sibyl Nelson (FAO). Box 17.8 was written by Karin Nichterlein and the TECA team (FAO). Box 17.9 was written by the CSDI team at FAO including Mario Acunzo, Federica Matteoli, Marzia Pafumi and Vanessa Vertiz.

Module 18 on assessment, monitoring and evaluation was written by Hideki Kanamaru (FAO) and Jim Hancock (FAO) with contributions from Louis Bockel (FAO), Ademola Braimoh (World Bank), Elisa Distefano (IFAD), Wiebke Förch (CCAFS), Uwe Grewer (FAO), Claudia Hiepe (FAO), Madeleine Jonsson (Swedish Cooperative Centre), Krishna Krishnamurthy (WFP), Sarshen Marais (Conservation South Africa), Federica Matteoli (FAO), Katia Medeiros (FAO), Sibyl Nelson (FAO), Christina Seeberg-Elverfeldt (FAO), Philip Thornton (CCAFS), Ophelie Touchemoulin (SAUR) and Tamara Vantwout (FAO). Figure 18.8 was created by Uwe Grewer (FAO). Box 18.1 was written by Hideki Kanamaru (FAO) with material provided by Christina Seeberg-Elverfeldt (FAO). Box 18.2 was written by Wiebke Förch (CCAFS) and Philip Thornton (CCAFS). Box 18.3 was written by Elisa Distefano (IFAD). Box 18.5 was written by Uwe Grewer (FAO), Ophelie Touchemoulin (SAUR) and Louis Bockel (FAO). Box 18.6 was written by Kanamaru with material provided by Sarshen Marais (Conservation South Africa). Box 18.7 was written by Madeleine Jonsson (Swedish Cooperative Centre). Box 18.8 was written by Hideki Kanamaru (FAO) with material provided by Tamara van't Wout (FAO). Box 18.10 was written by Hideki Kanamaru (FAO) with material provided by Federica Matteoli (FAO) and Madeleine Jonsson (Swedish Cooperative Centre). Box 18.11 was written by Hideki Kanamaru (FAO) with material provided by Christina Seeberg-Elverfeldt (FAO). Case Study 18.1 was written by Krishna Krishnamurthy (WFP). Case Studies 18.2 and 18.3 were written by Ademola Braimoh (World Bank).

Many other individuals provided useful materials that were not included in the final version of the Sourcebook. They are: Nicholas Tyack (Global Crop Diversity Trust); Jody Butterfield (Africa Centre for Holistic Management) and Daniela Ibarra-Howell (Africa Centre for Holistic Management); Do Trong Hoan (ICRAF), Delia C. Catacutan (ICRAF) and Peter Minang (ICRAF); Jesús Quintana (IFAD) and Clarissa Baldin (IFAD).

Executive Summary

Why is climate-smart agriculture needed?

Between now and 2050, the world's population will increase by one-third. Most of these additional 2 billion people will live in developing countries. At the same time, more people will be living in cities. If current income and consumption growth trends continue, FAO estimates that agricultural production will have to increase by 60 percent by 2050 to satisfy the expected demands for food and feed. Agriculture must therefore transform itself if it is to feed a growing global population and provide the basis for economic growth and poverty reduction. Climate change will make this task more difficult under a business-as-usual scenario, due to adverse impacts on agriculture, requiring spiralling adaptation and related costs.

To achieve food security and agricultural development goals, adaptation to climate change and lower emission intensities per output will be necessary. This transformation must be accomplished without depletion of the natural resource base. Climate change is already having an impact on agriculture and food security as a result of increased prevalence of extreme events and increased unpredictability of weather patterns. This can lead to reductions in production and lower incomes in vulnerable areas. These changes can also affect global food prices. Developing countries and smallholder farmers and pastoralists in particular are being especially hard hit by these changes. Many of these small-scale producers are already coping with a degraded natural resource base. They often lack knowledge about potential options for adapting their production systems and have limited assets and risk-taking capacity to access and use technologies and financial services.

Enhancing food security while contributing to mitigate climate change and preserving the natural resource base and vital ecosystem services requires the transition to agricultural production systems that are more productive, use inputs more efficiently, have less variability and greater stability in their outputs, and are more resilient to risks, shocks and long-term climate variability. More productive and more resilient agriculture requires a major shift in the way land, water, soil nutrients and genetic resources are managed to ensure that these resources are used more efficiently. Making this shift requires considerable changes in national and local governance, legislation, policies and financial mechanisms. This transformation will also involve improving producers' access to markets. By reducing greenhouse gas emissions per unit of land and/or agricultural product and increasing carbon sinks, these changes will contribute significantly to the mitigation of climate change.

Defining the concept

Climate-smart agriculture (CSA), as defined and presented by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, contributes to the achievement of sustainable development goals. It integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges. It is composed of three main pillars:

1. sustainably increasing agricultural productivity and incomes;
2. adapting and building resilience to climate change;
3. reducing and/or removing greenhouse gases emissions, where possible.

CSA is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change. The magnitude, immediacy and broad scope of the effects of climate change on agricultural systems create a compelling need to ensure comprehensive integration of these effects into national agricultural planning, investments and programs. The CSA approach is designed to identify and operationalize sustainable agricultural development within the explicit parameters of climate change.

FAO and its partners are aware that achieving the transformations required for CSA and meeting these multiple objectives requires an integrated approach that is responsive to specific local conditions. Coordination across agricultural sectors (e.g. crops, livestock, forestry and fisheries) as well as other sectors, such as with energy and water sector development is essential to capitalize on potential synergies, reduce trade-offs and optimize the use of natural resources and ecosystem services. To address this complex task and support member countries, FAO's different departments have worked together to articulate the concept of CSA. In carrying out this work, the Organization provides guidance about the practices, technologies, policies and financing that are required to achieve a productive, resilient and sustainable agriculture sector.

This approach also aims to strengthen livelihoods and food security, especially of smallholders, by improving the management and use of natural resources and adopting appropriate methods and technologies for the production, processing and marketing of agricultural goods. To maximize the benefits and minimize the trade-offs, CSA takes into consideration the social, economic, and environmental context where it will be applied. Repercussions on energy and local resources are also assessed. A key component is the integrated landscape approach that follows the principles of ecosystem management and sustainable land and water use.

CSA seeks to support countries in putting in place the necessary policy, technical and financial means to mainstream climate change considerations into agricultural sectors and provide a basis for operationalizing sustainable agricultural development under changing conditions. Innovative financing mechanisms that link and blend climate and agricultural finance from public and private sectors are a key means for implementation, as are the integration and coordination of relevant policy instruments and institutional arrangements. The scaling up of climate-smart practices will require appropriate institutional and governance mechanisms to disseminate information, ensure broad participation and harmonize policies. It may not be possible to achieve all the CSA objectives at once. Context-specific priorities need to be determined, and benefits and tradeoffs evaluated.

CSA is not a single specific agricultural technology or practice that can be universally applied. It is an approach that requires site-specific assessments to identify suitable agricultural production technologies and practices. This approach:

1. addresses the complex interrelated challenges of food security, development and climate change, and identifies integrated options that create synergies and benefits and reduce trade-offs;
2. recognizes that these options will be shaped by specific country contexts and capacities and by the particular social, economic, and environmental situation where it will be applied;
3. assesses the interactions between sectors and the needs of different involved stakeholders;
4. identifies barriers to adoption, especially among farmers, and provides appropriate solutions in terms of policies, strategies, actions and incentives;
5. seeks to create enabling environments through a greater alignment of policies, financial investments and institutional arrangements;
6. strives to achieve multiple objectives with the understanding that priorities need to be set and collective decisions made on different benefits and trade-offs;
7. should prioritize the strengthening of livelihoods, especially those of smallholders, by improving access to services, knowledge, resources (including genetic resources), financial products and markets;
8. addresses adaptation and builds resilience to shocks, especially those related to climate change, as the magnitude of the impacts of climate change has major implications for agricultural and rural development;
9. considers climate change mitigation as a potential secondary co-benefit, especially in low-income, agricultural-based populations;
10. seeks to identify opportunities to access climate-related financing and integrate it with traditional sources of agricultural investment finance.

CSA brings together practices, policies and institutions that are not necessarily new but are used in the context of climatic changes, which are unfamiliar to farmers, herders and fishers. What is also new is the fact that the multiple challenges faced by agriculture and food systems are addressed simultaneously and holistically, which helps avoid counterproductive policies, legislation or financing.

CSA implementation and the role of the sourcebook

There has been a rapid uptake of the term CSA by the international community, national entities and local institutions. However, implementing this approach is challenging, partly due to a lack of tools and experience. Climate-smart interventions are highly location-specific and knowledge-intensive. Considerable efforts are required to develop the knowledge and capacities to make CSA a reality. In large part, these are the same efforts required for achieving sustainable agricultural development which have been advocated over past decades, yet still insufficiently realized on the ground. CSA offers an opportunity to revitalize these efforts, overcome adoption barriers, while also adjusting them to the new realities of climate change. Organizations, educational establishments and other entities have started to fill these gaps, but information is still fragmented. A partnership between UN agencies (FAO, IFAD, UNEP, WB, WFP) and other organizations (CGIAR/CCAFS) has been created to address knowledge gaps and support countries in the implementation of climate-smart approaches.

The purpose of the sourcebook is to further elaborate the concept of CSA and demonstrate its potential, as well as limitations. It aims to help decision makers at a number of levels (including political administrators and natural resource managers) to understand the different options that are available for planning, policies and investments and the practices that are suitable for making different agricultural sectors, landscapes and food systems more climate-smart. This sourcebook is a reference tool for planners, practitioners and policy makers working in agriculture, forestry and fisheries at national and subnational levels. The sourcebook indicates some of the necessary ingredients required to achieve a climate-smart approach to the agricultural sectors, including existing options and barriers.

This sourcebook is divided into three main sections, which addresses the main following topics:

- Section A **"The Case for Climate-Smart Agriculture"** consists of two modules establishing a conceptual framework and is targeted to a broad audience. Module 1 explains the rationale for CSA and module 2 focuses on the adoption of a landscape approach.

- Section B **"Improved Technologies and Approaches for Sustainable Farm Management"** is divided in nine Modules. It is targeted primarily to the needs of planners and practitioners and analyzes what issues need to be addressed in the different sectors, in terms of water (Module 3), soils (Module 4), energy (Module 5) and genetic resources (Module 6) for up-scaling of practices of crop production (Module 7), livestock (Module 8), forestry (Module 9) and fisheries and aquaculture (Module 10) along sustainable and inclusive food value chains (Module 11).

- Section C **"Enabling frameworks"** encompasses seven Modules, targeted to policy makers, providing guidance on what institutional (Module 12), policy (Module 13) and finance (Module 14) options are available. It further provides information on links with disaster risk reduction (Module 15) and utilization of safety nets (Module 16) and also illustrates the key role of capacity development (Module 17) and assessments and monitoring (Module 18).

The sourcebook will be first published in a web platform which will also facilitate stakeholders' access to additional information, case studies, manuals, practices, and systems. The platform is dynamic and will be updated on a regular basis and it is available at http://www.climatesmartagriculture.org/72611/en/

MODULE 1:

WHY CLIMATE-SMART AGRICULTURE, FORESTRY AND FISHERIES

Overview

Agriculture has to address simultaneously three intertwined challenges: ensuring food security through increased productivity and income, adapting to climate change and contributing to climate change mitigation (FAO, 2010a; Foresight, 2011a; Beddington *et al.*, 2012a; Beddington *et al.*, 2012b; HLPE, 2012a). Addressing these challenges, exacerbating global pressure on natural resources, especially water, will require radical changes in our food systems. To address these three intertwined challenges, food systems have to become, at the same time, more efficient and resilient, at every scale from the farm to the global level. They have to become more efficient in resource use (use less land, water, and inputs to produce more food sustainably) and become more resilient to changes and shocks.

It is precisely to articulate these changes that FAO has forged the concept of climate-smart agriculture (CSA) as a way forward for food security in a changing climate. CSA aims to improve food security, help communities adapt to climate change and contribute to climate change mitigation by adopting appropriate practices, developing enabling policies and institutions and mobilizing needed finances.

This module gives an overview of climate smart agriculture, as an approach to address in an integrated way the interlinked challenges of food security and climate change. The first section describes the challenges to be addressed. It briefly recalls the current state of food insecurity and prospective of population and food demand growth. The main impacts of climate change on agriculture are summarized as well as the contribution of agriculture to global greenhouse gas emissions. The second section shows how two joint principles guide the necessary changes of systems: more efficiency in the use of resources, to increase production while reducing emissions intensity of the food produced and consumed and more resilience, to get prepared to variability and change. The third section briefly touches upon some of the issues to be addressed to implement climate-smart agriculture and progress towards efficient and resilient food systems. It requires comprehensive policies at every level, adequate institutions and proper governance to make the necessary choices. It also requires new financing to address the needs in terms of investments and research and to enable the farmers to overcome barriers to adoption of new practices including up-front costs and income foregone during the transition period. The last section articulates the concept of CSA closely linked issues of sustainable intensification, green growth and sustainable development.

Key messages

- Agriculture and food systems must undergo significant transformations in order to meet the related challenges of food security and climate change.
- Increasing resource efficiency is essential both to increase and ensure food security on the long term and to contribute to mitigate climate change.
- Building resilience to every type of risk is essential to be prepared for uncertainty and change.
- Efficiency and resilience have to be considered together, at every scale and from both environmental, economic and social perspectives.
- Implementing climate-smart agriculture can be a major driver of a Green Economy and a concrete way to operationalize sustainable development.
- Addressing food security and climate change requires concerted and coordinated involvement and action of all stakeholders on a long term perspective.
- Climate smart agriculture is not a new agricultural system, nor a set of practices. It is a new approach, a way to guide the needed changes of agricultural systems, given the necessity to jointly address food security and climate change.

Contents

List of Figures

List of Boxes

1.1 Food security and climate change: three intertwined challenges[1]

Agriculture and food systems must improve and ensure food security, and to do so they need to adapt to climate change and natural resource pressures, and contribute to mitigating climate change. These challenges, being interconnected, have to be addressed simultaneously.

Ensuring food security

The world is producing enough food, but in 2010-2012 there were still almost 870 million people estimated to be undernourished, (FAO *et al.*., 2012). In addition, another billion people are malnourished, lacking essential micronutrients. The paradox is that at the same time a large number of people – mainly in richer countries - are over-eating, causing long-term health problems and that 60 percent of the malnourished actually are food producers, smallholders and pastoralists, with 20 percent living in cities and 20 percent landless rural people. For the poor producers, food is not only a basic need, it is the single, and often fragile, support they have for maintaining their livelihood. What is true at the household level is also true at the macroeconomic level. There are 32 countries, 20 of them in Africa, facing food crises and in need of international emergency support. In most of these countries, paradoxically, agriculture is an important, if not the major, part of economy.

The objective is to ensure food and nutrition security, worldwide. Ensuring availability of calories and sufficient global production is not enough; we also need to make sure that enough food is accessible to everyone, everywhere, physically and economically. In addition, we need to ensure that this food is properly utilized in the right quality and diversity. The goal is to ensure the stability of these three components of food and nutrition security: availability, access and utilization.

Between now and 2050, the world's population will increase by one-third. Most of the additional 2 billion people will live in developing countries. At the same time, more people will be living in cities (70 percent against the current 50 percent). Urbanization and rising incomes in developing countries are driving increases in the consumption of animal products (FAO, 2009a). Given these trends, FAO estimates that production will have to increase by 60 percent by 2050 to satisfy the expected demands for food and feed (Conforti, 2011). Demand for biofuels, another important factor for the global market, is very dependent on national policies and global demand is expected to grow. According to the OECD-FAO projections, because of increasing mandates and consumption incentives, biofuel production is expected to double between 2005 and 2019 (OECD and FAO, 2010).

Impacts of climate change on agriculture

Climate change has already significantly impacted agriculture (Lobell *et al*, 2011) and is expected to further impact directly and indirectly food production. Increase of mean temperature; changes in rain patterns; increased variability both in temperature and rain patterns; changes in water availability; the frequency and intensity of 'extreme events'; sea level rise and salinization; perturbations in ecosystems, all will have profound impacts on agriculture, forestry and fisheries (Gornall, 2010; IPCC, 2007a; Beddington, *et al*,. 2012b; HLPE, 2012a; Thornton *et al.*., 2012). The extent of these impacts will depend not only on the intensity and timing (periodicity) of the changes but also on their combination, which are more uncertain, and on local conditions. Anticipating appropriately the impacts of climate change on agriculture requires data, tools and models at the spatial scale of actual production areas. Since the last Intergovernmental Panel on Climate Change (IPCC) report in 2007, some studies have attempted to anticipate these impacts and provide projections at such a scale, enabling us to have a more concrete vision of projected changes.

[1] This section draws heavily on Meybeck A. Gitz V. Towards Efficiency & Resilience in Agriculture for Food Security in a Changing Climate presented at the OECD-KREI Expert Meeting on Green Growth and Agriculture and Food in Seoul, Korea 6-8 April 2011

A prospective study in Morocco (World Bank, 2009a) points to gradually increasing aridity due to reduced rainfall and higher temperatures, with negative effects on agricultural yields, especially from 2030 onwards. Rainfed crops are expected to be particularly affected. If irrigation water continues to be available in sufficient quantities, crop yields are expected to continue to increase in spite of climate change. However, availability of water for irrigation is uncertain. In this study, agricultural yields are projected to remain more or less stable up to 2030, but they are predicted to drop rather quickly beyond that date (see Module 3 on water management).

A study in Brazil (EMBRAPA, 2008) shows that climate change can have dramatic changes in the potentials for the various crops analysed and their geographic repartition. Globally, the increase of evapotranspiration leads to an increase of the areas at high climatic risk for 7 of the 9 crops studied (cotton, rice, coffee, beans, sunflower, millet, soybean) and a decrease for cassava and sugarcane. It will also cause important displacements in areas suitable for crops, especially for coffee and cassava. In traditional production areas, coffee would be affected by lack of water or high temperatures. In the States of São Paulo and Minas Gerais coffee would no longer be cultivated in areas where it is currently cultivated. On the other hand, with the reduction of the risk of frost, there could be an increase of the production area in Paraná, Santa Catarina and Rio Grande do Sul. As a result, the global area at low climatic risk for coffee would be reduced by 9.5 percent in 2020, 17 percent in 2050, and 33 percent in 2070. On the other hand, more favourable conditions for sugarcane will considerably increase the area of production.

The impacts of climate change will have major effects on agricultural production, with a decrease of production in certain areas and increased variability of production to the extent that important changes may need to be made in the geographic area where crops are cultivated. Local impacts will bring global imbalances. Broadly speaking, with everything else being equal, climate change may lead to an increase in both crop and livestock productivity in mid- to high latitudes (IPCC, 2007a) and a decrease in tropical and subtropical areas. Among the most affected areas are economically vulnerable countries already food insecure and some important food exporting countries. This will induce significant changes in trade, impacting prices and the situation of net food importing countries. Consequently, climate change is expected to increase the gap between developed and developing countries as a result of more severe impacts in already vulnerable developing regions, exacerbated by their relatively lower technical and economical capacity to respond to new threats (Padgham, 2009). Smallholders and pastoralists will suffer complex, localized impacts (IPCC, 2007a). According to the International Food Policy Research Institute (IFPRI) (Nelson *et al.*., 2010), it will cause an increase of between 8.5 and 10.3 percent in the number of malnourished children in all developing countries, relative to scenarios without climate change.

The models used for such projections neither take into account the impacts of multiple stress induced by climate change, nor the impacts on the functioning of ecosystems, such as effects on pollinators (FAO, 2011a) and the balance between pests and their predators, nor impacts on animal diseases (FAO-OECD, 2012; HLPE, 2012 a).

It is likely that there will also be important effects on nutrition as a result of climate change. To date, studies mostly focus on cereals. There is a need to better capture all the nutritional consequences of the effects of climate change on livestock and on vegetables and wild foods, all of which have an important role in balanced diets and which are at risk (HLPE, 2012a; Bharucha and Pretty, 2010).

In terms of impacts, it is necessary to distinguish between increased variability and slow onset changes. The potential impacts of increased variability are often less emphasized than slow onset changes for a variety of reasons. This is because these impacts are less well known (HLPE 2012a) even though they will be felt first. The impacts of increased variability are situated between the much emphasized category of 'extreme events', and the much more 'easier to grasp' business as usual category of actual variability. What exactly is an 'extreme event'? What makes an event considered as "extreme"? Is it the intensity, the infrequency of a meteorological event? Or is it the extent and intensity of its consequences? For agriculture, a slight change in temperature at a critical stage of plant growing can compromise a crop. As changes in variability are easier for farmers to apprehend, they could constitute a first target for early adaptation measures (Padgham, 2009). It is therefore important to distinguish between these two categories of impacts to highlight two ways to adapt, each with different time ranges: increasing resilience now to be prepared for more variability, and increasing adaptive capacities and preparedness for slow onset changes. Furthermore, being prepared for increased variability is also a way to prepare for any other change, whatever it may be.

Agriculture's impact on climate change

The agriculture sector has to produce more food and it will be certainly impacted by climate change. As an integral part of the economy, it has also been called upon to contribute to mitigate climate change (UNFCCC 2008). The question is how and to what extent agriculture and food systems can contribute to climate change mitigation without compromising food and nutrition security.

In 2005, agriculture (crop and livestock) directly accounted for 13.5 percent of global GHG emissions (IPCC, 2007b). This figure is based on activities carried out in the fields and with livestock. But agriculture's role in climate change and, importantly, its mitigation potential, should be considered in a wider perspective of 'food systems'. This includes the impact these systems have on forests, the energy sector and transport. Expanding our consideration of agriculture's role in climate change is warranted because some of the on farm emissions are not included in the 13.5 percent figure, but are grouped in other sectors, such as electricity used in farm buildings and fuel used in farm equipment and food transport. Also, agriculture is a major driver of deforestation, which roughly accounts for an additional 17 percent of global GHG emissions (IPCC, 2007b). This is why agriculture is included in the study on the drivers of deforestation, which was requested by the UNFCCC's 17th Conference of the Parties (COP 17) in Cancun to the Subsidiary Body for Scientific and Technological Advice (SBSTA). Finally, within food systems, reductions of emissions in some areas could lead to increases elsewhere. For instance, depending on the efficiency of production systems, shorter food chains could reduce transport but increase agricultural emissions. Currently, there are no studies that quantify emissions from the global food system (Garnett, 2011). A study in 2006 estimated that 31 percent of the European Union's GHG emissions were associated with the food system (European Commission 2006). Therefore, when looking at challenges and opportunities to reduce GHG emissions using agriculture, it is paramount to look beyond the farm, vertically into the whole food chain and horizontally across impacted land-uses such as forests.

The main direct sources of GHG emissions in the agricultural sector are not only carbon dioxide (CO2). Agriculture is a source of nitrous oxide (N2O), accounting for 58 percent of total emissions, mostly by soils and through the application of fertilizers, and of methane (CH4), accounting for 47 percent of total emissions, essentially from livestock and rice cultivation. These emissions are dependent on natural processes and agricultural practices, which makes them more difficult to control and measure. On the other hand, agriculture is a key sector that, along with the forestry sector, if managed effectively. can lead to biological carbon capture and storage in biomass and soil, acting as "sinks". Their management can play an essential role in managing climate change (IPCC, 2007b), especially in the long term (Gitz, 2013).

As agricultural production is projected to increase in developing countries, so are agricultural emissions. IPCC estimates that N_2O emissions will increase by 35 - 60 percent by 2030 and CH_4 by 60 percent (IPCC, 2007b). The IPCC also projects additional land being converted to agriculture.

There are two ways by which agricultural production[2] can contribute to mitigate climate change that are in line with the 'food security first' objective. The first way is to improve efficiency by decoupling production growth from emissions growth. This involves reducing emissions per kilogram of food output (included in this calculation are the effects of emissions from reduced deforestation per kilogram of food). The second way is to

[2] A third way, (last section of the module) would be changes in consumption patterns, a subject that will not be touched upon in within this sourcebook.

enhance soil carbon sinks. The IPCC estimates the global technical mitigation potential from agriculture could reach the equivalent of 5 500-6 000 tonnes of CO_2 per year by 2030 (IPCC, 2007b). This is grossly equivalent to three quarters of the sector's emissions in 2030 (around 8 200 tonnes of CO2). About 70 percent of this identified potential lies in developing countries, 20 percent in OECD countries, and 10 percent for EIT countries. IPCC estimates that nine-tenths of the global mitigation potential of agriculture is linked, not to reduction of agricultural GHG (mainly CH_4 and N_2O) emissions, but to managing land carbon stocks. This involves enhanced soil carbon sequestration, reduced tillage, improved grazing management, the restoration of organic soils and restoration of degraded lands.

Reducing emissions per kilogram of a given output[3] might well be, for food security and agriculture, one of the main targets. Direct gains through increased efficiency also imply a series of indirect gains. These indirect gains include reduced emissions from deforestation (not accounted in IPCC's calculations of the 90 percent) as less land is necessary to produce the same amount of food. Indirect gains also include reduced emissions from the production of fertilizer or energy inputs used on the farm. Everything else being equal, a potential reduction equivalent to 770 tonnes of CO_2 per year by 2030 has been identified from reduction of fossil fuel use through improved on-farm energy efficiency (IPCC, 2007b). In addition, there are potential reductions through improved efficiency in food chains, including a reduction of post-harvest losses.

1.2 Towards more efficient and resilient systems

To address these three intertwined challenges, food systems have to become at the same time more efficient and resilient, at every scale from the farm to the global food system. They have to become more efficient in resource use: use less land, water and inputs to produce more food sustainably, and be more resilient to changes and shocks.

More efficient systems

Increase resource efficiency

Most of the GHG emissions of the agricultural sector are directly driven by the use of resources: new land being deforested or turned from grassland to crop land, fertilizers, livestock, energy. Increasing efficiency in the use of resources (i.e. producing more of a given output using less of a given input) is thus key to reducing emissions intensity per kilog of output. It is also key to improve food security, especially in resource scarce areas.

Before looking at how resource efficiency in food systems can be improved (by what means), we need to have a common understanding of what efficiency "means".

Agriculture and food systems not only utilize a very diverse range of resources but also produce a very diverse range of outputs. They provide physical products but also income and employment, for farmers, in agro-industry and as a driver of the non-farm rural economy. From a food security perspective, these three outputs are equally important. It implies a more complex conception of resource efficiency, by which employment, which is formally an input in pure economic terms, can be seen as a key output. This conception implies a shift from the classical economic targets of labour productivity towards resource efficiency with labour intensity being possibly an asset, as a system can be judged superior to another if it uses an equal amount of natural resources but provides more employment (and not less work related costs), everything else being equal. Agriculture is also a producer of environmental services at the landscape level: for example, through improved soil management practices, agriculture can increase carbon stored in soils. Ultimately the output of agriculture can also be defined as human diets.

[3] Comparing different types of food is extremely difficult as they have very different nutritional value (not only energy or protein content but also composition and micronutrients).

The green economy is driven by the idea that, in the long run, given the increasing scarcity of resources, physical resource efficiency and economic efficiency will become closer, due to market fundamentals and through policies, which would factor in environmental and social externalities (positive and negative) of input use and production. Agriculture needs to produce more with resources (land, water, energy and nutrients) that are becoming scarcer and thus more expensive. However, given the relative prices of the various inputs, production factors and outputs, this is not an easy thing to achieve, especially in smallholder farming systems. Evidence shows that farmers economize in their use of inputs in reaction to increased prices (OECD, 2011). A study of how US farmers reacted to higher energy and fertilizer prices in 2006 (Harris *et al.*, 2008) showed that 23 percent of commercial farms reduced their usage of both energy and fertilizers. To reduce energy consumption, they used machines less intensively and serviced engines more frequently. Lower usage of fertilizers was also achieved through greater use of soil testing, precision application and changes of crops.

Increasing efficiency in the use of resources is also one of the driving principles of CSA. GHG emissions from agriculture are linked to its use of resources. Three production factors have an important influence on total agricultural GHG emissions: (i) area, since converting land into cultivations would require either deforestation or grasslands being converted to croplands, which would induce higher CO_2 emissions; (ii) fertilizers, whose production is an important source of CO_2 and which at the field level translate into nitrous oxide emissions; and (iii) livestock, which is an important source of methane and nitrous oxide emissions. Physical capital, such as buildings and machines are also a factor, both directly by energy use and indirectly by their production. Everything else being equal, increasing the efficiency in the use of one of these production factors decreases the emissions intensity of output. As irrigation often demands considerable energy, water efficiency is another key factor for increasing production, adapting to climate change and reducing emissions.

Resource efficiency needs to be improved in every type of food system. Studies using the results of detailed on farm energy audits realized in France have shown that energy consumption per kilogram of output can be extremely variable between farms. It has, for instance, been shown (Bochu *et al.*, 2010) that the most efficient dairy farms consume per unit of output half of the energy consumed by the less efficient farms. Results of more than 400 farms have been analysed and categorized according to the importance of corn silage in the system (1-10 percent, 10-20 percent, 20-30 percent, more than 30 percent of the feed). It appears that variability within each of these categories is more important than between categories, and that in every category the more efficient farms use less than half of the energy used by the less efficient ones. This is also true in organic farms. This means that, no matter what the system, there can be important improvements in management practices.

Increase resource efficiency in plant production

As agriculture is an important driver of deforestation, reducing agricultural expansion through sustainable intensification on already cultivated land could have a major mitigation effect. The HLPE considers that ending most conversion of forest to cultivation should be a mitigation priority.

Studies show that, at the global level, from 1961 to 2005, crop production increased by over 160 percent, mostly as a result of 135 percent yield increases, with only 27 percent increases in crop area (Burney *et al.*, 2010). This intensification allowed farmers to increase food production while emitting the equivalent of 590 gigatons of CO_2 less than what would have been emitted by expanding the area under cultivation on the basis of assuming 1961 yields. They conclude that land use change emissions (even avoided ones) are much more important than direct emissions from agricultural systems. Therefore, improvement of crop yields should be prominent in any mitigation strategy. Moreover, these improvements will also contribute to preserving forest sinks and maintaining their capacity to store carbon over the long-term (Gitz and Ciais, 2004).

Other studies show that across the tropics, between 1980 and 2000, more than 55 percent of new agricultural land came at the expense of intact forests and another 28 percent came from disturbed forests (Gibbs *et al.*, 2010). Considering the role of agriculture as a driver of deforestation, sustainable intensification should also play a part in Reducing Emissions from Deforestation and Forest Degradation (REDD) programmes.

Sustainable intensification would be particularly efficient in areas where very low productivity systems, such as shifting cultivation in the Congo Basin, are replacing forests (Bellassen and Gitz, 2008; West *et al.,* 2010), comparing worldwide crop yields and carbon stocks, consider that concentrating reforestation and avoided deforestation in the tropics would have the greatest worldwide carbon sink effect with minimum opportunity costs in terms of reduced crop yields.

Studies (Fischer *et al.*, 2009) have shown the importance in many developing countries of the yield gap. The yield gap is the difference between actual farm yields, as represented by the average yield achieved by farmers in a defined region over several seasons, and the potential yields which are the maximum achievable yield with latest varieties and by removing as much as possible all the constraints as achieved in highly controlled experimental stations. Reducing this gap is essential to improve food security and reduce deforestation.

Nutrients are essential to increase yields. But production of synthetic fertilizers is energy intensive, with high CO_2 emissions and economic costs. In addition, when applied in the field, these fertilizers contribute to N_2O emissions. Therefore, there is a need to improve fertilization and to limit the economic costs and the emissions at the same time. Improving fertilizer efficiency is thus essential. This can be done through a variety of techniques. One way is to match more precisely the nutrients with plant needs during the growing season, such as by fractioning the total amount in multiple doses. Other techniques include precision farming and placing nutrients closer to plant roots, such as deep placement of urea for rice (see box 1.1).

Box 1.1
Urea Deep Placement

Urea Deep Placement (UDP) technique, developed by the International Fertilizer Development Center (IFDC), is a good example of a climate-smart solution for rice systems. The usual technique for applying urea, the main nitrogen fertilizer for rice, is through a broadcast application. This is a very inefficient practice, with 60 to 70 percent nitrogen losses contributing to GHG emissions and water pollution.

In the UDP technique, urea is made into "briquettes" of 1 to 3 grams that are placed at 7 to 10 cm soil depth after the paddy is transplanted. This technique decreases nitrogen losses by 40 percent and increases urea efficiency to 50 percent. It increases yields by 25 percent with an average 25 percent decrease in urea use.

UDP has been actively promoted by the Bangladesh Department of Agricultural Extension with IFDC assistance. In 2009, UDP was used on half a million hectares by a million farmers and there are plans to expand its use to 2.9 million more families on 1.5 million hectares.

The widespread adoption of the UDP technique in Bangladesh has had several important impacts:

- Farmers' incomes have increased because of both increased yields and reduced fertilizers use.
- Jobs have been created locally in small enterprises, often owned by women, to make the briquettes. There are now 2 500 briquette-making machines in Bangladesh.
- On-farm jobs have also been created as the briquettes are placed by hand, which requires 6 to 8 days labour per hectare. Higher yields and savings on fertilizer expenditures compensate for the additional field labour expenses.
- At the national level, imports of urea have been reduced, with savings in import costs estimated by IFDC at USD 22 million and in government subsidies of USD 14 million (2008), for an increase of production of 268 000 metric tons.
- At a global level UDP has reduced GHG emissions caused by the production and management of fertilizers.

It also increases the agricultural system's resilience. As fertilizer prices are linked to energy prices, and consequently very volatile, reducing fertilizer use also increases farm and country's resilience to economic shocks.

With the effectiveness of the technique now well proven, UDP is being scaled up, partly through South/South cooperation. For instance, the National Programme for Food Security of Nigeria (NPFS) is supported by South/South cooperation with China. This support includes the promotion and development of the UDP technique in several Nigerian states.

Source: Roy & Misra, 2003; Singh *et al.*, 2010; Ladha *et al.*, 2000; IFDC, 2011

The inclusion of legumes in crop rotations exploits symbiotic microbes to fix nitrogen, which is harvested in the crop and partly transferred to subsequent crops increasing their yields. In forage legume/grass mixtures, nitrogen is also transferred from legume to grass, increasing pasture production. The protein content of legumes makes them important from a nutritional point of view. When included in livestock feed, legumes increase the food conversion ratio and decrease methane emissions from ruminants, thus increasing efficiency and at the same time reducing GHG emissions. By providing proteins and the amino acid lysine, in which cereals are deficient, legumes complement cereals in human diets and can compensate for the lack of animal proteins. Unfortunately, the global area under pulses dropped from approximately 5 million hectares in 1968 to 3.9 million in 2007. Globally, consumption of pulses in terms of kilocalories per capita per day also dropped from 73 in 1968 to 57 in 2007.

Sustainable intensification of crop production (see box 2) aims to increase yields through the better use of natural resources and ecosystem functions.

Plant breeding has a crucial role to play to enhance genetic potential both to increase productivity and thus yields and to improve nutrient and water use as well as resistance to climate variability, diseases and pests.

Box 1.2
Save and Grow – More Sustainable Intensification

Sustainable crop production intensification (SCPI) can be summed up in the words "Save and Grow". Sustainable intensification means a productive agriculture that conserves and enhances natural resources. It uses an ecosystem approach that draws on nature's contribution to crop growth – soil organic matter, water flow regulation, pollination and natural predation of pests. It applies appropriate external inputs at the right time, in the right amount to improved crop varieties that are resilient to climate change. It also uses nutrients, water and external inputs more efficiently.

Increasing the sustainable intensification of crop production is achievable. This can be done through increasing resource use efficiency and cutting the use of fossil fuels. This saves money for farmers and prevents the negative effect of over-use of particular inputs. Inefficient fertilizer use is common in many regions. In some cases, this is a consequence of government subsidies. Yet over-use does not have the intended impact on plant growth and can result in the contamination of ground and surface water. Inappropriate insecticide use may actually induce pest outbreaks by disrupting the natural population of predators. Overuse of herbicides can lead to the emergence of herbicide-tolerant varieties of weeds. Problems of salinization or reduced soil health may also come from inappropriate management practices, such as irrigating without proper drainage. Better maintenance of ecosystem services can be accomplished through: adopting agricultural practices that are based on crop rotations, applying minimum tillage and maintaining soil cover; relying on natural processes of predation or biocontrol of pest or weed problems; managing pollination services; selecting diverse and appropriate varieties; and carefully targeting the use of external inputs. These practices are knowledge-intensive and they are often also interdependent. In the initial stages, encouraging these practices may require public support through targeted incentives and investment. Ideally, the price of agricultural commodities would increasingly reflect the full cost of production, including the potential damage done to natural ecosystems, thereby encouraging more sustainable consumption (FAO, 2011b).

Increase resource efficiency in livestock production

The livestock sector has expanded rapidly in recent decades and will continue to do so as demand for meat, eggs and dairy products is expected to continue to grow, especially in developing countries. Livestock grazing already occupies 26 percent of the earth's ice-free land surface, and the production of livestock feed uses 33 percent of agricultural cropland (Steinfeld *et al.*, 2006). There is an urgent need to improve the resource use and production efficiency of livestock production systems, both to improve food security and reduce the intensity of GHG emissions (FAO, 2009a; HLPE, 2012a). These efforts need to take into account the growing dichotomy between livestock kept by large numbers of small holders and pastoralists and those kept in intensive systems[4]. A study on cow milk (Gerber *et al.*, 2010) shows that the emissions per litre of milk are dependent on the efficiency of the cows: the more efficient the cows, the fewer emissions per litre of milk. This increased efficiency should be pursued in all possible ways, from livestock selection and nutrition to manure management.

The selection to improve efficiency and thus reduce GHG emission of livestock systems involves numerous parameters, including productivity per animal, early maturity, fertility, feed conversion ratio and longevity. In controlled environments, breeding for high performance has already resulted in significant reductions in the amount of feed per unit of product, especially for monogastrics and dairy cattle. The challenge now is to also improve productivity in more diverse environments (Hoffmann, 2010).

Improving animal health, including disease prevention and management, has a strong impact on the efficiency of livestock systems, food security and climate change. Establishing strong veterinary institutions and policies are essential both to improve livestock efficiency and increase the preparedness against new risks, including those that result from climate change.

Nutrition plays a critical role in making livestock production systems more efficient. Proper nutrition is imperative for achieving high reproductive efficiency in animals, protecting them from diseases and making animal health interventions more effective. Imbalanced feeding leads to productivity losses and increase in emission of green house gases, either as CH_4 from enteric fermentation in ruminants (between 2 - 12 percent of feed energy is lost in the form of methane) or as CH_4 and N_2O produced from manure. A balanced diet enhances animal performance and reduces GHG emissions per unit of animal product. Efficient nutritional strategies for monogastrics (pigs and chickens) include matching nutrient contents in feeds (taking into consideration both their level and availability to the animal) to the physiological requirements of animals; selecting feeds with high nitrogen availability in the animal body; and optimizing proteins and amino acids in diets to improve the feed conversion to animal products. For ruminants, techniques such as a) feeding of: diets balanced for nitrogen, energy and minerals - preferably as total mixed rations; chaffed forages, preferably of high quality; chaffed and water-soaked straws or urea-ammoniated straws; and grains- and b) use of feed additives, - e.g. ionophores, probiotics, enzymes, oils including essential oils, some tannins and saponins- can be used either to improve the feed conversion ratio and/or to specifically reduce methane emission and nitrogen release into manure.

Improving pasture productivity and quality, either by improving the composition of forage, especially in artificial pastures, and by better pasture management is an important means to improve food security, adapt to climate change and reduce both direct and indirect GHG emissions. Supplementing poor quality forages with fodder trees, as in silvo-pastoral systems, or with legumes, increases their digestibility, thereby improving the production efficiency of livestock and decreasing methane emissions. The introduction of legumes in pastures also increases forage production and reduces pressure on forests without a corresponding increased use of fertilizers. Improved grazing management could lead to greater forage production, more efficient use of land resources, enhanced profitability and rehabilitation of degraded lands and the restoration of ecosystem services. Grazing practices, such as setting aside, postponing grazing while forage species are growing, or ensuring equal grazing of various species can be used to stimulate diverse grasses; improve nutrient cycling and plant productivity and the development of healthy root systems; feed both livestock and soil biota; maintain plant cover at all times; and promote natural soil forming processes.

[4] Types of systems and size are not necessarily associated.

Box 1.3
Partnership on benchmarking and monitoring the environmental performance of livestock supply chains

Quantitative information on key environmental impacts along livestock supply chains is required to (a) analyse food systems and inform decisions at the production and processing levels to improve environmental performance; (b) develop and evaluate corresponding policy decisions (governmental and non-governmental); and (c) inform relevant stakeholders.

Valuable work aimed at improving the measurement of environmental performance is being carried out by the livestock industry, governments, academia and non-governmental organizations (NGOs). However, inconsistencies in the methods used and the one-off nature of many of the studies do not provide consistent guidance on the required changes in practices and the potential efficiency gains that can be achieved.

Consultations with stakeholders during 2010 and 2011 confirmed that there was demand for a partnership on benchmarking and monitoring the environmental performance of the livestock sector. A participative formulation process led to the identification of key functions and deliverables of the Partnership. It was agreed that representatives of private sector, NGOs, governments, science and international standard organizations should be involved.

The Partnership's objective is to improve environmental performance of the livestock sector, while considering its economic and social viability. This will be achieved through support to decision-making and by providing guidance on performance assessments (metrics and methods) and their use. The partnership was officially launched in July 2012. An important aspect of the work is to assess both negative and positive contributions (e.g. improved carbon sequestration in soils, soil organic matter, water retention and quality, and biodiversity) Activities are structured along four components:

- Component 1 - Sector-specific guidelines and methods for the life cycle assessment of GHG emissions from livestock food chains;
- Component 2 - Global database of GHG emissions related to feed crops;
- Component 3 - Measures of non-GHG environmental performance of livestock food chains; and
- Component 4 - Communication strategy.

Source: FAO, 2012e

Manure management is important both to increase food security and to mitigate climate change as it can be used as organic fertilizer and is also a source of CH_4 and N_2O emissions. When manure is used as organic fertilizer it contributes to the productivity and fertility of the soil by adding organic matter and nutrients, such as nitrogen, which are trapped by bacteria in the soil. It improves productivity and allows for reductions in use of synthetic fertilizers and the associated direct and indirect GHG emissions. The increasing geographic concentration of livestock production means that the manure produced by animals often exceeds the (nitrogen) absorptive capacity of the local area. Manure becomes a waste product rather than being the valuable resource in less concentrated, mixed production systems. Proper use of technologies can reduce direct emissions and also transform manure into a valuable resource and lead to a corresponding reduction in GHG emissions resulting from the use of synthetic fertilizers.

Integrated systems

Crop systems and livestock systems can also be improved by their better integration. Integrated crop and livestock systems, at various scales (on-farm and area-wide) increase the efficiency and environmental sustainability of both production methods. When livestock and crops are produced together, the waste of one is a resource for the other. Manure increases crop production and crop residues and by-products feed animals, improving their productivity. In these systems, livestock is a strategic element for adaptation. The animals provide an alternative to cropping in areas becoming marginal for cropping, offer a way to escape poverty and represent a coping mechanism in vulnerable and variable (in particular weather-related) natural environments. They also constitute a capital that can be converted to cash when needed.

Rice-Fish integrated systems have been traditionally practiced in many Asian countries, either as concurrent or alternate cultivation (FAO *et al.*, 2001) and constitute another example of very productive systems that also provide more balanced diets. They hold great potential to improve food security and nutrition and can be both improved and up-scaled as shown by recent research in Bangladesh (Ahmed N. and Garnett S., 2011; Dey M *et al.*, 2012).

Agroforestry is the use of trees and shrubs as part of agricultural systems. It contributes to prevent soil erosion, facilitates water infiltration and diminishes the impacts of extreme weather. Agroforestry also helps diversify income sources and provides energy and often fodder for livestock. Nitrogen-fixing leguminous trees, such as Faidherbia albida, increase soil fertility and yields (Bames and Fagg, 2003; Garrity, 2010). Community-led projects and relaxed forestry measures that enable farmers to manage their trees have led to considerable development of Faidherbia in Niger through farmer-managed natural regeneration (Garrity 2010). Since 2000, FAO has initiated special programmes for food security with the governments of Guatemala, Honduras, Nicaragua and El Salvador among others (see box 6). These programmes work together, sharing practices, experiences and results to improve and develop agroforestry systems. Agroforestry systems are promoted in the subregion as a substitute to traditional slash-and-burn systems, particularly on slopes. Under these systems, productivity of land and labour are increased. Yields are less variable, partly due to better retention of moisture in the soils. The soil is also protected from hydric erosion. Farm production, including wood products, is more diversified, which stabilizes incomes. As they are more efficient in the use of land, agroforestry reduces the pressure on forests, avoiding deforestation which contributes to climate change mitigation. As wood is produced in the fields, these systems also contribute to preventing forest degradation. Agroforestry systems use less fertilizer, reducing the direct emissions of N_2O and indirect GHG emissions created through fertilizer production. By increasing biomass above ground and in soils, they help create carbon sinks.

There is now interest for using carbon projects to facilitate the development of agroforestry. Examples include the Nhambita community carbon project in Mozambique, initiated in 2003. A small-scale agroforestry-based carbon sequestration project, registered with the Plan Vivo system aims to sequester carbon through agroforestry practices, sell carbon credits in international voluntary carbon markets and improve livelihoods in the local community. The Community Association, the body established in 2002 by the Rural Association for Mutual Support (ORAM) as a part of a national government programme to regularize traditional communities' tenure rights, helps to identify the households that wish to become part of the agroforestry scheme and is responsible for the management of the carbon payments, which are transferred into a community fund (Spirik, 2009).

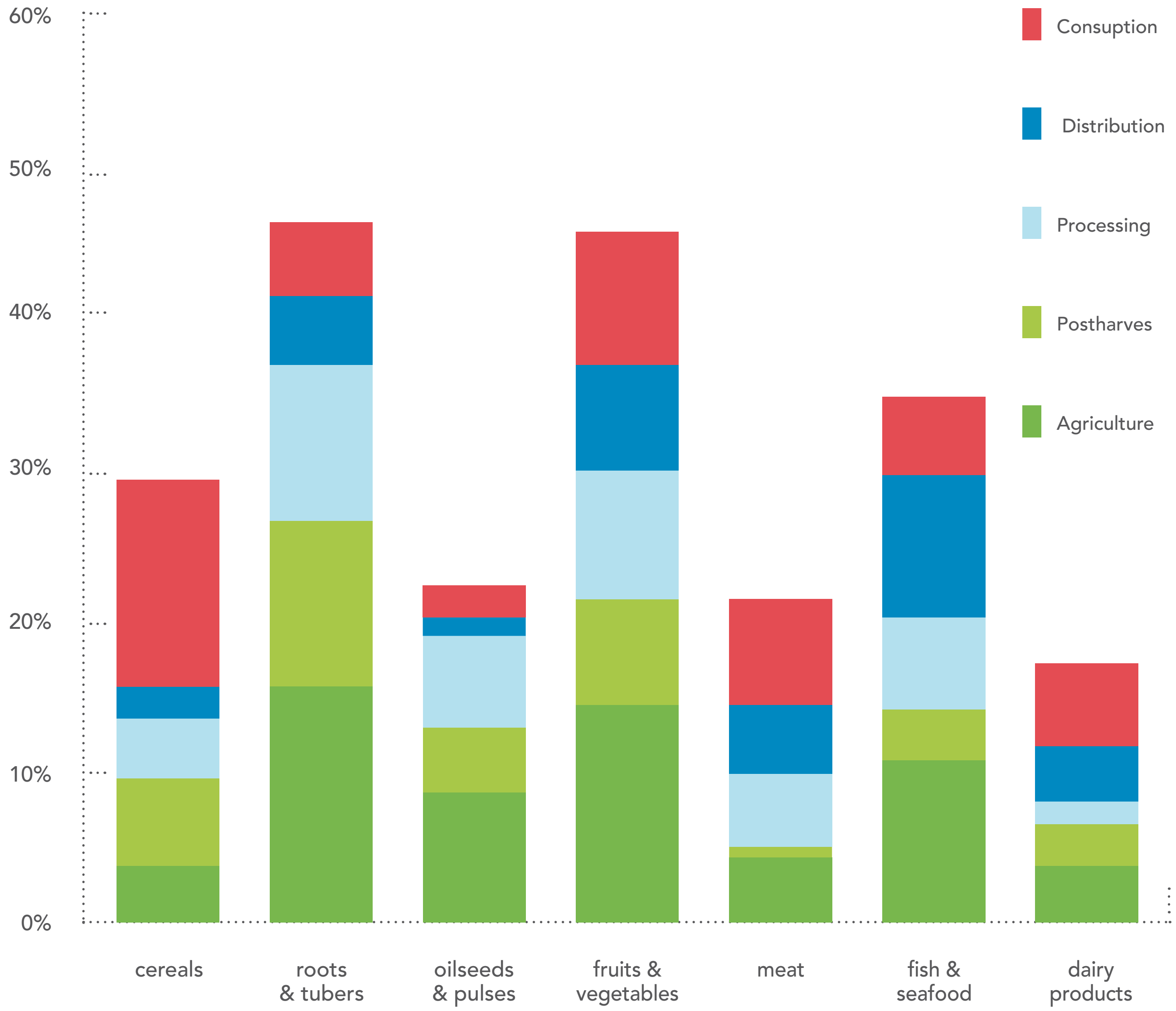
Reduce food losses and waste

Global food losses and waste amount to a third of all food produced (Gustavsson *et al.,* 2011). These losses and waste also mean that the GHG emitted during their production have served no useful purpose. This is especially true when the food has reached the end of the food chain, when the embedded emissions for transport and conservation are very high.

Global differences among regions in food loss and waste for the same type of products indicate potential areas for improvement (Gustavsson *et al.,* 2011). In Europe, cereal losses and waste are twice as high as in sub-Saharan Africa. On the other hand, in sub-Saharan Africa, milk losses and waste are twice as high as in Europe.

Depending on the products, regions, and levels of economic development, the distribution of the losses along the food chain is very different. For instance, in Africa cereals are lost in the first stages of the food chain. In Europe, they are lost mostly at the consumer stage: 25 percent against 1 percent in Africa. For fruits and vegetables, the differences between regions are also striking. In Africa, processing and distribution are the weak links. This highlights the need for investments in these stages of the food chain. In Europe, it is at the production and consumption stages where most losses occur.

Figure 1.1
Global food losses



Source adapted from Gustavsson *et al.*, 2011

However, there are techniques available to reduce food losses. One example is household metal silos for conservation of cereals or tubers (Mejia, 2008; Tadele *et al.*, 2001), which have been actively promoted by various organisations, including FAO and NGOs. The use of metal silos in Afghanistan has reduced storage loss from 15-20 percent to less than 1-2 percent. They are manufactured locally, creating jobs, small enterprises and possibilities for diversification of the local economy. The silos enable farmers to preserve food, making producers less vulnerable (either as sellers or buyers) to price fluctuations on local markets.

In developed countries, given that waste at the retail and consumption stages is extremely significant, reducing waste requires behavioral changes and the involvement of all concerned stakeholders, governments, private sector and civil society.

Box 1.4
The Save Food Global Initiative

In May 2011, FAO's Agriculture & Consumer Protection Department organized the international congress 'Save Food!' in partnership with Interpack/Messe Düsseldorf - a global player on trade fair organization, including the food and packaging industry. Speakers, stakeholders and high-level policy makers in the agriculture, food and packaging sectors from across the globe, signed a joint declaration to show their commitment to the goals of Save Food. The partnership launched the SAVE FOOD Initiative, which is a joint campaign to fight global food losses and waste. The Initiative aims at networking among stakeholders in industry, politics and research, encouraging dialogue and helping to develop solutions to food losses and waste along the food value chain. One of its objectives is to enlist the support of industry in initiating and sponsoring its own SAVE FOOD projects.

Source: Save Food Initiative, 2013

All along food chains, from agricultural production, transport, conservation, processing, cooking and consumption, there are potential areas for improving energy efficiency (FAO, 2011c). In Africa, 90 percent of the extracted wood is used for domestic purposes, mostly cooking. Improved energy-saving cooking stoves can contribute to reduce deforestation. However, trade-offs may need to be made between reducing losses and reducing energy consumption, especially for fresh perishable products, such as meat, dairy products, fish, fruits and vegetables. Consumption of perishable products, which often require cold chains and rapid transport, is increasing. Analyses of food losses and waste should therefore encompass the whole food chain to be able to consider all impacts and all potential solutions. For instance, processing fresh products transported over long distances into less perishable products can reduce foods losses and GHG emissions resulting from conservation and transport, as slower methods of transport can be used.

System efficiency

A change of practice in one component of a given system generally impacts the whole system. So it is not only a single technique or practice that has to be considered but the system as a whole, at the farm and household level and beyond the farm gate. Box 1.1 provides an example of the various consequences of the introduction of the UDP technique in Bangladesh.

Most of the changes in resource use of one factor of production impact on the use of other factors. Therefore, from a 'GHG efficiency' perspective, we need to assess the trade-offs between increasing resource efficiency regarding one or other input, for example, increasing yield per hectare through increased use of fertilizers. Thus, for improvements involving variations of several 'emitting' factors, a comprehensive assessment is needed, using life cycle analysis methodologies or GHG accounting tools.

As seen in the example of UDP in Bangladesh (Box 1.1), changes towards more resource efficiency, even through the introduction of a single new technique, can have major economic and social impacts which, in turn have impacts on food security, especially in terms of access to food. Whatever the 'efficiency' considered, there is a need to look at the allocation of factors and at the issue of scale. Indeed, production efficiency, GHG-efficiency, economic efficiency and food security do not always go hand in hand. For instance, to increase the workforce in the mix of factors of production might go against economic efficiency at the farm level, but may have a positive effect on food security. In that respect, efficiency should be assessed inside a system, at various scales and from various perspectives.

More resilient systems[5]

Climate change will profoundly affect, in any given place, the conditions under which agricultural activities are undertaken. It will affect existing risks and add new risks and uncertainties. As pointed out by the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2012a), models cannot project climate change

[5] This section draws heavily on Gitz V. & Meybeck A. 2012. Risks, vulnerabilities and resilience in a context of climate change. FAO/OECD Workshop: Building Resilience for Adaptation to Climate Change in the Agriculture Sector, Rome, Italy, 23-24 April 2012.

effects precisely, neither in time nor at the local scale needed for decision makers. Moreover, climate models do not deal with the consequences of increased variability, the impacts of stress combinations, the effects of climate change on whole agro-ecosystems, including crops, their pests and predators of these pests. As it is impossible to predict exactly these changes, it is often difficult to devise and promote precise adaptation measures. One of the most effective approaches to be prepared for uncertainty and new risks – a 'no regret' approach that is valid whatever changes happen – is to reduce vulnerability and increase resilience of a given system (FAO and OECD, 2012; HLPE, 2012a).

Risks

Agricultural production is subject to risks of various types: economic and price-related risks, climatic, environmental, pests and diseases, at different scales and, often, political instability. Yield risk in main staple crops is particularly important for smallholders who tend to consume a large part of their own production. Farmers are also exposed to economic risks, including land tenure insecurity, variations in access to inputs (fertilizers, seeds, pesticides, feed) in quantity and quality and variations in access to markets.

'Risk' is used here to designate the potential of shocks and stresses that affect, in different ways, the state of systems, communities, households or individuals. Probability, uncertainty (when probabilities of occurrence or even nature of impacts are unknown), severity, economic scale, time scales and direct and indirect costs are all factors that should be taken into account.

Risks affecting agricultural activities are generally categorized according to the nature of the associated shocks (e.g. biophysical, economic) (Eldin et Milleville, 1989; Holden *et al.*, 1991; Cordier, 2008; OECD, 2009). They are also often classified according to the intensity, frequency and predictability (degree of uncertainty) of the associated shocks. They can be also categorized according to their impacts and their nature, as well as their importance and scope both in space and time (INEA, 2011). Weather is in itself a major cause of risk and also has a major influence on other types of risks. Climate change is expected to affect the nature, extent and intensity of these risks, plant pests, animal diseases, and disruption of ecosystem functions (HLPE, 2012a; FAO and OECD, 2012).

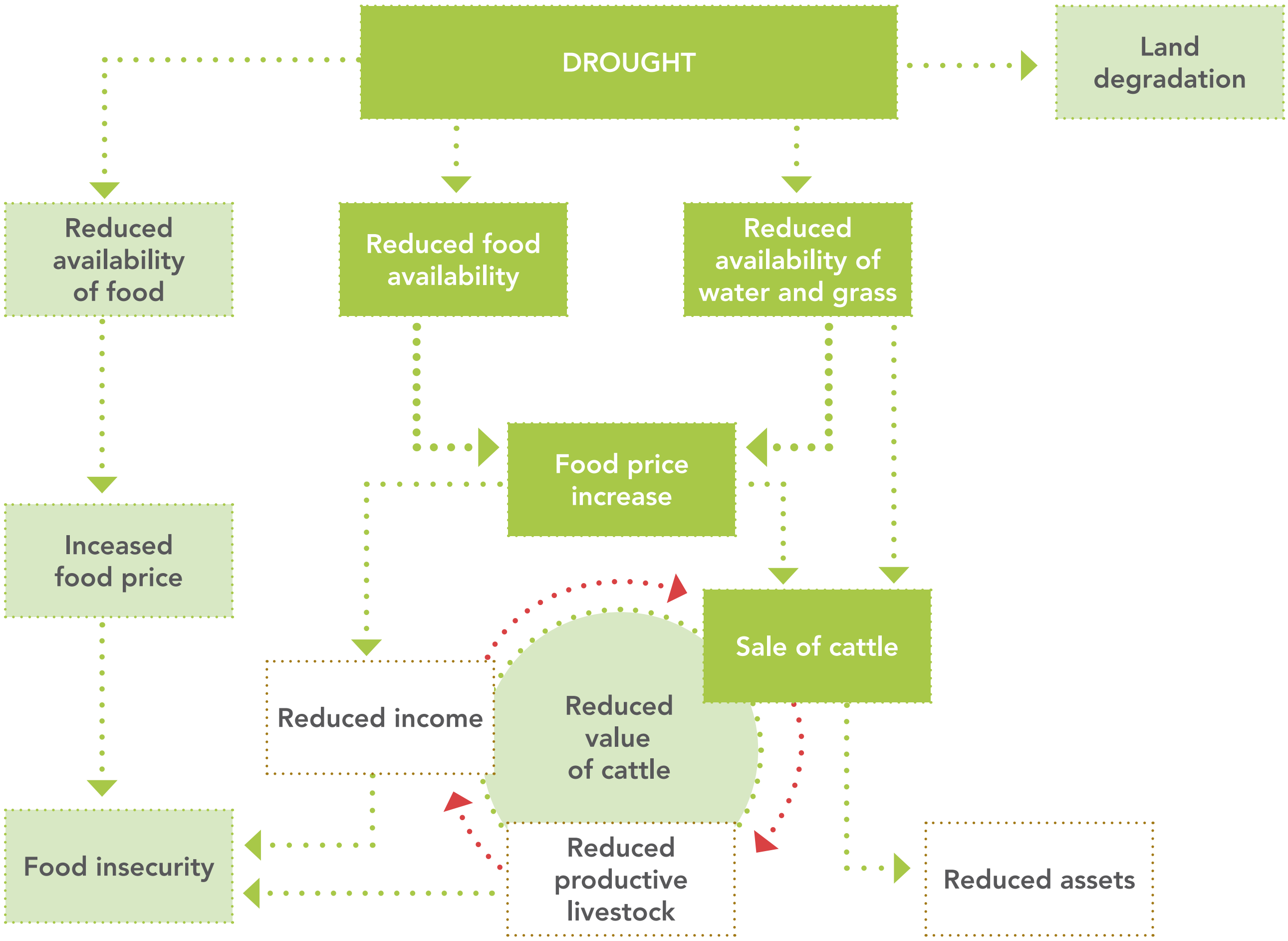
The impact of a risk depends on the shock itself and on the resilience of the system that receives the shock. Depending on their vulnerability, different systems will be more or less affected by the same shock. Depending on their resilience, different systems will recover more or less easily.

Food systems are by nature ecological, economic and social (Ericksen, 2008; Fussel and Klein, 2006). Each dimension has its own organization and interacts with the others. Food systems can be described and analyzed in each of their dimensions. There are also theories attempting to understand and describe 'complex systems' (Holling, 2001; Gunderson and Holling, 2001) to obtain a better grasp of the concept of sustainability.

Even when considering a single simple farming system, a single stress or shock can have various impacts of diverse nature and time scale. The global impact of a shock often also depends on the transmission of its effects from one dimension (biophysical) to the others (economic and social) and from one level (household) to another (community).

For instance, a drought in livestock grazing systems (see Figure 1.2) reduces the availability of water and grass – both directly and indirectly because as the watering points are reduced some pastures are no more accessible- and so increases the demand for feed at the very moment when there is less feed available. Increased demand drives a feed price increase, which forces livestock owners to sell their cattle. Massive sales while there is a reduced demand push down cattle prices, forcing livestock owners to sell even more to buy feed. These effects on prices reduce farm and household income and assets. Moreover, they reduce the value of assets (livestock) and productive capital for the future. Prolonged or repeated drought also has long-lasting degrading effects on land. The combination of drought and overgrazing, particularly near watering points, destroys the vegetal cover and increases soil erosion.

Figure 1.2
Impacts of drought



Gitz and Meybeck, 2012

Vulnerabilities

The net impact of a shock depends not only on the intensity of the shock itself but also on the vulnerability of the system to this particular type of shock.

Vulnerability can be defined as the propensity or predisposition to be adversely affected (IPCC, 2012). It is a complex concept (Fellmann, 2012) that needs to be considered across scales and across various dimensions (Gitz and Meybeck, 2012). It can be defined as vulnerability of 'what' to 'what' (Carpenter *et al.*, 2001).

The degree of 'specific' vulnerability of a system to a particular type of risk can be analysed as exposure and sensitivity to the potential shock that relates to this risk, and also depends on the 'adaptive capacity' of the system to cope with the impact of the shock. The adaptive capacity itself can also be affected by an external shock. In a given system, shocks in one dimension can spread to another dimension. For example, production shocks can be transmitted to the economic and social domains. This transmission can be linear, amplified or reduced, depending on the policies and institutions that are in place.

In many cases, there can be amplifying or positive correlations between the effects of shocks of diverse nature. In such cases, reducing vulnerability to one kind of shock can help also to reduce (specific) vulnerability to another kind of shocks. Vulnerability is also affected by the various shocks (e.g. a drought increases vulnerability to the next drought). By decreasing the strength of cattle, drought also increases their vulnerability to diseases. By reducing assets of households, drought also increases their vulnerability to other kind of shock.

Systems can be defined at various scales. An upper-scale system is generally composed of different systems defined at lower scales. For instance, from a biophysical perspective, landscape systems are composed of farm systems. The vulnerability of an upper-scale system depends on the vulnerability of the subsystems that it includes. It also depends on how other systems to which it is linked, including higher-scale systems, are vulnerable or insensitive to shocks. For example, the vulnerability of a farm to a certain risk is compounded by its own vulnerability and the vulnerability of the landscape in which it is situated, and whose vulnerability is in turn compounded by the vulnerabilities of the various farms situated in it and by the vulnerability of the higher-level system (e.g. the territory) in which it is situated.

Resilience

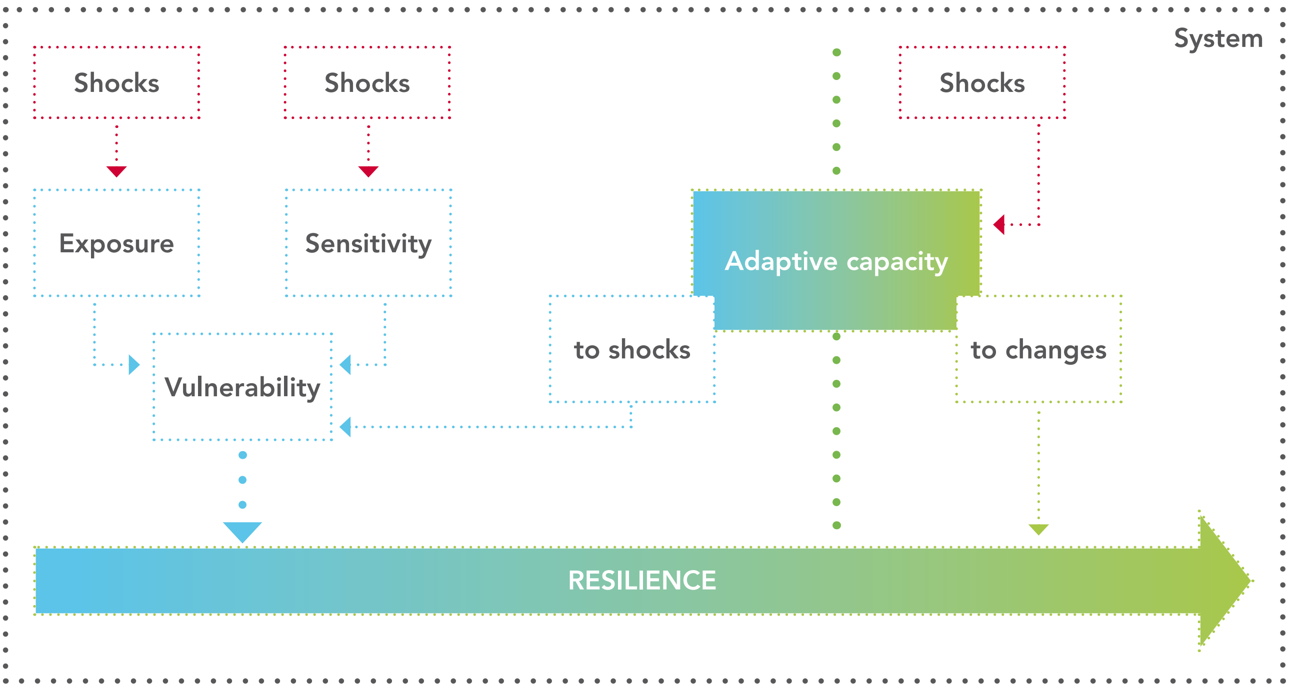
Resilience can be described as the capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk and recover from shocks. At first approximation, resilience is the opposite of vulnerability. However, resilience adds a time dimension. A system is resilient when it is less vulnerable to shocks across time and can recover from them. Essential to resilience is adaptive capacity. Adaptive capacity encompasses two dimensions: recovery from shocks and response to changes in order to ensure the 'plasticity' of the system.

For example, the organization of seed systems enables farmers who have lost a crop to have seeds for the next season. It also enables them to have access to seeds that are adapted to new conditions.

As for vulnerability, resilience can be specified as "resilience of what to what" (Carpenter *et al.*, 2001). However, focusing on specified resilience may cause the system to lose resilience in other ways (Cifdaloz *et al.*, 2010). This is why general resilience can be described as being "about coping with uncertainty in all ways" (Folke *et al.*, 2010).

And as for vulnerability, resilience can be considered in various dimensions (biophysical, economic and social) and at various scales. The way the various dimensions and scales interact is crucial, precisely because of the importance of general resilience for coping with uncertainty. For instance, studies show that increasing the level of education of farmers can be an efficient mean for reducing farmers' household vulnerability to climate change (Karfakis *et al.*, 2011).

Figure 1.3
Components of resilience



Source: Gitz and Meybeck, 2012

Resilience puts a greater emphasis on the capacity of a system to recover and transform itself over the long term, and adapt to its changing environment in a dynamic perspective. It implies that it is not only shocks, as a change relative to an average, that have to be considered, but also the change of the average itself. Ultimately, the question is until what point can a system adapt before changing to another type of system?

Building resilience

To a great extent increasing resilience can be achieved by reducing vulnerabilities and increasing adaptive capacity. This can be done by reducing exposure to risk, reducing sensitivity and increasing adaptive capacity for every type of risk. It can act in each domain, either biophysical or economic and social. One way to achieve better resilience is to reduce transmission of shocks between types of risks, between scales and between domains and to organize compensation between scales (for instance transport of feed) or between domains (for instance safety nets) to avoid cumulative and long-term effects.

In a first approximation we can identify the following three ways to build resilience:

1. Reduce exposure. There is a fundamental difference between climatic and non-climatic shocks in this regard because most of the shocks on farm can be reduced at the source, or limited in their extension, contrary to climatic shocks. The best example of a non-climatic shock is probably the eradication of Rinderpest, which has totally suppressed a major risk for livestock and those depending on it.
2. Reduce the sensitivity of systems to shocks. Using drought-resistant varieties or keeping adequate stocks of hay can for instance, reduce sensitivity to drought.
3. Increase adaptive capacity. This includes considering the modifications of a system and taking into account all the potential shocks and changes together (to take into account compensating, cumulative or exacerbating effects).

Box 1.5
Prevention of major Desert Locust upsurges in West and Northwest Africa

Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES Programme)
The Desert Locust is a highly destructive transboundary plant pest that threatens people's livelihoods, food security, the environment and economic development in more than 30 countries. In terms of bio-ecology, West and Northwest Africa (Western Region) is an indivisible distribution area of this pest. In that area more than 8 million people faced severe food shortage as a result of the 2003-2005 Desert Locust upsurge. It cost the international community and affected countries over USD 570 million to overcome it and 13 million litres of chemical pesticides were applied. The Sahelian countries also suffered from high crop losses ranging from 30 to 100 percent. To address the Desert Locust issue more effectively, the Western Region countries (Algeria, Burkina Faso, Chad, Libya, Mali, Morocco, Mauritania, Niger, Senegal and Tunisia) set up in 2002 the Commission for Controlling the Desert Locust in the Western Region (CLCPRO) under the aegis of FAO. To implement a sustainable preventive control strategy, they also joined the FAO EMPRES Programme, launched in 2006 in the Western Region. The Evaluation Missions of Phase 1 (2006-2010) of this Programme underlined that substantial progress had been made in achieving the objectives, in particular, in the frontline countries (Chad, Mali, Mauritania and Niger) in terms of: institutional building with the creation of autonomous National Locust Control Units (NLCUs); strengthening of locust control capacities and infrastructure; implementation of early warning systems and rapid interventions, developing health and environmental standards, and better preparedness to Desert Locust crises (ongoing contingency planning).

The improvement of more effective preventive control strategy became obvious during the control operations against locust outbreaks in 2006, 2008, 2009 and 2010-2011 in Mauritania and in 2009 in Niger. Also, a gradual funding of the recurrent costs for preventive control implemented by the NLCUs from the national budgets was observed: from 10 percent in 2006, it reached an average of 60 percent in the frontline countries at the end of 2010. The annual cost of preventive control in the Western Region is USD 3.3 million, less then 0.6 percent of the expenses incurred during the 2003-2005 major outbreak.

Source: Brader *et al.*, 2006; Cossée *et al.*, 2009

Finally, we have to consider that the occurrence of shocks is not certain. The nature of the shock may be uncertain as well as the nature or size of its impacts. In addition, their occurrence in time is generally unknown.

Therefore, building resilience goes hand in hand with the need to anticipate within uncertainty, within the system, or across scales. In that sense, specific risk monitoring not only reduces vulnerability but also increases resilience as it allows for the anticipation of risks and their changes.

A good example of actions to build resilience in the face of uncertainties due to climate change can be found in the domain of genetic resources (HLPE, 2012), which is being considered by the Commission on Genetic Resources for Food and Agriculture (CGRFA)[6] . If climate changes, farmers might need to rely on different genetic resources, some that are already used elsewhere, or other species or varieties that are now considered minor but that may be better adapted to new conditions. To do so, access to the largest possible pool of genetic resources is needed. Genetic resources, which are also threatened by climate change, are crucial for adaptation (see Module 6 on genetic resources). We need to preserve diverse genetic material, including traditional and improved crop varieties and their wild relatives. They are adapted to specific conditions, have been selected for different uses, and constitute the reservoir from which varieties can be developed to cope with effects of climate change, such as drought, the shortening of the growing season, increased incidence of pests and diseases. Preserving genetic resources increases the resilience potential of the whole system. To achieve this, the potential effective genetic resources have to be accessible to farmers where they are needed. It is not enough to have the appropriate genetic resources in a gene bank or a research centre. They have to be multiplied and distributed, which requires plant breeders, seed enterprises and the proper legal system to certify the quality of the seeds and the accuracy of the genetic information. All these actors and elements constitute 'seed systems', which enable farmers to have the seeds they need. Regional harmonization of seed rules and regulations is also essential, particularly as crops will move to adapt to climate change (Burke *et al.*, 2009).
In agroforestry systems the various dimensions and scales interconnect to increase the resilience of farming systems.

Box 1.6
A change of system: from slash and burn to agroforestry in Central America

Since 2000, FAO has initiated special programmes for food security with the governments of Guatemala, Honduras, Nicaragua and El Salvador, among others. To improve and develop agroforestry systems in the sub-region, these programmes worked together, sharing practices, experiences and results. Agroforestry systems are promoted as a substitute to traditional slash-and-burn systems, particularly on slopes. They are at the same time more efficient and resilient.

In traditional slash-and-burn systems, a family needs close to 6 hectares to maintain itself on a diet of corn and beans. The family exploits a plot for two years and then sets it aside for 14 years. In agroforestry systems a plot is exploited for 10 years, producing, along with corn and beans a variety of other products, often including livestock. The plot is then set aside for only 5 years. A family thus needs 1.4 hectares to sustain itself and enjoy a more diverse and balanced diet. Land is therefore almost 4 times more efficient. Efficiency also increases because in agroforestry systems, yields (which are comparable the first year) do not decline over time as they do very rapidly in slash-and-burn systems. In fact, yields can even increase slightly over time in agroforestry systems. Productivity of labour and of capital is also higher in agroforestry systems. Costs are reduced, especially for fertilizers, because of more organic matter in the soil and better use of nutrients by the plants. At the community level, diversification of production triggers the development of local markets. Consequently, in terms of resource use, agroforestry systems are efficient at safeguarding food security and the environment.

Agroforestry systems are also much more resilient:

- Yields are less variable, because of better humidity retention.
- They provide for more diverse production, which ensures in turn a buffer against both the variability of crop yields and price volatility.
- They offer diversified sources of income, including through selling wood for various uses (and at various time scales), which can also provide a buffer against some economic shocks.
- They protect the soil from erosion, which is a major concern in these areas. Studies have shown that in agroforestry systems erosion is reduced by a factor of more than 10.

Source: FAO, 2010d

[6] The Secretariat of the Commission on Genetic Resources for Food and Agriculture has commissioned and prepared several background papers (No 48, 53, 54, 55, 56, 57, 60) on climate change and genetic resources available at http://www.fao.org/nr/cgrfa/cgrfa-back/en/?no_cache=1.

Sustainable management of forests (Braatz, 2012) and sustainable management of fisheries (De Young, 2012) are good examples of where the actions towards increasing resilience in one domain of vulnerability, starting with the biophysical domain, also have positive effects on the resilience and vulnerability in other domains (social and economic). Landscape approaches can play an important role in building resilience (HLPE, 2012a).

Social protection can play an important role in increasing resilience at household and community level. This is especially true if national systems are designed as comprehensive programmes that exploit the synergies between various instruments in such a way as to cover the specific needs of various groups, especially the more vulnerable, and to be easily scaled up to address any kind of shock (HLPE, 2012b).

The notion of resilience is particularly powerful for bringing together interventions that cover different dimensions. Improving the sustainability of forest management not only increases the forest's resilience, but also contributes to improving water management, protecting the soil from erosion and to conserving agrobiodiversity (e.g. by providing habitat to pollinators). In this way, improvements in the sustainability of forest management contribute to improving the resilience of farming systems. As mentioned earlier, landscape approaches can play an important role in that respect (HLPE, 2012a). Forestry and fisheries provide complementary food and income and in so doing contribute to improving the resilience of households and food systems. This notion also helps clarify the relations between 'specific' vulnerabilities and resilience and how addressing known risks can allow for the creation of strategies to build general resilience to cope with uncertainty. As such, resilience provides an efficient way for implementing 'no regret' adaptation. A crucial element would be to better manage known risks, whether climatic or not, to increase preparedness to future, uncertain risks and changes.

Efficiency and resilience

Efficiency and resilience should be pursued together and at various scales in different agricultural systems and food chains. Being efficient without being resilient will not be helpful over the long term, given that shocks will occur more often due to climate change. Being resilient without being efficient or without allowing for an increase in production, will pose problems for ensuring food security over the long term and for supporting livelihoods. In the pursuit of these two goals, there might be trade-offs, but there will also be synergies. Increasing efficiency could lead to greater sensitivity to certain shocks. For example, more productive livestock is more sensitive to heat waves (Hoffmann, 2010). On the other hand, increased efficiency can be a factor in increasing resilience. For example, increasing production in food importing countries will improve their resilience to price volatility. Increasing soil carbon stocks, enhancing diversity in the field and improving trade are of particular interest with regard to improving efficiency and resilience of food systems.

Increasing soil carbon stocks

Increasing soil organic carbon improves both efficiency and resilience. It improves nutrient and water intake by plants, which increases yields and resource efficiency of land, nutrients and water. It also reduces soil erosion and increases water retention, especially as it is often combined with added soil cover, as in conservation agriculture. This combination makes the system more resilient to variability of precipitation and to extreme events. Increasing carbon sinks in the soils also captures carbon, which contributes to climate change mitigation. For all these reasons, restoring degraded lands and increasing the level of organic carbon in soils is a priority action (IPCC, 2007b; FAO, 2009b; FAO, 2010a; HLPE, 2012a).

Box 1.7
Participatory rangeland management in the Syrian Arab Republic

In the Syrian steppe (or Badia), IFAD is working on participatory rangeland management with local communities to reduce herders' vulnerability to climate change and restore the long-term productivity of rangelands. After years of severe drought and intensive grazing, rangelands in the Badia were severely degraded.

By reintroducing native plants that help meet fodder requirements, fix the soil and stop sand encroachment, ecosystems were restored and the local population's vulnerability to the effects of climatic instability was reduced. After two years of resting, reseeding and planting, birds, insects and animals returned to the area. The rehabilitated ecosystems offered further potential for income generation, as truffles grow in some areas of the Badia, and women could gather them to boost their family incomes. In 2010, a community with a 100 000-ha grazing area could earn up to USD1 million through the sale of truffles.

Higher household incomes provided a basis for the project to diversify income-earning opportunities for women through literacy classes and training courses in new skills such as first aid, food processing and sewing. With households being better off, there is less pressure on young girls to marry early, and as women gain more economic autonomy, they are finding that gender relations are shifting.

Source: IFAD, 2012a

Increasing diversity in the field

Increasing diversity of production at farm and landscape level is an important way to improve the resilience of agricultural systems (FAO, 2010a; FAO and OECD, 2012; HLPE, 2012a).

Specialized systems are often presented as being more efficient from an economic point of view, as they generate more income. These systems can benefit from the improved technologies and from economies of scale in the production and distribution of inputs, machines, and especially processing and trade.

Diversifying production can also improve efficiency in the use of land, as is the case in agroforestry systems for instance and of nutrients with the introduction of legumes in the rotation or in integrated crop/livestock or rice/aquaculture systems. Studies show that they can also be more efficient in terms of income (see for instance Box 1.6), especially if this is measured as an average over a period of several years. The Finnish project ADACAPA aims to identify means for assessing and enhancing the adaptive capacity of the Finnish agricultural sector to global environmental and socio-economic changes at various decision-making levels (farm, regional, national). The main hypothesis tested is that increasing diversity enhances resilience and thus adaptive capacity of agrifood systems. Some of the results of studies conducted in the ADACAPA project have shown that diversity can increase income (Kahiluoto, 2012). Farms that both grow crops and exploit forest generate a higher and more stable income. Regions growing more diverse varieties of barley have a higher average yield than areas growing a single variety. More diversified systems can also spur the development of local markets. An example of this is agroforestry in Central America (Box 1.6). Finally, systems providing more diverse types of food are also more efficient from a nutritional point of view as they facilitate more balanced and diverse diets.

Trade

Agriculture is a classical example that illustrates the role of trade to increase global economic efficiency by exploiting local comparative advantages (Huang *et al.*, 2011). This is, however, being questioned from a GHG emissions perspective, initially triggered by the promoters of the 'food miles' concept who advocate the consumption of local products to reduce GHG emissions. In reality, transport represents only a small part of global food systems' emissions. Emissions from transport are estimated to be 11 percent, of which 6 percent results from consumers' transport to buy food (Weber and Matthews, 2008). Obviously, these percentages will vary by distance and the agriculture/food product considered. Life cycle analysis of various products confirms that, apart from fresh fragile products, such as fish, fruits and vegetables, transport is not the determining factor of their carbon footprint (FAO, 2012c). In fact, a more efficient production system can more than compensate for the emissions resulting from transport. The emissions due to transport to retailers should not be isolated but considered on a case by case basis in conjunction with the emissions from the production stage as part of a life cycle analysis. Restricting trade and producing locally may both increase GHG emissions (and other environmental costs) per unit of output as well as reducing economic efficiency.

International trade is – and has been – an essential factor for the resilience of food systems (Meridian Institute, 2011; Nelson *et al.*, 2010; HLPE, 2012a). As shown above, climate change is expected to have different effects in various regions of the world. Available research indicates that climate change is expected to lead to important changes in the geographical distribution of agricultural production potential, with increases in mid to high latitudes and a decrease in low latitudes. International trade plays an important role in compensating, albeit partially, for regional changes in productivity that are induced by climate change. Together with productivity changes, changes in endowments of arable land and usable water, developments in energy markets, population growth and government policies, both existing agricultural policies and climate-related policies, all drive the patterns of regional specialisation and of international trade.

Trade can compensate for local production deficits caused by increased variability and extreme events. However, recent commodity price volatility has shown that trade does not always buffer local production variations (HLPE, 2011; MacMahon, 2011; FAO, 2012d). On the contrary, it can exacerbate and transmit the effects of a local shock, and consequently it can become a factor of systemic risk. In addition, price volatility has hit poor importing countries especially hard (HLPE, 2011). Trade could then appear as a factor of risk, rather than a way to cope with shocks. The ability to realize the compensating potential of international trade depends on a well-functioning international trade architecture. Imposing import restrictions, perhaps motivated by the desire to increase domestic production in the face of declining yields, and hence confounding food security with food self-sufficiency, is clearly not a sustainable solution. Likewise, imposing export restrictions in surplus regions, as witnessed during food price spikes in 2007/2008 and motivated by the objective to keep domestic prices low relative to world prices, creates problems for food importing countries and undermines the trust in the functioning of the global trade system.

Overdependence on imports to satisfy national needs can lead to severe food crises for the poor during price upsurges, which are often aggravated by measures to restrict exports. Trade's role in improving the resilience of food systems would be enhanced paying greater attention to food security concerns (HLPE, 2011and 2012a).

1.3 Increase systemic efficiency and resilience: policies, institutions finances

Appropriate policies, institutions and finances are essential to increase systemic resilience and efficiency at local, national and international level and to achieve needed changes in agricultural and food systems. These are detailed below (see also Module 12 on institutions, 13 on policies and 14 on financing CSA).

Invest in agriculture in developing countries

There is already a gap today in funding for investment in developing countries. The needs will increase. FAO estimated that cumulative gross investment requirements for agriculture in developing countries add up to nearly US$ 9.2 trillion until 2050 or nearly US$ 210 billion annually (FAO, 2009c). Therefore, the decreasing trend in funding has to be reversed. It includes increasing the share of Official Development Assistance directed to agriculture. Domestic efforts have to be pursued at the appropriate level.

The needs are even greater when the need to address the challenges of climate change is included (FAO 2010a, Nelson *et al.*, 2009, Nelson *et al.* 2010, HLPE 2012). It must be emphasized that the major part of these investments will be made by the private sector, and most of them by the farmers themselves. Public actors can play a key role in building an enabling environment, including policies, institutions and key investments. Reducing risk and improving resilience is key to enabling private actors, especially the more financially vulnerable, to invest. Often these private actors will also need support, particularly during the transition phase towards new systems. Payments for environmental services can play an important role to facilitate this transition (Lipper and Neves, 2011).

Among the needed investments are important land management schemes and infrastructure, such as local roads and irrigation systems, which are an important source of job creation in rural areas. These public works can be supported by social protection schemes in order to provide work, food and income to food-insecure people. A recent report of the HLPE (2012b) reviews some of these schemes and concludes that public works programmes have proved to be efficient in dealing with covariate shocks and, if they are well designed, can contribute to improving food security.

They also include major investments in research (HLPE 2012a, Beddington *et al.*, 2012c). To be able to embrace the whole range of issues to be addressed, these investments need to be coordinated at a global scale. Increased investment in public research is particularly needed in areas where return on investment cannot immediately benefit the private sector. To address systemic issues to be adapted to local specificities and needs, research will have to be closely linked to extension services and be open to local knowledge and to the demands addressed by all stakeholders, including small-scale food producers (HLPE 2012a). The transfer of technology will also play an important role. It should include the development of the human capacity to accommodate the technology and structured partnerships to ensure that it is adapted and established locally.

Manage risks at local, national, international levels

Climate change will add more risks to production and aggravate existing risks, especially for the more vulnerable. Increased variability and uncertainty make ever more necessary the establishment of risk management strategies to address every type of risk, whether climate, animal or plant diseases or even economic. Such strategies should aim to limit losses ex ante by monitoring risks, assessing vulnerability, identifying (ex-ante) damage reduction measures and acting at the earliest stage of the event. They would include quick reparation of losses to productive assets in order to avoid long-term consequences.

In doing so, such strategies should combine specific policies targeted to address specific agents and categories of risks.

Policies targeted at farmers can include measures aiming at building economic resilience at farm level either by increasing income, enabling saving, by promoting diversification (especially if the risks affecting each activity are not correlated) or by insurance (in certain cases). They also include measures to reduce or eliminate specific risks, such as plant pests and animal diseases, including advanced observation networks for quick response. Other measures either prevent the loss of productive assets, such as feed banks for livestock during droughts, or enable quick recovery, such as availability of seeds.

Policies should also address risks along the food chain (including for small scale food producers), including storage, post harvest losses and food safety risks. Prevention of food safety risks or effectiveness to handle large-scale food safety emergencies will depend on the services available (inspection and analytical capacities, information sharing, health services) (see Module 11 on sustainable food value chains).

Policies targeted at consumers would use measures specifically designed to address access to food that is nutritionally adequate, safe and culturally appropriate.

The efficiency of any specific risk management policy is largely dependent on the existence of enabling policies, institutions, coordination mechanisms, and basic infrastructures. For example, opening markets and adequate transport systems have an important role in diluting the impact of a shock over greater areas.

Enable farmers to overcome barriers to change

Land use and management play a crucial role in improving agricultural practices to address food security and climate change. Improving land management, soil fertility, or practices like implementing agro-forestry have long-term benefits but often imply up front costs either in inputs or labour. Securing land tenure is paramount to enable farmers to benefit from the value added on the land and to encourage them in adopting a long-term perspective. The Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security[7] recently adopted by the Committee on World Food Security promote secure tenure rights and equitable access to land, fisheries and forests as a means of eradicating hunger and poverty, supporting sustainable development and enhancing the environment. They can play an important role.

Whatever the change in farming systems envisaged or implemented, it involves costs. Even if a new practice will provide the same or an increased income in the long run, there are barriers to adoption: upfront costs, income foregone during the transition period or additional risks during the transition period which all have to be covered. Take for instance mitigation measures. Mitigation measures in the agricultural sector are considered among the cheapest, with a quarter of the technical mitigation potential being estimated as costing less than 20$/t$CO_2$ (IPCC, 2007b). But these estimations compare the income with a new practice to the income without the practice. They do not take into account transition costs, or the costs of the enabling environment, such as extension services for instance. These costs have to be assessed and taken into account (FAO, 2009a).

The recent report of the High Level Panel of Experts on food security and nutrition on Social Protection for Food Security (HLPE, 2012b) shows how social protection can be a powerful means to enable farmers, and especially the more vulnerable, to invest and modify their practices to improve their food security. Many measures, such as providing inputs or public works to improve infrastructures and landscapes have both direct short term and longer term impacts. In cash subsidies provided as social protection are often used to invest for improving livelihoods (HLPE, 2012b). Moreover an integrated and up-scalable social protection system is essential to enable investment particularly of the more vulnerable.

It is also essential to facilitate access to the needed knowledge, including for local specific practices, through the development and improvement of extension services and initiatives such as farmer field schools and formal and informal knowledge sharing networks (HLPE, 2012).

Need for a systemic approach

The changes required in agricultural and food systems will require the creation of supporting institutions and enterprises to provide services and inputs to smallholders, fishermen and pastoralists, and transform and commercialize their production more efficiently. These changes will also require major investments from both public and private sector. For this reason, they will drive economic development and create jobs, especially in rural areas and in countries where agriculture is a major economic sector.

Changes in the field require the introduction of new inputs, techniques and services. Making them accessible to smallholders, pastoralists, fishermen and foresters, both physically and financially, is a major challenge. This situation in turn creates opportunities for the development of small local enterprises dedicated to providing inputs and services to farmers.

Changes in farming systems should be accompanied by changes all along food chains. For instance, as pointed out by the HLPE (2012) increasing diversity in the field often requires changes in consumption patterns. In fact, diversification often requires changes along the entire food chain, from input production and distribution to collection, transformation and commercialization of products. For these reasons, diversification is often more easily carried out as a collective project. Several diversified farms can realize the same economies of scale on each of their production systems as a specialized one. This can lead to the creation of services, for example to share machinery and collect and sell their production.

[7] FAO, 2012f.

The introduction of better processing techniques that are more resource efficient not only reduces expenses but also often gives the opportunity to improve quality, exploit new markets and increase incomes. This in turn creates jobs in the agricultural and food sector, as well as in other rural-based sectors.

Comprehensive governance, from local to international

To improve efficiency and resilience of food systems at every scale requires comprehensive governance, at every level, local, national, regional and international. It shall involve all stakeholders, farmers, agro-industry, retailers, consumers and public authorities.

At a global scale, there is an urgent necessity to better consider the interrelations between agriculture, food security and climate change. The international community needs to establish appropriate links between the international fora discussing food security issues and climate change. Fortunately, this is starting to happen.

Food security and climate change policies have to be better integrated at every level. Implementing CSA, and particularly adaptation to climate change also requires adequate means to promote collective management of natural resources, such as water or landscape.

The 47 National Adaptation Programmes of Action (NAPA) prepared by the least developed countries provide a rich panorama of adaptation priority measures. These projects are of special interest and relevance because they have been designed and prioritized by the countries themselves. A close analysis of all the categories of projects (Meybeck *et al.*, 2012) shows that most of these priority projects are linked to agriculture, including forestry and fisheries.

As pointed out by the High Level Panel of Experts on food security and nutrition (2012a), "addressing food security and climate change requires concerted and coordinated involvement and action of many actors, farmers, private sector, and public actors national and international, civil society and NGOs. It is especially challenging as they are very different, sometimes have conflicting objectives and there is a need to work on a long-term perspective while most of them have to consider first a short term outcome. This requires the involvement of all stakeholders."

Integrating food security and climate change concerns has to be done at every level and pursued at different scales. It also needs to be done on a day-to-day basis at farm level. But it also must be carried out with a long-term perspective at the landscape level and country level to design locally specific, coherent, inclusive and cohesive policy packages.

1.4 What's new with CSA?

Indeed, what is different about CSA? (Grainger-Jones, 2011) Climate smart agriculture is not a new agricultural system, nor is it a set of practices. It is a new approach, a way to guide the needed changes of agricultural systems, given the necessity to jointly address food security and climate change. This section aims at clarifying how CSA relates to some other approaches.

CSA shares with sustainable development and green economy objectives and guiding principles. It aims also for food security and contributes to preserve natural resources. As such, it has close links with the concept of sustainable intensification, which has been fully developed by FAO for crop production (FAO, 2011b) and is now being extended to other sectors and to a food chain approach.

Sustainable development and Green Economy

The concept of sustainable development was given prominence by the Brundtland Commission in Our Common Future - Report of the World Commission on Environment and Development (1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The report's framing of the concept of sustainable development twinned environmental action with poverty reduction, and helped set the stage for the 1992 Earth Summit and Rio Declaration. The concept recognized the value of the environment, extended the time horizon and emphasized the role of equity. The Brundtland Commission noted that sustainable development embodies two key themes:

- The idea of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given; and
- The idea of "limitations" imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

In 1992, five years after the release of the 1987 Brundtland report, the United Nations Conference on Environment and Development (UNCED), also known as the "Earth Summit" was held in Rio de Janeiro, Brazil. The conference articulated the notion of sustainable development and launched milestone international agreements on environment, the "Rio conventions", including the United Nations Framework Convention on Climate Change (UNFCCC).

Twenty years after, the United Nations Conference on Sustainable Development, known as Rio+20 or the Rio Earth Summit 2012, was also held in Rio de Janeiro. While some progress has been made towards sustainable development between 1992 and 2012, large challenges remain as the human footprint on the planet is increasing and some 'planetary boundaries' are (or are close to be) crossed. We are now at a time when it is urgent to give a new and more concrete expression to the concept of sustainable development, make it more operational, and pave ways on how to integrate its three (economic, environmental and social) dimensions. This is also why the concept of the 'green economy' was developed.

In its Green Economy Report, UNEP has defined the green economy as follows:

> *"An economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities."*
>
> (UNEP, 2010)

Practically speaking, a green economy is one whose growth in income and employment is driven by investments that simultaneously:

- reduce carbon emissions and pollution,
- enhance energy and resource-use efficiency; and
- prevent the loss of biodiversity and ecosystem services.

As per the definition of the concept, green economy objectives should resonate with sustainable development agendas, highlighting a concern with human well-being and social equity – both now and for future generations; as well as balancing risks and scarcities faced by peoples across the globe.

As stated in the outcome document of the Rio + 20 conference the "green economy in the context of sustainable development and poverty eradication will enhance our ability to manage natural resources sustainably and with lower negative environmental impacts, increase resource efficiency, and reduce waste." (United Nations, 2012).

CSA and Green Economy and Sustainable Development

Agriculture, (intended in the FAO sense of 'agriculture, forestry and fisheries') is at the nexus of the challenges that need to be addressed to make sustainable development a reality (FAO, 2012a).

One of the first planetary boundaries, perhaps the most important one, is that the world needs to feed itself. But today, almost one billion people are hungry. Another billion is malnourished, lacking essential micronutrients. While, globally, enough food is being produced to feed the entire word, one-third of it is lost or wasted, and low incomes and problems of distribution mean that accessibility to food is still out of reach for one out of six people on our planet. By 2050, food production has to increase, both in quantity, quality, and diversity, especially in developing countries. Population and income growth will drive an ever- increasing demand, especially in developing countries (Lutz and Samir, 2010; Cirera and Masset, 2010; Foresight, 2011a; Foresight, 2011b). Assuming these trends continue, FAO estimates that production has to increase by 60 percent between now and 2050, especially in developing countries (Bruinsma, 2009; Conforti, 2011). Agriculture is also an essential driver of economic growth, particularly in rural areas and least developed countries. At the national level boosting agricultural production stimulates overall economic growth and development, particularly in those countries with a high economic dependence on agriculture. According to the World Bank (2008), investment in agriculture is particularly efficient in creating new jobs. Agricultural and rural development acts as an engine for sustainable economic development, making an effective contribution to national economic growth. At the community level, agricultural development increases farm productivity, reduces food deficits, increases food surpluses and raises incomes. Improved agriculture production provides opportunities to sustainably reduce poverty, food insecurity and malnutrition and thereby improves livelihoods.

At the same time, food production and consumption already exerts a considerable impact on the environment (UNEP, 2010; FAO, 2012b). Food systems rely on resources, especially land, water, biodiversity, and fossil fuels, which are becoming ever more fragile and scarce.

Agriculture is essential for a green economy. In fact, FAO considers that there can be no green economy without agriculture. This is why FAO proposed "Greening Economy with Agriculture" as the basis key message for Rio+20 (FAO, 2012b).

Climate-smart agriculture contributes to the goals of making sustainable development concrete. It integrates the three dimensions of sustainable development in addressing food security and climate concerns in a forward-looking perspective. It is guided by the need for more resource efficiency and resilience. These principles are also central in the Rio + 20 outcome document[8], which recognizes resource efficiency as key to a green economy and affirms the need to enhance agriculture's resilience.

The green economy and CSA share the common goal of integrating the three dimensions of sustainable development. Both make sustainable development tangible by focusing on issues that can and must be addressed right now in local communities but that have global, long-term consequences.

CSA brings together global and local concerns, climate change to be addressed globally, climate change to get adapted to locally; and first of all, food security, which has to be addressed both locally and globally. To do so it brings together practices, policies and institutions, which are not necessarily new. What is new is the harmonization and synchronization needed of practices and policies in order to address multiple challenges, faced by agriculture and food systems, now and for the future. What is also new is the objective of avoiding contradictory and conflicting policies by internally managing trade-offs and synergies in the pursuit of multiple objectives.

Food security and natural resources: sustainable intensification

CSA takes into account the four dimensions of food security, availability, accessibility, utilization and stability[9]. Still, the entry point and the emphasis is on production, on farmers, on increasing productivity and income, and on ensuring their stability. As such it is centered on the key dimension of food security, - availability, which is associated with stability. It also has much to do with raising and stabilizing incomes of smallholders, and thus with accessibility to food. Diversification of production is a powerful way to increase efficiency and resilience; it is also an essential path towards more balanced and nutritious diets.

[8] Id paragraphs 108-118.

[9] Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". (World Food Summit, 1996)

The emphasis on resource efficiency has obvious environmental co-benefits. It preserves natural resources, water, resources, both agrobiodiversity and wild biodiversity (by preserving land). The project Enhanced Strategies for Climate-Resilient and Environmentally Sound Agricultural Production (C-RESAP) in the Yellow River Basin (Licona Manzur and Rhodri, 2011) aiming to contribute to the adaptation of vulnerable communities to climate change and to reduce the impact of agricultural practices on the environment provides a good example of these potential synergies. When focussing on a single environmental issue (here climate change) potential trade-offs with other issues have to be identified and addressed (IFAD, 2012b).

CSA shares objectives and principles with sustainable intensification of crop production. Sustainable crop production intensification (SCPI) can be summed up in the words "save and grow". Sustainable intensification means a productive agriculture that conserves and enhances natural resources. It uses an ecosystem approach that draws on nature's contribution to crop growth – soil organic matter, water flow regulation, pollination and natural predation of pests – and applies appropriate external inputs at the right time, in the right amount to improved crop varieties that are resilient to climate change and use nutrients, water and external inputs more efficiently. A CSA approach adds a more forward looking dimension, more concern about future potential changes and the need to be prepared for them.

1.5 Conclusions and focus of the sourcebook

Addressing food security and climate change challenges has to be done in an integrated manner. To increase food production and to reduce emissions intensity, thus contributing to mitigate climate change, food systems have to be more efficient in the use of resources. To ensure food security and adapt to climate change they have to become more resilient.

This has to happen globally, worldwide and everywhere. Increased efficiency in one part of the world provides food and income where it takes place but it also provides more food, globally and thus can provide food elsewhere and reduce its cost, globally. With increased risks, increasing resilience of the worldwide food system also means that efficiency and resilience have to be improved everywhere, so as to spread risk. Therefore CSA is a dynamic approach that concerns all farmers, all over the world. But developing countries are more at risk of food insecurity. They are more at risk of climate change. They also have more potential for mitigation (and adaptation?), because they have to increase their production more, and because there is an important efficiency gap. On the other hand developing countries have less means, policies and institutions to address these challenges. Therefore, this book will be primarily aimed at developing countries.

The changes outlined in this book have to be supported by efforts to harness consumption. Consumption patterns play an important role in the increased demand on agriculture, on the impact of food systems on environment and also on food security. More sustainable patterns of consumption would, in particular, play an essential role to mitigate climate change (HLPE 2012a). Sustainable diets are defined by FAO as "those diets with low environmental impacts that contribute to food and nutrition security and to healthy lives for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, nutritionally adequate, safe and healthy, while optimizing natural and human resources" (FAO, 2010d). But, to a great extent the tools, policies and institutions that could influence consumption and diets, especially in developed countries, are very different from those that would be used to transform agricultural systems. This is why this book does not address, as such, the issue of consumption patterns as a driver of environmental impact.

Notes

This module was written by Alexandre Meybeck (FAO) and Vincent Gitz (FAO) and contributions were made by Richie Ahuja (EDF–India), Kevern Cochrane (FAO), Anette Engelund Friis (World Farmers Organization), Elwyn Grainger-Jones (IFAD), Hsin Huang (OECD), Chang-Gil Kim (KREI-South Korea), Atta-Krah Kwesi (Bioversity International), James Lomax (UNEP), Dr B. Mantlana (South Africa), Hayden Montgomery (New Zealand), Lucia Perugini (University of Perugia) and Dipti Thapa (World Bank).

Acronyms

CH_4	methane
CGRFA	Commission on Genetic Resources for Food and Agriculture
CLCPRO	Commission for Controlling the Desert Locust in the Western Region
CSA	climate-smart agriculture
CO_2	carbon dioxide
EIT	Economies in Transition
EMBRAPA	Brazilian Agricultural Research Corporation
EMPRES	Emergency Prevention System
FAO	Food and Agriculture Organization of the United Nations
FSCA	Food Security for Commercialisation for Agriculture
GDP	gross domestic product
GFFBO	Good Father Fishery Based Organization
GHG	greenhouse gas
HLPE	High Level Panel of Experts on Food Security and Nutrition
IDP	internally displaced persons
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
N_2O	nitrous oxide
NAPA	National Adaptation Programmes of Action
NGO	non-governmental organization
NLCUs	National Locust Control Units
NPFS	National Program for Food Security
OECD	Organization for Economic Co-operation and Development
ORAM	Rural Association for Mutual Support
REDD	Reducing Emission from Deforestation and Forest Degradation
SBSTA	Subsidiary Body for Scientific and Technological Advice
SCP	sustainable consumption and production
SCPI	sustainable crop production intensification
SIDS	Small Island States
UDP	urea deep placement
UNCED	United Nations Conference on Environment and Development
UNCTAD	United Nations Conference on Trade and Development
UN DESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNCSD	United Nations Conference on Sustainable Development
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization

References

Ahmed, N. & Garnett, S.T. 2011. *Integrated rice-fish farming in Bangladesh: meeting the challenges of food security.* Food Security.

Barnes, R.D. & Fagg, C.W. 2003. *Faidherbia albida: monograph and annotated bibliography*. Tropical Forestry Papers No. 41. Oxford, UK, Oxford Forestry Institute,.

Beddington, J., Asaduzzaman, M., Clark, M., Fernández, A., Guillou, M., Jahn, M., Erda, L., Mamo, T., Van Bo, N., Nobre, C.A., Scholes, R., Sharmam R. & Wakhungu, J. 2012b. *Achieving food security in the face of climate change: final report from the Commission on Sustainable Agriculture and Climate Change.* Copenhagen, Denmark, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). (available at www.ccafs.cgiar.org/commission)

Beddington, J.R., Asaduzzaman, M., Clark, M.E., Fernández Bremauntz, A., Guillou, M.D., Jahn, M.M., Lin, E., Mamo, T., Negra, C., Nobre, C.A., Scholes, R.J., Sharma, R., Van Bo, N. & Wakhungu, J. 2012c. *The role for scientists in tackling food insecurity and climate change*. Agriculture and Food Security, 1: 10.

Bellassen, V. & Gitz, V. 2008. *Reducing emissions from deforestation and degradation in Cameroon: assessing costs and benefits*, Ecological Economics: 68 (1–2): 336–344.

Bharucha, Z. & Pretty, J. 2010. *The roles and values of wild foods in agricultural systems.* Philosophical Transactions of the Royal Society B-Biological Sciences, 365: 2913–2926.

Bochu, J-L., Bordet, C., Metayer, N. & Trevisiol, A. 2010. *Références planete*. Fiche 2- Production: Bovins lait et cultures. Toulouse, SOLAGRO, 25 p.

Braatz, S. 2012. *Building resilience to climate change through sustainable forest management.* In FAO & OECD Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Rome.

Brader, L., Djibo, H., Faye, F.G., Ghaout, S., Lazar, M., Luzietoso, P.N. & Ould Babah, M.A. 2006. *Évaluation multilatérale de la campagne 2003–05 contre le criquet pèlerin*. Rome, FAO. (avaliable at http://www.clcpro-empres.org/fr/pdf/Evaluation_compagne200_2005_Fr.pdf).

Brazilian Agricultural Research Corporation (EMBRAPA). 2008. *Aquecimento global e a nova geografia da produção agrícola no Brasil.* São Paulo.

Bruinsma, J. 2009. *The resource outlook to 2050.* Expert Meeting on How to Feed the World in 2050. FAO, Rome.

Brundtland, G.H. 1987. *Report of the World Commission on Environment and Development: our common future.* (available at http://www.un-documents.net/our-common-future.pdf)

Burke, M.B., Lobell, D.B. & Guarino, L. 2009. *Shifts in African crop climates by 2050, and the implications for crop improvement and genetic resources conservation*. Global Envt. Change, 19(3): 317–325.

Burney, J.A., Davis, S.J. & Lobell, D.B. 2010. *Greenhouse gas mitigation by agricultural intensification.* Proceedings of the National Academy of Sciences, 107(26): 12052–12057.

Carpenter, S.R., Walker, B., Anderies, J.M. & Abel, N. 2001. *From metaphor to measurement: resilience of what to what?* Ecosystems, 4:765–781.

Cifdaloz, O., Regmi, A., Anderies, J. & Rodriguez, A.A. 2010. *Robustness, vulnerability, and adaptive capacity in small-scale social–ecological systems: the Pumpa Irrigation system in Nepal.* Ecology and Society, 15(3): 39. (available at http://www.ecologyandsociety.org/vol15/iss3/art39/)

Cirera, X. & Masset, E. 2010. *Income distribution trends and future food demand*. Phil. Trans. R. Soc. B., 365: 2821–2834.

Conforti, P., eds. 2011. *Looking ahead in world food and agriculture: perspectives to 2050*. Rome, FAO.

Cordier, J. 2008. *La gestion des risques en agriculture.* De la théorie à la mise en oeuvre: éléments de réflexion pour l'action publique. Notes et études économiques – No. 30.

Cossée, O., Lazar, M. & Hassane, S. Rapport de l'evaluation à mi-parcours du Programme EMPRES composante Criquet pèlerin en Région occidentale. Rome, FAO. (available at http://www.clcpro-empres.org/fr/pdf/Rapport_evaluation%20mi_parcourEMPRESro_Fr.pdf)

De Young, C., Soto, D., Bahri, T. & Brown, D. 2012. *Building resilience for adaptation to climate change in the fisheries and aquaculture sector.* In FAO & OECD Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Rome.

Dey, M.M., Spielman, D.J., Mahfuzul Haque, A.B.M., Rahman, Md. S. & Valmonte-Santos, R.A. 2012. *Change and diversity in smallholder rice-fish systems, recent evidence from Bangladesh.* International Food Policy Research Institute.

Eldin, M. & Milleville, P., eds. 1989. *Le risque en agriculture.* Paris, ORSTOM. p. 619.

Ericksen, P.J. 2008. *Conceptualizing food systems for global environmental change research.* Global Environmental Change, 18(1): 234–245.

European Commission. 2006. *Analysis of the life cycle environmental impacts related to the final consumption of the EU-25.* Environmental Impact of Products (EIPRO). (available at http://ec.europa.eu/environment/ipp/pdf/eipro-report.pdf)

FAO. 2009a. *The state of food and agriculture: livestock in the balance.* Rome.

FAO. 2009b. *Food security and agricultural mitigation in developing countries: options for capturing synergies.* Rome.

FAO. 2009c. *The investment imperative.* Paper from the FAO High Level Conference on World Food Security: The Challenges of Climate Change and Bioenergy. Rome.

FAO. 2010a. *"Climate-smart" agriculture: policies, practices and financing for food security, adaptation and mitigation.* Rome.

FAO. 2010c. *Promoting the growth and development of smallholder seed enterprises for food security crops, case studies from Brazil, Côte d'Ivoire and India.* FAO Plant production and protection paper No. 201.

FAO. 2010d. *Biodiversity and sustainable diets: united against hunger.* Rome.

FAO. 2011a. *Potential effects of climate change on crop pollination, by M.* Kjøhl, A. Nielsen, & N.C. Stenseth. Rome.

FAO. 2011b. *Save and grow: a policymaker's guide to the sustainable intensification of smallholder crop production.* Rome.

FAO. 2011c. *Energy-smart food for people and climate.* Issue brief. Rome. (available at http://www.fao.org/docrep/014/i2454e/i2454e00.pdf).

FAO. 2012a. *Improving food systems for sustainable diets.* GEA Rio+20 Working Paper No. 4. Rome.

FAO. 2012b. *Stability of food security in a green economy environment.* FAO GEA Rio+20 Working Paper No. 3. Rome.

FAO. 2012c. *Towards the future we want: end hunger and make the transition to sustainable agricultural and food systems.* Rome. (available at http://www.fao.org/docrep/015/an894e/an894e00.pdf)

FAO. 2012d. *Greening the economy with agriculture.* Rome. (available at http://www.fao.org/docrep/015/i2745e/i2745e00.pdf)

FAO. 2012e. *AGA in acton.* Animal Production and Health. (available at http://www.fao.org/ag/againfo/home/en/news_archive/AGA_in_action/2011_livestock_food_chains.html)

FAO. 2012f. *Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security.* (available at http://www.fao.org/docrep/016/i2801e/i2801e.pdf)

FAO, ICLARM & IIRR. 2001. *Integrated agriculture-aquaculture: a primer.* FAO Fisheries technical paper No. 407. Rome.

FAO & OECD. 2012. *Building resilience for adaptation to climate change in the agriculture sector.* Proceedings of a joint FAO & OECD workshop. Rome. (available at http://www.fao.org/agriculture/crops/news-events-bulletins/detail/en/item/134976/)

FAO, WFP & IFAD. 2012. *The state of food insecurity in the world 2012: economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition.* Rome.

Fellmann, T. 2012. *The assessment of climate change related vulnerability in the agricultural sector: reviewing conceptual frameworks.* In FAO & OECD Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Rome.

Fischer, R.A., Byerlee, D. & Edmeades, G.O. 2009. *Can technology deliver on the yield challenge to 2050?* Background paper to the Expert Meeting on How to feed the World in 2050. Rome, FAO.

Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T. & Rockström, J. 2010. *Resilience thinking: integrating resilience, adaptability and transformability. Ecology and Society,* 15(4): 20. (available at http://www.ecologyandsociety.org/vol15/iss4/art20/)

Foresight. 2011a. *The future of food and farming: challenges and choices for global sustainability.* Final Project Report. London, The Government Office for Science.

Foresight. 2011b. *Foresight project on global food and farming futures.* Synthesis Report C1: Trends in food demand and production.

Füssel, H.-M. & Klein, R.T.J. 2006. *Climate change vulnerability assessments: an evolution of conceptual thinking.* Climatic Change, 75(3): 301–329.

Garnett. T. *2011.* Where are the best opportunities for reducing greenhouse gas emissions in the food system (including the food chain)? Food Policy, 36(1): S23–S32.

Garrity, D.P., Akinnifesi, F.K., Ajayi, O.C., Weldesemayat, S.G., Mowo, J.G., Kalinganire, A., Larwanou, M. & Bayala, J. 2010. *Evergreen Agriculture : a robust approach to sustainable food security in Africa.* Food Security, 2: 197–214.

Gerber, P., Vellinga, T., Opio, C., Henderson, B. & Henning, S. 2010. *Greenhouse gas emissions from the dairy sector a life cycle assessment.* FAO Report. Rome. (available at http://www.fao.org/docrep/012/k7930e/k7930e00.pdf).

Gibbs, H.K., Ruesch, A.S., Achard, F., Clayton, M.K., Holmgren, P., Ramankutty, N. & Foley, J.A. 2010. *Tropical forests were the primary source of new agricultural land in the 1980s and 1990s*. Proceedings of the National Academy of Sciences,107 (37).

Gitz, V. 2013. *Usage des terres et politiques climatiques globales: la physique, l'économie et les politiques de l'usage des puits de carbone pour lutter contre le changement climatique.* Presses Académiques Francophones. Saarbrücken, Germany.

Gitz, V. & Ciais, P. 2004. *Future expansion of agriculture and pasture acts to amplify atmospheric CO_2 levels in response to fossil fuel and land-use change emissions.* Climatic Change, 67(2–3): 161–184.

Gitz, V. & Meybeck, A. 2012. *Risks, vulnerabilities and resilience in a context of climate change*. In FAO & OECD Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Rome.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K. & Wiltshire, A. 2010. *Implications of climate change for agricultural productivity in the early twenty-first century.* Philosophical Transactions of the Royal Society B-Biological Sciences, 365: 2973–2989.

Grainger-Jones, E. 2011. *Climate-smart smallholder agriculture: what's different?* IFAD occasional paper No.3. Rome. (available at http://www.ifad.org/pub/op/3.pdf).

Gunderson, L & Holling, C.S., eds. 2001. *Panarchy: understanding transformations in human and natural systems*. Island Press, Washington D.C.

Gustavsson, J., Cederberg, C., Sonesson, U., van Otterdijk, R. & Meybeck, A. 2011. *Global food losses and food waste: extent, causes and prevention*. Rome, FAO.

Harris, J.M., Erickson, K., Dillard, J., Morehart, M., Strickland, R., Gibbs, R., Ahearn, M., Covey, T., Bagi, F., Brown, D., McGath, C., Vogel, S., Williams, B. & Johnson, J. 2008. *Agricultural income and finance outlook*. AIS 86. Economic Research Service, US Department of Agriculture.

High Level Panel of Experts (HLPE). 2011. *Price volatility and food security.* A report by the HLPE on Food Security and Nutrition of the Committee on World Food Security. Rome.

HLPE. 2012a. *Food security and climate change.* A report by the HLPE on Food Security and Nutrition of the Committee on World Food Security, Rome.

HLPE. 2012b. *Social protection for food security.* A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

Hoffmann, I. 2010, *Climate change and the characterization, breeding and conservation of animal genetic resources.* Animal Genetics, 41: 32–46.

Holden, D., Hazell, *P.* & Pritchard, A., eds. 1991. Risk in agriculture: proceedings of the Tenth Agriculture Sector Symposium. World Bank.

Holling, C.S. 2001. *Understanding the complexity of economic, ecological, and social systems.* Ecosystems, 4: 390–405.

Huang, H., von *Lampe, M.* & van Tongeren, F. 2011. Climate change and trade in agriculture. Food Policy, 36: S9-S13.

International Fund for Agricultural Development (IFAD). 2012a. *Syrian Arab Republic: thematic study on participatory rangeland management in the Badia.* (available at http://www.ifad.org/pub/pn/badia.pdf).

IFAD. 2012b. *Environment and natural resource management policy.* Resilient livelihoods through the sustainable use of natural assets. (available at http://www.ifad.org/climate/policy/enrm_e.pdf).

International Fertilizer Development Center (IFDC). 2011. *Fertilizer Deep Placement (FDP).* (available at http://ifdc.org/getdoc/81fcf68e-c3b8-406a-a252-5148b99d8684/Fertilizer_Deep_Placement_(UDP))

INEA. 2011. *Prospettive della gestione del rischio in agricoltura: riflessioni per un sistema integrato per la PAC post 2013.* Roma, Quaderno, Istituto Nazionale di Economia Agraria.

Intergovernmental Panel on Climate Change (IPCC). 2007a. *Climate change 2007: impacts, adaptation and vulnerability, M.L.* Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linder & C.E. Hanson, eds. pp. 869-883. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Glossary. Cambridge, Cambridge University Press.

IPCC. 2007b. *Climate Change 2007: mitigation, B.* Metz, O.R. Davidson, P.R. Bosch, R. Dave & L.A. Meyer, eds. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge, United Kingdom and New York, USA, Cambridge University Press.

IPCC. 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation.* A Special Report of Working Groups I and II of the IPCC. Cambridge, UK and New York, USA, Cambridge University Press. 582 pp.

Kahiluoto, H. 2012. *Crop production in a northern climate.* In FAO & OECD Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Rome.

Karfakis, P., Knowles, M., Smulders, M. & Capaldo, J. 2011. *Effects of global warming on vulnerability to food insecurity in rural Nicaragua*. ESA-FAO WP series No. 11–18.

Ladha, J.K., Fisher, K.S., Hossain, M., Hobbs, P.R. & Hardy, B. Eds. 2000. *Improving the productivity and sustainability of rice-wheat systems of the Indo-Gangetic plains: a synthesis of NARS-IRRI partnership research.* Discussion Paper No. 40. International Rice Research Institute.

Licona Manzur, C. & Rhodri, P.T. 2011. *Climate resilient and environmentally sound agriculture or "climate-smart" agriculture: an information package for government authorities.* Institute of Agricultural Resources and Regional Planning, Chinese Academy of Agricultural Sciences and Food and Agriculture Organization of the United Nations.

Lipper, L. & Neves, N. 2011. *Payments for environmental services: what role in sustainable agriculture development?* ESA Working Paper No. 11–20. FAO. (available at http://www.fao.org/docrep/015/an456e/an456e00.pdf).

Lobell, D., Schlenker, W. & Costa-Roberts, J. 2011. *Climate trends and global crop production since 1980*. Science.

Lutz, W. & Samir, K.C. 2010. *Dimensions of global population projections : what do we know about future population trends and structures?*, Phil. Trans. R. Soc. B, 365: 2779–2791.

MacMahon, P., Barley, D. & Holmes, L. 2011. *What price resilience ? Towards sustainable and secure food systems*. London, The Prince's Charles Charities' International Sustainability Unit.

Mejia, D. 2008. *Household metal silos: key allies in FAO's fight against hunger.* FAO, Rome. (available at http://www.fao.org/fileadmin/user_upload/ags/publications/silos_E_light.pdf)

Meridian Institute. 2011. *Agriculture and climate change: a scoping report.* (available at http://www.climate-agriculture.org/Scoping_Report.aspx)

Meybeck, A., Azzu, N., Doyle, M. & Gitz, V. 2012. *Agriculture in National Adaptation Programmes of Action (NAPA).* In FAO & OECD Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Rome.

Nelson, G.C., Rosegrant, M.W., Koo., J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M. & Lee, D. 2009. *Climate change impact on agriculture and costs of adaptation*. International Food Policy Research Institute, Washington D.C.

Nelson, G.C., Rosegrant, M.W., Palazzo, A., Gray, I., Ingersoll, C., Robertson, R., Tokgoz, S., Zhu, T., Sulser, T., Ringler, C., Msangi, S. & You, L. 2010. *Food security, farming, and climate change to 2050: scenarios, results, policy options*. International Food Policy Research Institute, Washington D.C. (available at www.ifpri.org/sites/default/files/publications/rr172.pdf)

Organization for Economic Co-operation and Development (OECD). 2009. *Managing risk in agriculture: a holistic approach.* Paris.

OECD. 2011. *Joint working party on agriculture and the environment: a green growth strategy for food and agriculture.* Paris.

OECD & FAO. 2010. *Agricultural outlook 2010-2019.*

Padgham, J. 2009. *Agricultural development under a changing climate: opportunities and challenges for adaptation.* Washington D.C., The World Bank.

Roy, R.N. & Misra, R.V. 2003. *Economic and environmental impact of improved nitrogen management in Asian rice-farming systems.* In Sustainable rice production for food security.

Proceedings of the 20th Session of the International Rice Commission. Bangkok. *International Rice Commission & FAO.*

Save Food Initiative. 2013. *Save food solutions for a world aware of its resources.* (available at http://www.save-food.org/)

Singh, U., Wilkens, *P.,* Jahan, I., Sanabria, J. & Kovach, S. 2010. Enhanced efficiency fertilizers, 2010 19th World Congress of Soil Science. Soil Solutions for a Changing World. Brisbane, Australia. (available at http://www.iuss.org/19th%20WCSS/Symposium/pdf/1506.pdf)

Spiric, J. 2009. *Investigating the socio-economic impact of REDD scheme implemented in the Nhambita community carbon project, Mozambique.* Universitat Autònoma de Barcelona. (Master thesis)

Steinfeld, H., Gerber, *P.,* Wassenaar, T., Castel, V., Rosales, M. & de Haan, C. 2006. Livestock's long shadow. Environmental issues and options. FAO, Rome.

Tadele, T., Kanampiu, *F.K.,* De Groote, H., Hellin, J.. Mugo, S., Kimenju, S., Beyene, Y., Boddupalli, P.M., Shiferaw, B. & Banziger, M. 2011. The metal silo: an effective grain storage technology for reducing post-harvest insect and pathogen losses in maize while improving smallholder farmers' food security in developing countries. Crop Protection, 30(3): 240—245.

Thornton, P. & *Cramer, L.,* eds. 2012. Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR's mandate. CCAFS Working Paper No. 23. CCAFS, Copenhagen, Denmark.

United Nations. 2012. *The future we want.* (available at http://www.uncsd2012.org/thefuturewewant.html)

United Nations Environment Programme (UNEP). 2010. *Assessing the environmental impacts of consumption and production: priority products and materials, by E.* Hertwich, E. van der Voet, S. Suh, A. Tukker, M. Huijbregts, P. Kazmierczyk, M. Lenzen, J. McNeely & Y. Moriguchi. A Report of the Working Group on the Environmental Impacts of Products and Materials to the International Panel for Sustainable Resource Management.

United Nations Framework Convention on Climate Change (UNFCCC). 2008. *Challenges and opportunities for mitigation in the agricultural sector.* Technical paper.

Weber, C.L. & *Scott Matthews, H.* 2008. Food-miles and the relative climate impacts of food choices in the United States. Environmental Science & Technology, 42(10): 3508–3513.

World Bank. 2008. *World development report 2008: agriculture for development.* Washington D.C, The World Bank.

World Bank. 2009. *Morocco study on the impact of climate change on the agricultural sector: impact of climate change on agricultural yields in Morocco.* Washington D.C, The World Bank.

West, P.C., Gibbs, H.K., Monfreda, C., Wagner, J., Barford, C.C., Carpenter, S.R. & Foley, J.A. 2010. *Trading carbon for food: Global comparison of carbon stocks vs. crop yields on agricultural land*. Proceedings of the National Academy of Sciences of the USA.

Additional Resources

Beddington, J.R., Asaduzzaman, M., Clark, M,E, Fernández Bremauntz, A., Guillou, M.D., Howlett, D.J.B., Jahn, M.M., Lin, E., Mamo, T., Negra, C., Nobre, C.A., Scholes, R.J., Van Bo, N. & Wakhungu, J. 2012a. *What next for agriculture after Durban?* Science, 335.

FAO. 2010b. *Sistemas Agroforestales, Seguridad Alimentaria y Cambio Climático en Centroamérica.* Honduras. (available at http://www.pesacentroamerica.org/boletin/boletin_sistemas_agroforestales.htm)

World Bank. 2012. *Inclusive green growth: the pathway to sustainable development.* Washington D.C, The World Bank

MODULE 2:

MANAGING LANDSCAPES FOR CLIMATE-SMART AGRICULTURAL SYSTEMS

Overview

This module describes how a gradual transition to climate-smart agriculture (CSA) can take place. The first section describes the landscape approach and explains why this approach should be followed when moving towards CSA. In a landscape approach, the management of production systems and natural resources covers an area large enough to produce vital ecosystem services, but small enough to be managed by the people using the land which is producing those services.

The module's second section outlines different elements of the landscape approach and offers suggestions about how the approach could be implemented. The approach integrates many different sectors, engages multiple stakeholders and operates on a number of different scales. The second section also looks at multistakeholder negotiations and planning. It gives insights into policy and finance options for promoting integrated landscape governance and highlights the importance of monitoring landscapes. The third section presents case studies that illustrate what the implementation of a landscape approach looks like in practice.

Key messages

- Managing agriculture, forestry and fisheries at a landscape scale is key to achieving sustainable development.
- Appropriate land-use planning and decision making at the landscape level should be based on a participatory, consensus-based and people-centred approach.
- Production sectors are often managed in isolation from each other, and this can be counterproductive. Coordination at the landscape level facilitates the integrated management of production systems and the natural resources that underpin ecosystem services needed for all sectors. Climate-smart agriculture, which follows a landscape approach, can address the challenges involved in intersectoral natural resources management.
- Measuring and monitoring the multiple benefits of climate-smart landscapes is essential for tracking the impact of intersectoral efforts.
- Scaling up CSA and moving from pilot projects to large-scale programme and policies by applying a landscape approach requires a diverse range of strategies and practices. It is important to create awareness and partnerships between sectors, mainstream CSA into policies and build capacities at all levels. These activities must be supported by an enabling policy and market environment.

Contents

List of Figures

List of Tables

List of Boxes

List of Case Studies

2.1 Why is a landscape approach needed for achieving CSA?

Governing landscapes for the multiple objectives of CSA

CSA provides opportunities, but also presents considerable challenges. To seize these opportunities and meet these challenges, a more holistic, integrated approach in which all stakeholders participate actively is required. An integrated approach ensures greater efficiency in the use of resources and more sustainable management of natural and human-created processes in the landscape. Production systems must be incorporated into landscapes, in ways that capitalize on natural biological processes, recycle waste and residues and create integrated and diversified farming systems. This integration can greatly reduce the pressure on the natural resources and minimize the need for external inputs (e.g. energy, chemical fertilizers and pesticides) and other management interventions.

The landscape approach is key to achieving the multiple objectives of CSA. In a landscape approach, the management of production systems and natural resources covers an area large enough to produce vital ecosystem services and small enough so the action can be carried out by the people using the land and producing those services.

A landscape approach builds on the principles of natural resource management systems that recognize the value of ecosystem services to multiple stakeholders. The principles that underpin the landscape approach provide guidance on how to pursue different land-use objectives and livelihood strategies (MEA, 2005). More recently, the term 'landscape approach' has been redefined to include societal concerns related to conservation and development trade-offs. It also includes increased integration of poverty alleviation, agricultural production and food security. The approach puts the emphasis on adaptive management, stakeholder involvement and the simultaneous achievement of multiple objectives (Sunderland, 2012).

Experiences have shown that by managing natural resources in a way that ensures the resilience of ecosystems, it will be possible to reverse natural resource degradation, safeguard agricultural productivity and maintain ecosystem services (e.g. the provision of water, pests and disease control, pollination and climate regulation). Healthy ecosystems are the basis for sustainable agriculture, forestry and fisheries. To achieve healthy ecosystems, participatory and people-centered approaches and management structures are needed. This approach will simultaneously improve the resilience of production systems and people's livelihoods.

Current pressures and constraints of the natural resource base

All civilizations are based on human-managed farming, forestry and fishery systems. Converting land from forests to fields and pastures has on occasion created more diverse ecosystems. In many areas, however, it has also led to environmental degradation, loss of many vital environmental services and the loss of biodiversity. To date, agricultural expansion has cleared or converted 70 percent of grasslands; 50 percent of savannahs; 45 percent of temperate deciduous forest; and 27 percent of tropical forests (Foley *et al.*, 2011).

Many current agricultural production systems are based on vast monocultures that rely on a small number of plants and varieties with a very narrow genetic base. The cultivation of these monocultures depends heavily on the use fossil fuels. These systems also fail to close the nutrient cycles. Many production systems are not sustainable because of their environmentally-damaging soil management practices and their wasteful use of water resources. Also, in some agricultural production systems, there is a significant gap between the technical yield potential and actual yields. Because of this untapped potential, pressure to convert forest land to fields and pastures continues to increase.

Based on the current trends, food supply will need to grow by another 60 percent by 2050 to meet the demands of a more populous, more urbanized and more affluent world. At the same time, agricultural production systems will face increasing competition for resources with other sectors. In fact, expanding cities, infrastructure and human activities will infringe on fertile agricultural lands.

Climate change threatens ecosystems

Climate change is affecting production systems, disrupting the functioning of ecosystems and increasing the pressure on ecosystem services. In some areas, climate change may also lead to new production possibilities as the long-term impacts may open up new options for agriculture. The frequency of extreme weather events, such as droughts and floods, are predicted to increase. According to the Intergovernmental Panel on Climate Change (IPCC), the impacts of climate change and associated costs will fall disproportionately on developing countries and may undermine the achievement of the global goals of reducing poverty and safeguarding food security (IPCC, 2001). The 2011 drought in the Horn of Africa, which threatened 12 million people with malnutrition, disease and loss of livelihoods, is a recent example of an extreme weather event. As such events become more frequent, the number of vulnerable or directly affected people will increase.

Reversing trends through CSA

Large-scale environmental degradation is not inevitable and can be reversed (Bai *et al.,* 2008). The Global Assessment of Land Degradation and Improvement (FAO and ISRIC, 2008) established that while land degradation was still spreading between 1991 and 2008, the trend was not clear cut. There are areas where land quality has been declining (24 percent of the global land surface), but also areas where land quality has improved (16 percent) (Steenbergen *et al.,* 2011). The reversal from degradation to sustainable production has in some cases been very rapid, taking only a matter of years. In many cases, these reversals have been made in areas where populations have increased. There are many examples that illustrate that it is possible to realize the scenario: 'more people, more trees, more livestock, more water, better lives and better economies' (e.g. see Critchley, 2010 and Box 2.1).

Box 2.1
Positive dynamics: re-greening of the Sahel

In the 1970s and 80s, the Sahel region experienced disastrous droughts that caused widespread famine. However, over the past three decades, helped by moderate increases in rainfall, hundreds of thousands of farmers in Burkina Faso and Niger have transformed arid landscapes into productive agricultural land by modifying traditional agroforestry, water and soil management practices. This 're-greening' of the Sahel began when local agricultural practices were rediscovered and enhanced in simple, low-cost ways by innovative farmers and non-governmental organizations (NGOs). An evolving coalition of local, national, and international actors promoted the dissemination and continued use of these improved practices. Policy changes regarding land tenure, and changes in opportunities for off-farm employment also contributed to the progress.

To improve water availability and soil fertility in Burkina Faso's Central Plateau, farmers have sown crops in planting pits and built stone contour bunds. In southern Niger, farmers have developed innovative ways of regenerating and multiplying valuable trees. These lands now support increasing amounts of trees, crops, and livestock, which has enhanced the food security of about 3 million people. Water levels in wells has increased significantly, and some farmers can maintain small vegetable gardens near the wells, which adds to their incomes and improves nutrition. Although millet and sorghum remain the dominant crops, farmers working on rehabilitated land are also growing cowpea and sesame. With increased quantities of fodder and crop residues, farmers can keep livestock closer to their fields in more intensive and profitable livestock production systems. The manure can then be used as fertilizer to improve soil fertility. These innovations have also greatly improved the supply of fuelwood over the past 20 to 30 years, allowing women to reallocate the time once spent on collecting fuelwood to other activities.

Source: Reij *et al.*, 2009; World Bank, 2011

Sustainably increased productivity and income for better livelihoods

The ultimate aim of CSA is to improve livelihoods and sustainably increase productivity through the efficient use of resources. In management planning at the landscape level, diverse groups and institutions work together to increase farm incomes and diversify economic opportunities while ensuring that natural resources are used efficiently and that ecosystem functions and services are protected. One of the primary benefits of placing efforts on coordination at the landscape level is that sectors and production systems that had previously been managed separately and often counterproductively can be integrated in ways that maintain vital ecosystem services needed for all sectors.

To achieve food security and better livelihoods in the agricultural sector, ecosystems need to remain in a productive state. They need to deliver a variety of resources and processes that are crucial for crop, livestock, forest and aquatic production systems and rural livelihoods. Productivity depends on ecosystem functioning, which builds on the processes shaped by interactions among biological communities of both wild and domesticated species, and biophysical processes, such as water regulation and nutrient cycling. Ecosystem functioning ultimately ensures the delivery of ecosystem services.

Ecosystem services are generally classified according to the benefits that they deliver: provisioning services (e.g the provision of food, fiber, energy and water); regulating services (e.g. the regulation of pest and disease outbreaks, the cycling and purification of water or regulation of greenhouse gas [GHG] emissions and carbon sequestration); supporting services (e.g. pollination and nutrient recycling); and cultural services (MEA, 2005). The provisioning services depend upon a wide variety of supporting and regulatory services, such as soil fertility and pollination (MEA, 200) that determine the underlying biophysical capacity of agro-ecosystems. Biodiversity underpins all ecosystem services. A rich genetic base increases the likelihood that there will be species present in the system that have the traits necessary to fulfil different functional roles in the ecosystem and allow the continued delivery of ecosystem services in a changing climate (see also table 2.1 and more on genetic resources in Module 6).

Sustainable production intensification (SPI) is an important tool for increasing production in climate-smart systems. SPI saves natural resources, time and money by increasing the efficiency of farming systems. More is produced with less inputs by applying appropriate inputs at the right time and in the right amount, optimizing resource use and reducing waste. SPI uses knowledge-intensive approaches, such as conservation agriculture, integrated plant nutrient management, integrated pest management, water management and pollination management.

Similarily, organic agriculture is a holistic production management system that promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity (FAO, 2009). It builds on many of the principles of SPI, but it covers the whole food system, from production to labeling and commercialization according to precise standards.

The ecosystem approaches to fisheries and aquaculture (EAFA) are holistic strategies for managing capture fisheries and aquaculture that integrate ecological, socio-economic and governance dimensions. These strategies facilitate the sustainable use of natural resources and the integration of fisheries and aquaculture with other production sectors in coastal ecosystems (also see Case Study 2.3 and Module 10 on fisheries and aquaculture).

Table 2.1
Global status of provisioning, regulating, and cultural ecosystem services

Service	Sub-category	Status	Notes
Provisioning Services			
Food	crops	▲	substantial production increase
	livestock	▲	substantial production increase
	capture fisheries	▼	declining production due to overharvest
	aquaculture	▲	substantial production increase
	wild foods	▼	declining production
Fiber	timber	+/–	forest loss in some regions, growth in others
	cotton, hemp, silk	+/–	declining production of some fibers, growth in others
	wood fuel	▼	declining production

Service	Sub-category	Status	Notes
Genetic resources		▼	lost through extinction and crop genetic resource loss
Biochemicals, natural, medicines, pharmaceuticals		▼	lost through extinction, overharvest
Fresh water		▼	unsustainable use for drinking, industry, and irrigation; amount of hydro energy unchanged, but dams increase ability to use that energy
Regulating Services			
Air quality regulation		▼	decline in ability of atmosphere to cleanse itself
Climate regulation	global	▲	net source of carbon sequestration since mid-century
	regional and local	▼	preponderance of negative impacts
Water regulation		+/–	varies depending on ecosystem change and location
Erosion regulation		▼	increased soil degradation
Water purification and waste treatment		▼	declining water quality
Disease regulation		+/–	varies depending on ecosystem change
Pest regulation		▼	natural control degraded through pesticide use
Pollination		▼ [a]	apparent global decline in abundance of pollinators
Natural hazard regulation		▼	loss of natural buffers (wetlands, mangroves)
Cultural Services			
Spiritual and religious values		▼	rapid decline in sacred groves and species
Aesthetic values		▼	decline in quantity and quality of natural lands
Recreation and ecotourism		+/–	more areas accessible but many degraded

Note: For provisioning services, we define enhancement to mean increased production of the service through changes in area over which the service is provided (e.g., spread of agriculture) or increased production per unit area. We judge the production to be degraded if the current use exceeds sustainable levels. For regulating and supporting services, enhancement refers to a change in the service that leads to greater benefits for people (e.g., the service of disease regulation could be improved by eradication of a vector known to transmit a disease to people). Degradation of regulating and supporting services means a reduction in the benefits obtained from the service, either through a change in the service (e.g., mangrove loss reducing the storm protection benefits of an ecosystem) or through human pressures on the service exceeding its limits (e.g., excessive pollution exceeding the capability of ecosystems to maintain water quality). For cultural services, enhancement refers to a change in the ecosystem features that increase the cultural (recreational, aesthetic, spiritual, etc.) benefits provided by the ecosystem.

[a] Indicates *low* to *medium* certainty. All other trends are *medium* to *high* certainty.

Source: MEA, 2005

Resilient systems

Greater frequency of extreme events, increased temperatures, changes in rainfall patterns and greater intensity of rainfalls that are expected to result from climate change will increase uncertainty and risk in agricultural production. Long-term changes in temperature will slowly lead to fundamental changes in the plant and animal species that can be used for agriculture in a particular location. The emergence of new pests and diseases as well as new trading patterns are likely. To cope with these changes, land users need to be flexible and develop a learning attitude. The diversification of production and the management of natural resources at the landscape level provides this flexibility and facilitates risk management.

Improving productivity and livelihoods in a sustainable way can only be achieved by safeguarding the productivity of the natural resource base on which these livelihoods and production systems depend. For this reason, the foundation of CSA is resilient livelihoods and ecosystems. Resilience is the capacity to adapt to changes and disturbances and, at the same time, maintain core functions. Key strategies for ensuring that agriculture can adapt to change include: sustainable soil and water management practices; the active promotion of biodiversity; and the diversification of income sources inside and outside the farms.

Climate change will have an impact, be it positive or negative, on all production systems. Every system will have to adapt. This can happen spontaneously by adjusting to the changes as they come or in a planned manner in which the potential impacts are assessed and actions are taken to improve short- and long-term resilience. Adapatation efforts must build the capacity to cope with increasingly difficult conditions and gradual changes in climate (FAO, 2011b).

Management approaches should aim to keep the system in a state that will allow it to continue delivering valued ecosystem goods and services, or if necessary to move towards more resilient, productive systems. Both risk management and change management form an integral part of these approaches. Disaster risk management focuses on preventing, mitigating, preparing for and responding to shocks in short- and medium-time scales. Change management adds a strategic, long-term objective to policy, legal and research frameworks (FAO, 2011b). Fisher *et al.* (2006) outline ten guiding principles for protecting biodiversity, ecosystem functioning and resilience in commodity production landscapes (see Box 2.2).

Box 2.2
Ten guiding principles for protecting biodiversity, ecosystem functioning, and resilience in commodity production landscapes.

Principles for protecting biodiversity, ecosystem functioning, and resilience in commodity production landscapes include: pattern-oriented management strategies, such as maintaining and creating large, structurally complex patches of native vegetation throughout the landscape; creating corridors, stepping stones and buffers around sensitive areas; and maintaining heterogeneity across environmental gradients. Process-oriented management strategies to target specific key species or environmental processes are recommended. Strategic activities include: maintaining key species' interactions and functional diversity; understanding the impacts that particular disturbances have on ecosystems; controlling aggressive, over-abundant, and invasive species; minimizing specific threats, such as chemical pollution or hunting; and maintaining species of particular concern.

Source: Fisher *et al.*, 2006

Water management and the efficient use of available water will be of fundamental importance in building resilient production systems and improving the management of climate change-induced risks (see also Module 3 on water management). The efficient and equitable management of water catchments is generally only possible when done in a landscape context and combined with farm-level water management practices. Water management requires common agreements on the modalities of use. These agreements will be best achieved through participatory governance processes related to integrated land-use planning. Large catchments, such as river basins, need layers of nested planning approaches, starting at the river basin scale, with implementation activities planned in detail on the landscape scale.

Maintaining high levels of genetic diversity is fundamental to decrease risk, ensure multiple needs are met and maintain stability. This is why many small-scale farmers continue growing traditional crop varieties even if improved varieties are available (Frison *et al.*, 2011). It is also widely recognized that maintaining crop diversity in production systems is crucial to avoid vulnerability and widespread crop loss resulting from particular biotic or abiotic threats (Wolfe, 2000). Likewise, the diversity of livestock and soil micro-organisms will improve the resilience of the farming systems. Promoting genetic diversity and diverse production strategies for risk management, including climate risks, is a crucial component of promoting CSA (see Module 6 on genetic resources). Equally important is the biodiversity in the production system and in the landscape. This is also critical, for example, for pollination services (see Box 2.3).

Successful integration of biodiversity conservation into agricultural production is fundamental to maintain functioning ecosystems. For this reason, protected areas are important tools in many landscape and ecosystem approaches. However, establishing protected areas is often not feasible, especially in densely populated areas.

Box 2.3
Climate change impacts on pollination services

Pollination is an essential ecosystem service for crop production. Over 75 percent of the leading global food crops are dependent on pollination services provided by animals. The global monetary value of this service has been estimated to US$ 214 billion per year. Pollinators, especially bees, affect 35 percent of world crop production. Many pollinators and the crops that are dependent on them are sensitive to high temperatures and drought. In the tropics, most pollinators are already living close to their optimal range of temperature tolerance. Temperatures are expected to increase from 1.1-6.4 °C in the course of the 21st century. Consquently, climate change may have detrimental effects on pollination. CSA implemented on the landscape level can help protect this vital ecosystem service by building the agro-ecosystem's resilience through the protection of the species, resources and processes that control ecosystem functioning.

Source: FAO, 2011a; IPCC, 2007a

Mitigation co-benefits

Many agricultural and land management systems and practices (e.g. sustainable land management, agroforestry and integrated food-energy systems) are climate smart. They increase the carbon content of the soils and aboveground biomass and enhance productivity and resilience. Mitigation co-benefits can be enhanced through integrated landscape management by seizing mitigation opportunities of any particular landscape through increased biomass production.

Sustainably increasing or intensifying productivity offers important opportunities for mitigating climate change by decreasing deforestation, rehabilitating eroded soils and reducing pressure on surrounding natural ecosystems. Similarly, holistic management of grassland ecosystems will help to regenerate degraded areas and improve vegetation cover. Grassland management can also be accompanied by the introduction of trees, which sequester carbon in the soils and biomass. Improved grazing management (management that increases production) can lead to an increase of soil carbon stocks (Conant, 2009) (more on livestock management in Module 8). If their biological processes are preserved, valuable ecosystems like wetlands and peatlands perform important water regulatory services and constitute a large carbon sink (see Box 2.4). Landscape-level land-use planning strategies need to identify these kinds of key ecosystems and protect the high value of the ecosystem services they provide in their natural state. Special attention should also be paid to the management of organic soils as their emission potential is significant.

Different sectoral policies may have different goals regarding land use. Climate change mitigation policies aim at reducing emissions from all sectors including land use. Agricultural and national development policies aim at food security and economic development. At landscape level these policy goals can conflict. CSA and landscape management help to solve these conflicst by aiming at increasing productivity on cultivated areas, to relieve pressure on forests through sustainable agricultural intensification and to increase the carbon content of the landscapes (see also Module 9 on forestry). A transparent, participatory governance system is vital for arbitrating between these different goals.

Box 2.4
Peatlands as climate change mitigation hotspots – towards wiser management

Rising the water levels on drained peatlands by blocking ditches can be done with low-cost techniques and local materials. Dam in a channel in Mentangai, Indonesia

Peatlands are ecosystems where GHG emissions can often be reduced in a cost-effective manner. Peatlands or organic soils have a substantial layer of organic matter near the surface. Unlike mineral soils, most pristine peatlands are wet during most of the year. Peatlands, which are found in almost every country in the world, contain 30 percent of the world's soil carbon but cover only three percent of the global land area (Joosten, 2009; see also Victoria *et al.*, 2012). Draining a part of a peat dome or excessive extraction of irrigation water lowers the water table in the entire peatland area and causes GHG emissions. Emissions from drained peatlands and fires in drained peatlands are responsible for almost one-quarter of carbon emissions from the land-use sector (Joosten, 2009; Victoria *et al.*, 2012). Over the last few decades, there has been a rapid growth in emissions from peatlands as they have been drained for forestry, food crops and cash crops, such as for palm oil and other plantations. The cultivation of peatlands has in many cases lead to their serious degradation, subsidence, and finally abandonment (e.g. Ukraine and South-East Asia). Abandoning peatlands significantly increases the risk of fires.

To reduce GHG emissions from peatlands it is essential to determine their status: whether they are pristine, drained, abandoned or in productive use. There are three main approaches for reducing emissions from peatlands:

- The undrained peatlands should be conserved to prevent emissions.
- The drained peatlands should be rewetted through blocking canals and grids.
- When there is pressure to drain peatlands for agriculture or forestry, the first step is to increase the productivity on the existing farmland. Secondly the land managers should target the conversion of mineral soils to agricultural land instead of organic soils. If the peatlands cannot be rewetted their management should be adapted to reduce emissions.

Rewetted peatlands can provide income and other benefits to people through agriculture, forestry and cultivation under wet conditions, a practice known as paludiculture. Paludiculture can be carried out wherever there are marketable plants and animals living in wet conditions. It can be used to produce biomass for bioenergy, feed for livestock, fibre, building materials (e.g. for construction) and food, such as berries. In South-East Asia natural rubber is collected from Jelutung paludicultures. Local communities are earning up to half of their income from raising fish in the blocked grids alongside the rubber production (FAO and Wetlands International, 2012). Paludicultures represent the only sustainable mode of agricultural production on peatlands. There are however, technical and socio-economic constraints that can prevent drained peatlands from being rewetted. In such cases, the negative environmental and socio-economic impacts of utilization should be restricted, for example, by choosing crops that are adapted to high soil moisture; minimizing drainage as much as possible to reduce peat oxidation and land degradation; and limiting the use of fertilizers.

2.2 How can a landscape approach be implemented?

Setting the stage for a landscape approach

In the area of land use-planning and environment policy, there is widespread acceptance that integrating decisions across all land-use sectors (i.e. agriculture, forestry, aquaculture and their supporting ecosystem services) is crucial for sustainable development (Geerlinsg and Steed, 2003). This is why the landscape approach is recommended for implementing CSA. Combining the efforts from different land-use sectors, all of which are affected by climate change, will lead to greater progress towards reaching sustainable development goals. This will require a shift from single-objective production systems to the management of the entire landscape to meet CSA's multiple objectives. An integrated approach is particularly important as resources are limited and the demand for goods and services are high. CSA requires cross-sectoral planning and management to make the most efficient use of valuable natural resources.

In addition, integration across multiple administrative levels (local, subnational, national and international) is crucial for sustaining landscape interventions. Bottom-up approaches are necessary to ensure local stakeholders have ownership over landscape management, are accountable for the results and are able to reap tangible benefits. However, the climate-smart management of resources at the local level can only succeed if subnational and national governments are involved in the process and can create an enabling policy and institutional environment. Stakeholders at all levels must identify, negotiate, and manage the benefits and impacts of different land uses to ensure that the envisioned goals materialize at the local level (Scherr *et al.*, 2012). This process must also recognize the connections that link rural, peri-urban and urban communities, including peri-urban and urban forests, gardens, farms and open spaces that tie landscapes together in a mosaic of natural green spaces.

Although the landscape approach, which involves multisector and multistakeholder interventions across multiple scales, makes planning and management challenging, there are no other options for achieving CSA's goals (Holmgren, 2012).

Strategic steps towards a landscape approach

In a landscape approach, the management of production systems and natural resources covers an area large enough to produce vital ecosystem services, but small enough to be managed by the people using the land producing those services. However, there are many definitions of the term 'landscape' (see Box 2.5). It is important to delineate the common elements of a successful landscape approach and to describe how it can be a viable strategy for achieving CSA.

Box 2.5
Definitions of landscapes

The Council of Europe (COE) defines a landscape as "an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (COE, 2000). Cultural landscapes have been defined by the World Heritage Committee as "distinct geographical areas or properties uniquely representing the combined work of nature and of man, illustrative of the evolution of human society and settlement over time, under the influence of the physical constraints and/or opportunities presented by their natural environment and of successive social, economic and cultural forces, both external and internal" (WHC 1996). Expanding on this, landscapes may be defined as the concrete and characteristic products of the interaction between human societies and culture with the natural environment.

Agricultural landscapes can be described in terms of the three elements: structure, which concerns the interaction between environmental features, land-use patterns and human-made objects; functions, which are the provision of environmental services for farmers and society; and the values society puts on agricultural landscapes and the costs of maintaining and enhancing landscape provisions by agriculture (Jongman, 2004). Because the underlying human and natural processes are subject to change and evolution, landscapes are 'dynamic systems' (Washer *et al.*, 1999).

People have been managing the world's natural resources and landscapes for generations to meet multiple needs, including food, fibre, fodder, fuel, building materials, medicinal products and water. Farming, forestry and fisheries systems have evolved and adapted to variable environmental conditions and population pressures. These systems have been influenced by other factors, such as settlement patterns, tenure arrangements, labour availability and resource, credit and market access. Because of these complex interactions, there is a huge diversity of natural, semi-natural and man-made landscapes that contain many differently sized livelihood systems.

Source: Reiche *et al.*, 2012

Integrated landscape planning and management is an umbrella term for natural resource management that recognizes the value of various ecosystem services to multiple stakeholders, and how different values can lead stakeholders to pursue different land-use objectives or livelihood strategies (MEA, 2005). More recently, the term has been re-defined to also include societal concerns related to conservation and development trade-offs, including increased integration of poverty alleviation goals, increased integration of agricultural production and food security with an emphasis on adaptive management, stakeholder involvement and multiple objectives (Sunderland, 2012). The common underlying philosophy of integrated landscape planning and management is to find and promote synergies among production systems, livelihoods, biodiversity conservation and ecosystem services, with the ultimate goal of ensuring sustainability.

This type of planning and management needs to be supported by governace structures, including policies and financial mechanisms that are all part of a multilevel governance process. This support would be incomplete without a comprehensive, participatory and user-friendly system for monitoring landscape management and assessing the progress being made towards reaching different objectives. Indicators in a landcape monitoring system could include biomass, income, and biodiversity .

Land use planning and decision-making processes

Managing landscapes demands an understanding of how the needs of local communities can be addressed without eroding biodiversity and disprupting the functioning of ecosystems. To achieve successful outcomes, the people who have an impact on the landscape must come together to plan and negotiate acceptable practices and management actions.

Ensuring the participation of all stakeholders is key for sustainably managing landscapes and increasing the scale of CSA. Facilitating participatory decision-making processes is essential for fostering collaboration and sharing information among different stakeholders. Often, stakeholders have different visions and understandings of landscape planning and goals. The negotiation of the elements that are to be included in a landscape management planning process is vital to avoid conflicts and tension as well as create space for dialogue. Negotiation processes involve taking note of all stakeholders' interests in the formulation of land-use plans. They must follow procedures and rules that the stakeholders have agreed upon in advance and that are enforced by a credible and legitimized third party. The negotiation and planning process can be facilitated through the development of a database that integrates local and scientific sources of information on the state of land resources (e.g. soil, water and biological resources) and various drivers of change, including climate information (see Box 2.6 for an example of such an assessment).

Box 2.6
An example of the assessment approach for landscape planning and management

The Land Degradation Assessment in Drylands (LADA) project has developed a methodology and tools for assessing a number of factors relating to land management, including: the status and trends in land resources; the drivers of land degradation and sustainable land management (SLM); impacts on ecosystem services and livelihoods; and the effects of response measures adopted by land users and promoted by different stakeholders. The methodology shifts attention from the conventional focus, which assesses the biophysical aspects of land degradation, to a balanced assessment that looks at both negative and positive effects of land management, trends in land use and management of natural resources, as well as ecosystem services and livelihoods. The methodology integrates socio-economic aspects into land-use planning and management.

The main emphasis of the assessment is on the current status and dynamics of land resources (e.g. soil, water and vegetation) and the delivery of the main provisioning services for livelihoods (e.g. food, fodder, fuel, water, income). A second important consideration is the need to identify and evaluate the significant impacts of land management practices on the supporting and regulating ecosystem services that determine productivity and ecosystem resilience (e.g. soil nutrients and organic matter, carbon cycling, maintenance of the hydrological cycle and water supply and the conservation and sustainable use of biological diversity). Besides income and food security, other socio-cultural factors (e.g. knowledge management, the capacity of land users to organize themselves and adapt to change) are considered.

The LADA approach is intended to enhance the capacity of users to conduct integrated and participatory assessments of land degradation, and monitor the impacts of interventions or changes in land management. As it serves as a baseline diagnostic, the assessment should be undertaken at the beginning of the SLM investment planning for integrated landscape management. By identifying the most suitable SLM practices for preventing and mitigating degradation through participatory discussions with the communities and stakeholders, the assessment results can be used to inform SLM interventions and improve their design, planning and implementation. The assessment can be fed into national inventories and contribute to national agricultural and environmental strategies and reports to international conventions.

Source: Bunning *et al.*, 2011

Local stakeholders and institutions responsible for coordinating and facilitating landscape management activities need to be empowered to make informed decisions with a long-term perspective. Other stakeholders from the subnational and national level, and occasionally from the international level, will also participate in the landscape management planning process. It is essential to audit the state of land, water and other natural resources in a way that quantifies the impacts of climate change. Ideally this should be done at the river basin, watershed, or agro-ecosystem level. When the impacts of climate change are uncertain, no-regret options should be proposed based on existing experiences and research.

It is worth investing time and effort early in the participatory process in order to build trust and collaboration when planning landscapes. It may also be necessary to adopt new practices and ways of thinking at the farm level and modify governance structures (e.g. land tenure regimes and decentralization).

A participatory process can strengthen stakeholders' sense of ownership of the objectives of landscape management and encourage them to engage in defined activities. However, engaging in a participatory process is often time consuming. Results may not be perceived immediately as processes of social change can take generations. It is therefore important that stakeholders involved in the process, especially those that do not live in the area, tolerate uncertainty and see landscape management as a long-term activitiy. However, landscape management also needs to achieve some short-term results that can provide stakeholders with incentives to continue the process. In view of limitations in time and resources, external project interventions have to be catalytic in nature, triggering change while ensuring inclusiveness.

Carrying out interrelated actions at different levels also means making trade-offs. Managing natural resources and community needs at a landscape level involves linking actions undertaken on smaller land units to land-use management at the broader landscape level. For example, there are trade-offs that may need to be made between increasing productivity and reducing GHG emissions, and between different land uses (e.g. harvesting non-timber products and logging in forests). Defining, evaluating and balancing different legitimate interests and objectives to create a common vision is central to integrated landscape management. A shared vision ensures that there is alignment among the various local management and production strategies, national development strategies, climate and environmental strategies, as well as among policies, institutions and other enabling structures.

When discussions about change become the core of the planning process, they are expected to lead to behavioural changes and sustainable outcomes (Sangha Group, 2008). To ensure that they can participate actively in policy and decision-making processes, local stakeholders should receive the support they need to ensure that they can protect their rights and livelihood choices.

The contractual agreement emerging from this negotiated process is the result of a participatory process, which includes plans for local development activities or initiatives (short, medium, and long term) that are defined by different stakeholders in a given landscape. To implement this contractual agreement, external support may be required to build capacities and create opportunities to access resources. In addition to concrete agreement on activities, institutional arrangements and the distribution of resources, the negotiated process also leads to improved social cohesion within the communities in the landscape. The least powerful stakeholders gain increased bargaining power to defend their interests. The process also incorporates the diversity of stakholders' interests that might otherwise not be voiced and integrated in decision-making processes (more on local institutions in Module 12).

Both policy-makers and land users gain from organized and democratic planning that aligns land use with local and national goals. Ideally, land-use planning is a countrywide effort, from grassroot villages through districts and provinces, that harmonizes local needs with national priorities. Relevant stakeholders may include village and municipal authorities, private sector interests, district authorities and members of the country's planning ministry or national planning commission. At the local level, it is important that all community groups are represented, including men and women, young and old, wealthy and poor, farmers and herders (FAO, 2009).

Many of the factors that drive land-use change operate or interact in different geographic areas and at different time scales. It is necessary to apply a planning framework that links these diverse planning processes (for example see Case Study 2.8 in section 2.3). If planning is made at the national or regional level without the involvement of local stakeholders, the chances that the implementation of planned activities will not be successful or sustainable increase. Conversely, activities planned at the landscape or community level that are not supported by enabling policies or governmental authorities may struggle to succeed due to a variety of factors, including, insufficient land tenure, poor infrastructure, and inadequate institutional and market structures. Policies should be developed to support the planning processes at local levels and allow communities to manage and benefit from the resources on the land where they live.

Planning for sustainable management of transboundary resources, such as water and animal species, requires coordination among stakeholders with competing claims, and among the institutions, laws and policies intended to create incentives for the sustainable use of resources. When land-use planning takes place at both macro- and micro-levels, national and local goals can be harmonized.

Landscape management and implementation

Adaptive capacity is the key to implementing landscape management plans and strategies. Since landscapes change and evolve over time, the objective of sustainable management is not to maintain the *status quo* but to ensure the continued and growing supply of goods and services by practicing adaptive management (Sangha Group, 2008). Institutional structures and approaches, and the mindset of the stakeholders, need to acknowledge the fact that landscapes are dynamic systems: stakeholders come and go, weather and climate patterns change, markets fluctuate.

Adaptive management for climate-smart agricultural landscapes should be characterized by a sound understanding of ecosystem dynamics and take a flexible approach to governance that considers policies as works in progress and management actions as experiments that encourage learning and adjustments. As changes become apparent, new information is gained and incorporated into management processes. This allows for the review and revision of objectives and management strategies. The monitoring of drivers of change in the landscape is crucial for generating the data that can enable robust learning and adaptation.

Gathering information is all the more important considering that local stakeholders face high uncertainties about the impacts of environmental processes. They are also facing rapid economic and technological changes that can have dramatic effects on their livelihoods. In addition, local communities may have to react to new institutional and governance processes, such as more decentralized government administration or the increased involvement of the private sector. Social processes change with economic and institutional change. Box 2.7 presents a case where local citizens became involved in the discussions and the decision-making process regarding ecosystem and landscape management in an urban context.

Box 2.7
Ethekwini Municipality: governance of the ecosystem management

The Ethekwini Municipality, which governs the city of Durban, is located in southeast part of South Africa. For the past 25 years, it has been undergoing a sustainable development transformation that has sought to improve the local environment and develop plans to establish more open space within the city. Natural open spaces sustain goods and services, such as water, erosion control, food production, and the raw materials for fuel and building. Citizens have engaged with the local government through the Local Agenda 21 Programme to guide the city towards an environmentally sustainable path. Having a diverse range of citizens with disparate interests, varying socio-economic and environmental backgrounds involved in discussion has made the development process challenging, but it is necessary to ensure that all stakeholders are held accountable.

Source: ICLEI, 2013

Gender relations, demographic trends (e.g. urban-rural migrations, southern-northern migrations) and cultural identities vary widely. These social factors need to be taken into account when considering how to adapt to complex changes. Understanding how individuals and households support themselves and try to secure and improve their well-being in the face of this complexity is a major challenge. If these social factors are not acknowledged and monitored in the management system, they may cause profoundly negative consequences for long-term sustainability. Empowering rural communities by facilitating their organization at the landscape level, through citizen groups or productive institutions (e.g. watershed committees and rural producers associations), can help these communities plan and manage land use more sustainably. It also allows them to improve their livelihoods by harnessing new technologies and knowledge.

Landscape management is an iterative and evolving process. Over time, key assumptions underpinning the work and new elements will need to be re-examined. The participatory process should be a learning process in which social dialogue is constantly being renewed to bring about negotiated agreements involving all stakeholders. For the process to be easily understood and to allow stakeholder involvement in all phases, it needs to be coherent and feasible given the available resources. The process should also be simple and practical and ensure transparency and accountability, so that all stakeholders can meet their responsibilities.

There can be many reasons why conflicts may arise during policy, programme and project implementation. Some factors that can lead to disputes include: policies that are imposed without local participation; conflicting interests among land users; lack of harmony and coordination between legal bodies and procedures; poor identification of and inadequate consultation with stakeholders; and uncoordinated planning. In addition, poor information sharing, limited institutional capacity, inadequate monitoring and evaluation of programmes, and a lack of effective mechanisms for conflict management are all potential sources for conflict when negotiating and planning climate-smart agricultural activities at the landscape level with multiple stakeholders. It is essential to have in place effective conflict management mechanisms that have been agreed upon by stakeholder groups, that are based on rule of law and supported by institutional structures that everyone recognizes as legitimate.

Promoting landscape governance through policy and finance options

Expanding landscape management approaches so that they become significant on a global scale will require sharing and expanding the knowledge-base regarding the uses of natural resources and strengthening institutional capacities. An enabling policy and market environment is also needed. As mentioned, achieving multiple objectives at the landscape level will require harmonizing sectoral policies so that different planning frameworks are aligned. So far, many policy, legal and institutional frameworks are based on implementing separate actions for ecosystem management, agricultural productivity, forestry and rural livelihoods. This situation creates problems for interventions that follow a cross-sectoral approach.

A good example of a harmonized approach is the development of the Reducing Emissions from Deforestation and Forest Degradation (REDD+) mechanism. REDD+ policies address different drivers of deforestation both within and outside the forestry sector. When designing national REDD+ strategies, policies, laws and action plans, consideration should be given to agricultural and rural development goals, and an integrated landscape approach should be adopted.

There is a need for a more supportive policy environment for landscape. In some cases, major policy barriers will need to be removed (see also Module 13 on policies). Joint planning and coordinated interaction between ministries is essential and can be fostered through mechanisms for cross-sectoral consultations. Core policy needs, at the local, national and international level are:

- compatibility and coordination of policies for agricultural development, forest, water, climate and biodiversity conservation;
- environmental legislation that acknowledges the potential and rights of farming communities; and
- the removal of public subsidies and incentives that harm biodiversity.

Achieving financial viability for development initiatives that operate at the landscape level requires that the incomes of all stakeholders are sufficiently high to prevent them from engaging in activities detrimental to local ecosystems and sustainable livelihoods. Several possibilities exist for creating these conditions and they are explained in more detail in Module 14 on financial instruments. Payments for environmental services (PES), a mechanism for compensating farmers and farming communities for maintaining ecosystem services, is an example of a market-based innovation for scaling up SLM and sustainable forest management. Economic incentives are effective when they provide financial benefits to producers for their contribution to environmental stewardship. These can come in the form of payments for conservation efforts, tree planting or improved agricultural management. These incentives have the added advantage of increasing the financial attractiveness of alternative practices. Several examples of these incentive mechanisms already exist in developing countries, such as the Pro-poor Rewards for Environmental Services in Africa Programme and the Rewards for, Use of and Shared Investment in Pro-poor Environmental Services in Asia. In addition, eco-certification systems for major agricultural commodities, such as coffee and cocoa, provide economic incentives for investments in agricultural initiatives that protect environmental services.

For climate finance in rural landscapes to be effective, the interventions need to be coordinated with local rural development activities. For example, REDD funds can be utilized to support CSA and the needed institutional development.

There are several opportunities for securing private and public climate finance, such as domestic and foreign direct investments, and bilateral and multilateral climate change funds and programmes, including carbon markets (see Module 14). Policy makers are now faced with the challenge of developing institutional and funding environments that support integrated landscape climate projects. In light of harmonizing sectoral approaches, climate finance should be linked to agricultural development finance. Nationally Adaptation programmes (NAPAs), NAPS (National Adaptation Plans) and Nationally Appropriate Mitigation Actions (NAMAs) and REDD+ are all relevant for landscape interventions, as they provide the flexibility to fund policy development in support of climate change adaptation and mitigation on a large scale. Another option is to use REDD+ funds for creative agricultural investment strategies. The redesign of the clean development mechanism (CDM) and other carbon markets mechanisms could also expand the scope of REDD projects to include integrated landscape carbon projects.

Measuring and monitoring landscapes for multiple objectives

It is necessary to measure and monitor the multiple benefits of interventions designed to establish climate-smart landscapes. Monitoring objectives must be locally defined, and cover livelihoods, biodiversity and ecosystem services. The principles and processes of monitoring should be agreed upon at the beginning of a consultative, participatory process when embarking on a landscape plan addressing multiple objectives. Right from the outset, all stakeholders should have a common understanding about the objectives to be met. The monitoring process also needs to be user-friedly.

Monitoring becomes especially important if the multiple objectives within the landscape and close relationships among different users leads to conflict. For example, agriculture is an important driver of deforestation and needs to be treated in REDD+ policies to address the multiple objectives of the land users. No single strategy can both protect forest cover over the long-term and support agricultural development. Plans dealing with these closely related issues must be made on a case-by-case basis and require site-specific analysis to predict the impact of forest and agricultural interventions.

A landscape approach for measuring and monitoring biodiversity, climate change mitigation, ecosystem health and local livelihoods, which focuses on large, ecologically and agriculturally diverse areas, can help to ensure that impacts are truly being felt on the ground and that the tradeoffs being made are acceptable to all stakeholders. The results of this monitoring, particularly on the status of compensation, the distribution of benefits, and the impacts on rights and conflict resolution, will need to be transparent and easily accessible to all stakeholders (Shames *et al.*, 2011).

For more details on monitoring CSA in landscapes, see Module18.

2.3. Examples of landscape approaches

Different landscapes will require different approaches, depending on the state and nature of the resources, land use dynamics, and social and economic contexts. The following case studies illustrate some aspects of a holistic landscape approach in different contexts.

Case Study 2.1
Pastoralism in Laikipia, Kenya

Two Maasai livestock owners

Introduction

The Laikipia Wildlife Forum is a 500 member organization that includes pastoralists, commercial ranchers, and small- and large-scale farmers spread over 10 000 square kilometers in the area surrounding Mt. Kenya. In 2008, the Laikipia Wildlife Forum initiated a 10-year Rangeland Rehabilitation and Management Programme, which has been implemented by Natural Capital East Africa. The Programme's emphasis was on rehabilitating bare land across the district as part of a strategy to build the region's resource base and reduce competition for natural resources, which has at times led to fatal conflicts over pasture and water.

The *Il Ngwesi* Group Ranch is approximately 200 square kilometers (20 000 hectares or 48 000 acres) of acacia grassland in northern Kenya, evenly split between the hills of the Mukugodo Forest and flat lowlands. It is jointly occupied by some 550 Maasai families, but there is movement in and out by Maasai neighbours and other groups (e.g. Somali, Turkana and Samburu).

The landscape approach

The Rangeland Rehabilitation and Management Programme focuses on capacity-building (defined as 'competence, confidence and commitment') and makes use of two well-developed tools: planned grazing and vision setting. Planned grazing is a technical solution to land degradation while vision setting provides the human or managerial context for improved practice.

Technical demonstrations proved the value of properly managed animal herds as plant regenerators and led to community planning and the successful implementation of a grazing plan for 6 000 cattle and 3 000 sheep and goats in their dry season reserve. The plan's most important elements involve dividing a controlled area into blocks; calculating the number of grazing days for the herds in each block based on community-informed forage assessment; and combining animals into as few herds as possible, which move through the blocks by a pre-determined sequence according to water availability, grazing competition, distance, and other factors. Most importantly, animals are gathered into tight herds as they graze to maximize soil disturbance and graze a different section of the block in use each day to eliminate overgrazing. The immediate results included: improved land health, livestock survival and productivity, youth involvement and community unity. The successful land restoration can be attributed to the focus on enhancing the four ecosystem processes that together determine ecosystem health and productivity: water cycle, mineral cycle, energy flow and plant and living communities. Much of the training focuses on 'eco-literacy', combined with techniques for low-stress handling of large herds. This has restored the traditional value of herding and herders in the eyes of the community. Not only does this process reverse land degradation, it is also reversing a long-term trend of carbon release from soil to atmosphere. Given their expanse, the planet's grasslands hold massive potential for climate change mitigation.

However, the above approach does not guarantee success, as there are a number of social factors that present barriers to adoption. A major challenge arose when community members resisted their leaders' decision to adopt the plan throughout their lands. The goal-setting and future visioning component of the programme was then introduced to the leadership. This component requires an articulation of the quality of life desired: what needs to be produced or created (tangible and intangible) to attain that quality of life; and what future resource base is needed to meet these needs. The value of this exercise is two-fold; it allows deep self-reflection and it guides and encourages more socially, ecologically and economically-sound decisions.

One startling result of applying the visioning tool was that the leadership realized that current management structures were producing opposite results than what they desired. It was decided that a reorganization of the community management structure was necessary. This process resulted in the formation of 'village' management forums written into their constitution, whereby primary responsibility for all management actions was placed in the hands of a Village Forum, with the overall community management bodies playing a supporting rather than directing role as they had previously tended to do. This resulted in a shift from a top-down to a bottom-up structure and a pooling of the previously separate management committees for different issues (e.g. water, education, grazing) under the single village management body. It all came about when the community identified that the separation of activities that were in fact closely connected, resulted in activities that were undermining each other.

These changes allowed members to adopt improved practices while the programme continued to focus on facilitating building capacity of the new Village Forums, with each village forming its own 'future-vision' to guide social, economic and environmentally-related decisions. Challenges (mainly social) constantly arise, but discussions using the visioning tool usually facilitates appropriate solutions; a process which communities have found empowering. As many elders have commented: "we never thought we had a choice about our future."

Lessons learned and recommendations

The following are the most fundamental lessons from Laikipia:

- Land degradation is primarily a social issue rather than a technical one.
- Creating the 'transformation process' involves a number of key, interconnected elements that have at least four different characteristics: personal; relational; collective, and systemic (structural). Not enough effort is put into the social aspects and their synchronization with the technical issues.
- Social transformation is not something someone else can do for you. This changes the role of interventionists from solution-providers to problem-posers and also requires that the intervention staff connect psychologically with communities. In pastoralist settings, it makes sense to have pastoralist intervention staff.
- No one issue can be sustainably tackled in isolation. Each situation compromises a complex 'whole' composed of interconnected social, environmental and economic dimensions. Only alignment of all aspects can bring lasting, positive results: aligning the 'what' with the 'who', 'how', 'when' and 'where.'
- Every situation is unique. Common sense principles and processes, rather than off-the-shelf 'fixes', put in the hands of managers rather than experts give the flexible application necessary to respond to each unique situation based on willingness and ability.

Case Study 2.2
Preserving the Kihamba agro-forestry system, Mt. Kilimanjaro


© FAO/David Boerma

Introduction

The Kihamba system covers 120 000 hectares on the southern slopes of Mt. Kilimanjaro. The 800 year-old system stands out among agroforestry systems as one of the most sustainable forms of upland farming. Without undermining sustainability, it has been able to support one of the highest rural population densities in Africa, providing livelihoods for an estimated one million people. In the world's other upland areas expanding populations have caused serious deforestation and soil erosion. Only recently, when people started to abandon their ancestral farming systems, did this type of land degradation become a problem in this area.

The Kihamba system has a multilayered vegetation structure similar to a tropical montane forest and is composed of four main vegetation layers. The uppermost layer consists of sparsely spaced trees which provide shade, medicine, fodder, fruits, firewood and timber. These trees also fix nitrogen. Under these trees, multiple varieties of bananas are grown as a staple crop. Under the bananas there are coffee shrubs and under these, vegetable plots. This multi-layer system maximizes the use of limited land and provides a large variety of foods all year around. The Kihamba is irrigated by a traditional irrigation system complemented by water storage ponds (Nduwas) which help overcome water shortages in the dry season. The Chagga people who inhabit the Kihamba maintain a high plant biodiversity (higher than the native forest) with over 500 species, including 400 non-cultivated plants. Farm animals (cows, pigs, chicken and rabbits) provide valuable proteins and contribute to nutrient cycling. The agroforestry system also provides substantive environmental services beyond the areas where it is practiced. Because of the high quantities of biomass it produces and its capacity to recycle organic matter on farms, the agroforestry system contributes significantly to carbon storage, above and below ground. The trees and dense vegetation help considerably to ensure that Mt. Kilimanjaro can remain the 'water tower' for the region. Urban communities and commercial flower and seed farms in the lowlands surrounding Mt. Kilimanjaro critically depend on this service.

Coffee was incorporated at the end of the 19th century. As an ecologically compatible cash crop, it allowed the Kihamba system to adapt successfully to the emerging cash economy. However, in the 1990's, coffee prices on the world market plummeted at the same time as pests and diseases were increasing. Additionally, many coffee shrubs had reached an age (over 50 years) when they produce less beans. These factors led to a sharp decline in productivity and profitability in the Kihamba. Although food security was still not an issue, farmers were unable to meet their cash needs, mainly for the school fees of their children. As a consequence, farmers began to cut down trees to earn money from timber. They then grew maize for a couple of cycles until the soil nutrients were depleted. Finally they stopped managing their plots altogether and the soil was left to erode. It is estimated that 20 percent of the farms in the area have been abandoned. If this process is allowed to continue, it will have massive environmental and socio-economic implications in the landscape around Mt. Kilimanjaro in terms of food security, carbon storage, water catchment and soil erosion.

The landscape approach

Under FAO's Globally Important Agricultural Heritage Systems Initiative, activities were piloted in the 660 households of Shimbwe Juu village to enhance farmers' cash income while preserving the ecological and social integrity of the *Kihamba* system. The project implemented an action plan, formulated together with the community, with the following key activities:

- Rethinking sources of cash income.
  Most Kihamba farmers only have 2-3 acres at their disposal. High value, knowledge intensive niche crops that did not demand much water and land were needed. Three interventions were agreed on:
  - Conversion to certified organic coffee farming. Organic coffee is not only a more stable commodity today, but organic farming also helps farmers avoid vulnerability to fluctuating agrochemical prices. This activity includes replacement of ageing coffee trees and establishment of coffee tree nurseries.
  - Introduction of vanilla as a high value additional cash crop since Vanilla grows as a vine, and fits well into the Kihamba agro-forestry system.
  - Introduction of trout aquaculture along the canals of the irrigation system, which can be sold to hotels in the region.
- Rehabilitation of the irrigation system to reduce water loss and expansion of the capacity of storage ponds to cope with longer dry seasons due to climate change.
- Training in sustainable land management.

The interventions in coffee management alone are expected to increase farm cash income by 25 percent in three years. If the analysis of the project is correct concerning the drivers of change, the expected increase in farm income should be able to sustain the *Kihamba* and its environmental services for many years to come.

Since the participation in the project was intended to be a long-term choice for the maintenance of the *Kihamba*, the community needed to make an independent and informed choice to ensure its sustainability. Opting to participate meant that the community, while expecting benefits from such a choice, had to forego other development options, such as the conversion to less sustainable, but perhaps more immediately profitable uses. To facilitate an informed and independent decision by the community, the project organized a Free Prior Informed Consent (FPIC) process. All project documentation was made available to the community. Preparatory consultations were held with local government officials, traditional elders, and women's representatives, where the the pros and cons of different development options were discussed. Local and traditional leaders held internal consultations, in accordance with their local customs. Following this, a day-long assembly was organized for all community members to raise concerns and reach a decision. During the assembly, representatives of all project partners were present to respond to queries. Finally, the participation in the project was put to a vote to all community members. The FPIC process, though time consuming, helped all the stakeholders to align their goals.

Lessons learned and recommendations

Raising awareness and acceptance among policy makers of the importance of the Kihamba system for the region, and its future viability, was essential at the beginning of the project. This took nearly a year, partly due to prejudices against 'backward' farming practices. A crucial step to build support in the government was to engage focal points in a Project Facilitating Committee (PFC). Four ministries (agriculture, livestock, natural resources and heritage, and environment), the district and local authorities, NGO's, farmer cooperatives, businesses and community leaders were involved in the planning and execution of the project. To support the Kihamba, it was essential to work across sectors and levels, with agents with different expertise and government mandates. Because an intervention in one part of the system is likely to have repercussions in other parts, a sectoral view cannot encompass the full ecology and the human aspects of the farming system. For example, the choice of coffee variety for replanting affects tree cover and microclimate, which affects other crops. The various interventions need to be continuously harmonized. This process requires high levels of information sharing, discussion and cooperation. Frequent joint field visits and community consultations by the PFC proved to be very effective in creating a common understanding of the linkages in the farming system.

Case Study 2.3
Implementation of the ecosystem approach to fisheries and aquaculture in Estero Real, Nicaragua

©Doris Soto

Introduction

The EAFA contains holistic strategies for managing capture fisheries and aquaculture that includes ecological, socio-economic and governance dimensions. The approach facilitates the sustainable use of natural resources and integrates fisheries and aquaculture with other uses of coastal ecosystems (see also Module 10 on climate-smart fisheries and aquaculture). These strategies build on three core principles: fisheries and aquaculture should be developed in the context of ecosystem functions and services with no degradation of these beyond their resilience capacity; fisheries and aquaculture should improve human well-being and equity for all relevant stakeholders; and fisheries and aquaculture should be developed in the context of (and integrated with) other relevant sectors, policies and goals. Other important principles guiding the EAFA are the participation of stakeholders all along the development and implementation of the management plans and the use of the best available information. The EAFA is considered a relevant strategy to enhance adoption and implementation of the Code of Conduct for Responsible Fisheries.

The tropical mangrove estuary Estero Real is located along the north Pacific coast of Nicaragua and forms the southernmost part of the Gulf of Fonseca. Despite the fact that the estuary was declared a protected site in 1983 and recognized by the Ramsar Convention in 2003 as area of international interest, it is at high risk of degradation partly due to shrimp fisheries and aquaculture. The Estero Real is also home to some of the country's poorest communities who depend on local natural resources for survival and livelihoods. Local communities rely on fishery resources, mangrove products such as lumber, mangrove clearance for small-scale agriculture and aquaculture activities. Shrimp farming, which has increased significantly in the area, generates livelihood opportunities but also creates social conflicts and raises environmental concerns. Large-scale shrimp farming coexists with small-scale farmers organized in cooperatives and small-scale fishers, some of whom use unsustainable fishing practices, such as the use of fishing bags in the mangrove area. These bags collect not only small shrimp but also many kinds of fish larvae, which are mostly discarded. The estuary is also coping with other significant environmental impacts, mainly as a result of agricultural practices, urban waste and deforestation in the higher parts of the basin. Climate variability and climate change are putting additional pressures on the estuary. Heavy sedimentation from poor watershed management, the increased use of pesticides and the loss of mangrove forests are also threatening coastal aquaculture, fisheries and biodiversity in the mangrove ecosystem.

The landscape approach

Implementation of the EAFA through participatory planning and management with an ecosystem perspective, can allow fishers and fish farmers to maintain and increase food and income from fish products in the Estero Real, while preserving ecosystem services and increasing community resilience to climate change and other factors. Implementation of the ecosystem approach in Estero Real has been led by national and local fisheries and aquaculture institutions, with FAO technical support.

The first stage of the pilot project involved the following steps:

1. Discussions were held with government authorities to make a first estimate of the goals and scope of the project.
2. Field visits and participatory workshops were conducted in the closest locality to the Estero Real. They included fisheries and environment authorities at the national and local level, representatives of fishers, fish farmers, local municipalities, NGOs, universities and the Ramsar area management authority. The discussions had the following goals:
   - introduce the EAFA's concepts and methodology to the relevant stakeholders;
   - review information and establish consensus on what are the current social, environmental and governance issues that need to be addressed in the Estero Real in the fisheries and aquaculture sector and other external factors affecting the sector.
   - perform a risk-based prioritization exercise using a participatory process based on a description of the key issues to identify the highest priorities.

The second stage of the pilot implementation involved gathering relevant inputs for the development of an EAFA implementation plan based on the agreed priorities. This involved collecting the information and resources needed to address issues identified in the workshops (e.g. clarifying concepts and methodologies to assess the environmental status of Estero Real). Some of the most important activities in this stage included: carrying capacity estimates of the estuary for shrimp culture and other fishery activities; designing an improved integrated environmental monitoring programme; and developing a hydrodynamic model of the estuary. During the second stage, support programmes and instruments were elaborated. For example, a programme was set up to help people who are practicing unsustainable bag-fishing engage in other economic activities, such as aquaculture, apiculture and mangrove planting.

The third stage of the project involves the development of the EAFA implementation and management plan and road map that has been validated with stakeholders. At this stage, a set of indicators is agreed and monitored and human and economic resources are made available. This is required, for example, to implement the alternative livelihood programme for fishers. This stage is the most challenging because it requires a profound local engagement, political will and commitment on the part of national and relevant authorities. There is also a need for negotiations between different institutions and political will to recognize the social value of the fisheries sector. Often this stage requires external donor support. It is advisable to streamline such support to capacity development and technical strengthening of relevant stakeholders. The EAFA in Estero Real is currently going through this stage.

Lessons learned and recommendations

- An ecosystem approach to watershed management is needed to address landscape issues, such as sedimentation and pollution from tributaries. This approach must include and integrate fisheries, aquaculture, agriculture and forestry. Fragmentation of institutions has so far been an obstacle. The implementation of an EAFA often opens an opportunity for wider ecosystem approach management in coastal zones and watersheds. The social role of fisheries and aquaculture must be recognized, especially considering their role in poverty alleviation and food security. This will become particularly important as the impacts of climate change (e.g. droughts) become more pronounced.
- The involvement of national and local authorities and stakeholders from the beginning is fundamental. Establishing ownership of the process among the stakeholders, building trust among all parties and promoting relevant decision-making power at different levels is the best way to move forward in implementing an ecosystem approach to fisheries and aquaculture.
- Coastal fishery and aquaculture communities have become better informed and more resilient to the impacts of climate change and other threats.
- Better integration is needed between fisheries, environment, agriculture and resource management institutions.

Case study 2.4
Preserving forest resources and improving livelihoods through communal tenure rights in the Maya Biosphere Reserve, Guatemala

Introduction

Before 1990, the largest economy in Guatemala's Petén state was the extraction of latex (the raw material for the manufacture of chewing gum) from the sapodilla tree (*Manilkara zapota*) and logging of precious wood (cedar and mahogany). The timber industry had unique access to the forested areas.

In 1990, the government created the Maya Biosphere Reserve, which at 2.1 million hectares covers over 50 percent of Petén state. Connected with other protected areas in Belize and Mexico, the Maya Biosphere Reserve is one of the largest areas of tropical forest north of the Amazon. The Reserve is divided into three types of zones with different levels of protection, according to the United Nations Educational, Scientific and Cultural Organization (UNESCO) criteria for the Biosphere Reserve Model. It has three core areas of state-owned national parks and wildlife reserves, which are restricted from harvest activities. One of these areas, the Tikal World Heritage site, now brings many national and international tourists each year and generates significant revenues to the state. Multiple-use zones under state ownership are dedicated to regulated harvest of zate palms, chicle gum, allspice and timber. A less regulated buffer zone covering privately owned land has been rapidly changing from a forested landscape with scattered agricultural patches to an agricultural landscape with an increasingly fragmented forest.

The landscape approach

Before the creation of the Biosphere Reserve, logging companies operating under concessions for selective harvesting of timber and aggressive colonization programmes, neither of which had proper management plans and safeguards, were causing severe degradation of the tropical forest ecosystem. With the establishment of the Maya Biosphere Reserve, these activities were suspended, pending the development of a Master Plan, and rules and regulations for the use and management of natural resources.

The early management phase of the multiple-use zones was complicated and conflicted. The logging industry was reluctant to lose its exclusive rights to the land, and local communities fought hard to prove their management capacity and gain secure tenure rights. A long-term model had to be found that could both improve local production systems and, at the same time, guarantee the protection and sustainable management of the natural resources. Even though the creation of the Biosphere Reserve and the Master Plan, which was approved in 1992, paved the way for the allowance of concessions to communities, the process remained difficult. The first community concession was granted in 1994. This cleared the way for other concessions and presented a new alternative of communitarian development. The allocation of management rights to land-use stakeholders was based on renewable 25 year contracts. The ownership of the forest land within these models remains with the government, while communities are given management rights.

The communities that lie within the 800 000 hectare multiple-use zones have the possibility to sustainably harvest wood and non-timber forest products. However, to do so, community operations are required by law to be certified (the Forest Stewardship Council system has been widely used) and retain the certification throughout the duration of the contract, proving that they are managing the forests to conserve the integrity of the ecosystem. Currently, 13 forest concessions covering 500 000 hectares have been granted to local communities, which are organized under different legal configurations depending on their interests and type of technical support. Two concessions have been granted to the forestry industry.

This system of community forest concessions is unique in the world. It has enhanced the interest of forest resource users to protect and manage the forest; led to better forest governance; created jobs; increased income from non-timber forest products; and generated training and technical and organizational revenues. This has encouraged the concession holders to act as protectors of the forest. By shifting the emphasis on wood products to a combined valuation of timber and non-timber products and services, the system strengthens the links between forest ecosystem services and the needs and livelihood strategies of the people.

Lessons learned and recommendations

The community forest concession system has significantly changed the organizational and institutional landscape in northern Petén and has brought a higher level of sophistication and capability to the forest management regime. Key challenges for the future include simplification of the certification process and the harmonization of the requirements between different certification systems.

Case study 2.5
Addressing forest fires by improving livelihoods in the forest-agriculture interface in Syria

Farming woman with her cows on small holding

Introduction

The forest lands of Syria cover approximately 500 000 hectares, of which 232 000 are natural forest and 268 000 are plantations. Despite their relatively minor extent, the forests play a significant role in regulating water supply, controlling desertification, preventing soil erosion and flooding, and providing habitats for biodiversity. Because of high population pressures and resource use, the forests have become increasingly degraded, particularly by fire. Land tenure plays a large role in the process of land degradation. All forests have traditionally belonged to the state, with no access rights granted to the local population. As productivity of agricultural land has decreased due to erosion, and grazing resources are limited, forests have been illegally exploited and degraded. The key activities that have brought about forest degradation are burning to promote pasture inside the forest, overgrazing and the extraction of fuelwood. Key underlying drivers of forest degradation are the lack of legal access rights to resources and the limited number of viable livelihood options in the farming areas surrounding the forest.

More than timber harvesting, the forest provides economic benefits in the form of grazing land, fuelwood, and the harvest of non-timber forest products, such as mushrooms, wild herbs and medicinal plants. There is also increasing recognition among citizens and authorities alike that forests deliver valuable indirect economic benefits by safeguarding the water supply and protecting against soil erosion. The Participatory and Integrated Forest Fire Management Plan Project promotes more sustainable uses of the forest, including: controlled grazing; bee-keeping; harvesting of non-timber forest products; employment of local people in forest management activities, such as pruning; and ecotourism. Controlled grazing allows a stable source of feed for livestock and has the additional benefit of reducing fuel load in the forest near villages, which mitigates fire risks.

The landscape approach

In Syria, there is a strong political will to support afforestation and other forestry activities. The main goal of the forestry policy, which has been committed to at high political levels, is to preserve the existing natural forest and establish new plantations so that 15 percent of the country's land area is covered by forest. Currently, forest covers only about 2.7 percent of the land. Between 2004 and 2012, the Participatory and Integrated Forest Fire Management Plan Project was conducted in four provinces, an area that included 50 percent of the country's forest. The project was designed to address the key underlying drivers of forest degradation and create a greater awareness that forests cannot be managed in isolation from activities on adjacent land and in a manner that excludes local people. Only by enhancing the perceived value of the forest to local communities, and supporting livelihood options that do not encourage forest degradation, will forest management improve and fire regulation be possible.

The project worked on several different levels to build capacities to implement a participatory and integrated fire management plan for the Syrian forest-agriculture landscape.

- **National policy**
  Policies, laws, regulations, strategic and management plans, operational practices and institutional capacities of the Ministry of Agriculture and Agrarian Reforms were reviewed. There was a particular focus on expanding the forest access rights of local communities. These rights were strenghtened in Forestry Legislation No. 25, adopted in 2007. Through the project, community-based approaches were also recognized and incorporated into a national Integrated Forest Fire Management Strategy. The Strategy was developed by a multidisciplinary team with thorough consultation among different stakeholders, including numerous government agencies, local NGOs, (e.g. Peasants Union and the Womens Union) and academic institutions. As this strategy has been signed at the ministerial level, foresters are now mandated to take local communities into consideration and involve them in wild fire management. The Strategy can be considered as a substantial step forward for the protection of Syria's forests and biodiversity.
- **Capacity development of central and decentralized authorities**
  In the past, due to local communities' lack of legal rights to forest resources, staff at the Forestry Department did not have a collaborative relationship with forest users. Technical forestry staff of the Forestry Directorate, as well as agricultural extension staff involved in project activities at central and provincial levels, required greater capacity for developing and implementing integrated management plans together with communities. In addition, the Forest Fire Management Units were provided with technology, training and institutional strengthening to better address both fire suppression and fire prevention. The establishment of a Fire Incident Management System was important for improving the technical execution and coordination of the different stakeholders involved in fire suppression activities. Previously, fire suppression was disorganized and ineffective, and therefore dangerous.
- **Strengthening communities**
  Starting in pilot areas, communities were given support to diversify their livelihood options, increase the empowerment of women and rehabilitate agricultural land. As mentioned above, suitable forest uses were encouraged. Organic agriculture was promoted to improve income through the production of high value crops, such as herbs and medicinal plants. Women were given training in activities that could generate income, including the marketing of handicrafts and the packaging of cash crops. First aid training was also provided, which was welcomed due to the lack of access to medical services, which are especially important during wild fires. Villagers were supported in gaining access to resources in order to create or modernise small enterprises (e.g. small businesses near tourist spots).

Lessons learned and recommendations

By acknowledging the root causes of forest degradation and addressing these drivers in the forest-agriculture landscape in an integrated way, the project has been able to create a foundation for sustainable forest managment in Syria. At the same time, it has been able to contribute meeting CSA's objectives. Fire was a problem due to deliberate burning in the forest and the negligence of fire control on agricultural land. By giving local communities a stake in the well-being of the forest, the fires could be prevented and not merely suppressed once the damage was already done. The project directly targeted local communities to improve their capacity for self-reliant economic development and independence. This was achieved through education, better access to health services and care, and creating greater awareness in the country of the importance of resource access rights, rural employment and the role of women as agents for development and social change.

Ongoing processes for reform as a result of the project include: the development of community-based watershed management programmes; the strengthening of land tenure laws; and additional institutional development.

Case study 2.6
Ecosystem services of peatlands of the Ruoergai Plateau

The Ruoergai peatland pastures on the Tibetan Plateau: a major milk and meat producing area in China

Introduction

The extensive Ruoergai peatlands on the eastern Tibetan Plateau are a major link between the Tibetan uplands and large lowland rivers. These peatlands, which serve as grazing lands, contain an estimated carbon content of 750 megatonnes (Björk, 1993); a significant proportion of Chinese peat carbon resources. Home to numerous endangered and endemic species, the peatlands are important reservoirs of biodiversity (Tsuyuzaki *et al.*, 1990; Ekstam, 1993; Schaller, 1998).

Throughout history, the peatlands on the Ruoergai Plateau have acted like sponges. They absorbed and retained water during periods when water supplies were abundant and slowly released water when it was scarce. In this way, the peatlands slowed down peak discharge, prevented erosion, reduced downstream flooding and guaranteed a steady supply of water to the Huanghe (Yellow) River, a water source that millions of people depend on.

The introduction of livestock grazing 5 000 years ago completely changed the peatlands on the Ruoergai Plateau. Sedimentation of clay, silt and sand from the grazed mineral uplands combined with the continuous passing of yaks caused the peatlands to lose their spongy character. As a result, the peat has become more compact and is much more susceptible to erosion (Joosten *et al.*, 2008). At the same time, herders developed a complex system of land management, which included sharing grazing lands and their rotational use to prevent overgrazing and erosion. This system of resource management is part of the unique cultural heritage of communities on the Ruoergai Plateau. Not only in Ruoergai but in the entire high altitude of the Himalayan region, peatlands still function as grazing pastures for nomadic herders, especially when the peatlands are frozen or not completely waterlogged. Eighty percent of the peatlands on the Tibetan Plateau are grazed or browsed by domestic animals in winter and early summer. The herders prefer peatlands because of the early plant growth, the higher productivity of forage, the better nutrient availability due to the diversity of forage species, and the availability of water for watering and cooling the livestock.

Peatland degradation increased dramatically with the construction of roads in the 1970s and the rising demand for food, fuel and rangeland. Overgrazing and the resulting decrease in the quality of pasture fuelled the demand for new rangeland. This led to increased pressure on untouched peatlands (Wiener *et al.*, 2003; Wang *et al.*, 2006; Gao *et al.*, 2009), of which almost 50 percent were drained (Yang, 2000).

To increase milk and meat production, traditional husbandry was replaced by a more market-oriented economy. Collective livestock and pastures were divided and allocated to individual households (Yan and Wu, 2005). Pastures were fenced and more infrastructure was developed. Livestock numbers increased dramatically and migration routes of animals were blocked (Li *et al.*, 1986; Long and Ma, 1997), which aggravated overgrazing, peatland degradation, erosion and desertification. Peatlands in Ruoergai were leased to individual Tibetan herders, and this led to long-term conflicts between nature conservation and livestock grazing (Yan and Wu, 2005). The more sedentary managing system brought about new challenges not only for pastoral development but also for peatland conservation. Currently, the peatlands provide irreplaceable grazing ground for thousands of yaks, horses and sheep that are central to the livelihoods of local herder families and provide the country with animal products. Healthy peatlands can also create employment in other areas, such as tourism.

During the last forty years the area of degraded peatlands has almost doubled, and less than 20 percent of the peatland remain in good condition (Schumann *et al.*, 2008). Peatland degradation leads to increased GHG emissions. On the other hand, more moderate grazing may reduce methane emissions and carbon sequestration (Chen *et al.*, 2008 and 2009). For this reason, peatland restoration is considered an effective low-cost mitigation tool.

The landscape approach

At the farm level, herders fenced parts of the winter pastures near their winter houses to create hay meadows to supply supplementary fodder to animals and decrease grazing pressures on the peatlands in spring. Some core zones of protected areas and peatlands that are important as black neck crane habitats were also fenced to prevent direct grazing.

On the community and local level, pilot projects by national and international organizations supported peatland restoration by replanting vegetation (forage cultivation), rewetting (ditch blocking) and establishing comanagement systems that involved multiple stakeholders in the planning and decision making regarding the diverse uses of rangeland resources.

On the regional level, the Provincial People's Congresses of Gansu and Sichuan approved Wetland Conservation Regulations in 2007 and 2010 to promote the conservation of biodiversity and enhance the livelihood of local communities. These regulations prohibit drainage and peat mining, promote the reclamation of peatlands and encourage local people and organizations to get involved in peatland restoration. The Provincial People's Congress of Sichuan allocates 0.3 percent of its yearly budget to peatland restoration. Since 2008, the Chinese government has been working to establish a PES mechanism to compensate local herders for reducing the number of livestock.

On the national level, during the last decade the government of China has encouraged the ecological restoration of degraded rangelands and forage cultivation in winter pastures to reduce grazing pressure on peatlands in winter and spring. Since 2009 the programme 'Returning grazing to grasslands' (*Tui Mu Huan Cao*) in the eastern Tibetan Plateau has provided local herders with payments for ecosystem services when they decrease the number of livestock and fence pastures for hay making or restoration.

Lessons learned and recommendations

Human influence on the peatlands and rangelands of the Ruoergai Plateau started long before intensified land use directly affected the peatlands. Today most peatlands on the Ruoergai Plateau show moderate to severe degradation. Prevention of any further degradation and strict protection of the hydrologically important untouched peatlands should be the highest priority.

When they were not backed up by adequate management of grazing intensities, technical approaches to restore peatland functions showed only minor and ephemeral success. This important precondition for restoration and sustainable peat and rangeland use can only be achieved by actively involving local people in decision-making processes. Furthermore, the global benefits for biodiversity conservation and climate change mitigation and the national and regional benefits of water regulation must be directly linked with the local benefits of sustainable livestock production. Awareness raising and educational activities are needed to ensure that local communities understand how these different benefits are inter-related.

The development of an integrated peatland management regime has to respond to the demands of the local population. The management approach must be acceptable to local communities and be communicated in a comprehensible and consistent way. In Ruoergai County, for example, peatland conservation is the responsibility of the local forestry bureau, whereas rangelands (including grazed peatlands) are managed by the animal husbandry bureau. To achieve optimal landscape management that integrates the interests of all stakeholders, communication and cooperation between the different responsible organizations should be optimized.

The Ruoergai example shows how sound peatland management may serve multiple goals. By keeping groundwater levels high, the peatlands support the productivity of the upland rangelands. By reducing the speed of water flow, the peatlands retain sediments and provide a supply of good quality, well-filtered water. In addition, untouched and restored peatlands provide important soil carbon storage, whereas reduced degradation leads to significantly less carbon dioxide emissions.

Case Study 2.7
Assessing ecosystem services at a territorial scale – options for policy making, planning, and monitoring in the Kagera river basin

Lake Burera in Rwanda

Introduction

The goal of the Transboundary Agro-ecosystem Management Project for the Kagera River Basin (Kagera TAMP) (described at http://www.fao.org/nr/kagera/), which is funded by the Global Environment Facility (GEF) and implemented by FAO, is to adopt an integrated ecosystem approach for the management of land resources in the Kagera River Basin. The Basin is shared by Burundi, Rwanda, Uganda and the United Republic of Tanzania. Interventions are being monitored in terms of the local, national and global benefits that are generated. These benefits include: restoration of degraded lands; carbon sequestration; climate change adaptation; sustainable use of agricultural biodiversity; and improved agricultural production and rural livelihoods. Indirect benefits that are being monitored are the project's contribution to the protection of international waters and enhanced food security. In the project's monitoring framework, a participatory multisector process for assessing and mapping of land degradation and sustainable land management was undertaken for the entire basin.

The landscape approach

There are various land assessment tools that are suitable for application at a landscape scale for planning and management of natural resources and ecosystems and for supporting CSA interventions. The land degradation and SLM appraisal was based on a method jointly developed by the LADA project (www.fao.org/nr/lada/). The LADA project was executed by FAO and supported by GEF/United Nations Environment Programme (UNEP) in collaboration with the World Overview of Conservation Approaches and Technologies Secretariat. The assessment was conducted across the entire river basin: at the national level in Burundi and Rwanda, where the basin covers more than 60 percent of the national territories; and in relevant parts of the Kagera basin in Uganda and the United Republic of Tanzania. A series of participatory meetings were held that included selected multisectoral experts. Also carried out was an assessment and mapping of the extent, severity and intensity of various degradation types or processes encountered in the basin, as well as the extent and effectiveness of various SLM measures that were applied by diverse land users in the basin. The results, built up through consensus among groups of experts from multiple sectors, provided the baseline information and a harmonized territorial estimation of the tangible elements of the ecosystem's good and services (e.g. impacts of land use and management practices on soil, water, biomass, biodiversity, and its social and economic implications).

The method, which takes into consideration biophysical, social, economic, and ecological dimensions (see Table 2.2), is cost-effective and can be conducted in a relatively short amount of time. For the Kagera Basin, which covers nearly 60 000 km2, the entire assessment cost around US$ 150 000. Included in these costs was capacity development in methods for the participatory expert assessment with multiple sectors, quality control, and the validation and finalization of the database and maps. In this case, six months were sufficient to complete a first draft set of maps. One year should be sufficient to complete the entire validation process and make available the data set and maps for future planning by districts and technical sectors.

Table 2.2
The various dimensions used by the LADA questioinnaire for mapping method

Biophysical	Use of the land	Ecological	Socio-Economic
Elevation, slope, hydrology, land cover soil, soil fertility Climate: temperature, rainfall	Livestock density, crop type, land use		Population density, poverty
Direct causes of land degradation or SLM due to land use and management practices			Indirect causes of land degradation (driving forces) or SLM
Trend in land-use change and intensity of trend variation Type, rate, degree, and extent of land degradation Type, extent, effectiveness of SLM technologies			
		Impacts on ecological services (water, soils, biomass, biodiversity, climate): negative or positive impact due to land degradation or SLM	Impacts on productive and socio-economic services: negative and positive impact due to land degradation or SLM

After finalizing the collection and validation process, the data and maps are used to guide the cross-sectoral interventions at the landscape level so that multiple goals, including those that address specific climate threats, can be reached. In this way, LADA can be used to promote sustainable and climate-smart land resource management.

Lessons learned and recommendations

An important lesson that has been learned is that the data and maps can be used to: inform the project intervention strategy; identify best SLM practices for scaling up; and guide effective and responsive interventions at various scales. This is backed up by SLM implementation at the farm and catchment levels, field assessments of SLM performance and impacts, and an analysis of constraints to wider uptake.

This process will in turn inform policy making, planning and budgetary allocations by technical sectors at the district and transboundary levels and will establish a baseline for more integrated landscape management approaches. A handover and ownership building process is under way to transfer the results to select governmental institutions. Decision makers in the four countries will be assisted in analysing what type of land degradation processes are occurring, including those exacerbated by climate change; where they are happening; what are the trends and why; and what are the expected ecological and socio-economic impacts. An example of the type of issue that could be analysed would be how changes in carbon storage in soil and biomass resulting from certain land-use practices would affect the supply of food and energy and agro-ecopological resilience. Decision makers will also be informed about how to analyse current SLM technologies and approaches in terms of extent and trends, and their effectiveness in reversing land degradation and improving SLM. For example, a comparison of maps showing degradation (Figures 2.1 and 2.2) and SLM effectiveness (Figure 2.3) will allow decision makers to identify areas requiring interventions, select good practices that can be scaled up, and choose additional SLM measures that are needed to address specific degradation problems (see figure 2.1). Policy makers should be informed on the causes of land degradation (as distinct from poor quality land) such as poor cropland management, the removal of natural vegetation and deforestation, over-exploitation of vegetation for domestic use, overgrazing, and climate-related factors (e.g. changes in temperature or seasonal rainfall, extreme rainfall, floods or droughts) (see Figure 2.2).

The participatory assessment could be repeated at the basin level (at the end of the project) or preferably at the farm and catchment level at regular intervals (e.g. mid-term and end of project). These would monitor the impacts of the project in terms of specific SLM interventions, their impacts at field and farm level, and their combined effects at a wider catchment and territorial scale.

The method could also be used during project implementation to help identify required improvements to SLM interventions, determine potential areas for scaling up specific SLM measures and analyse the best practices that deserve wider investment.

The process can be used by communities and districts to justify and develop proposals for catchment level interventions and develop more substantive investment programmes requiring external support for landscape or basin-scale interventions. Information gathered will allow for landscape and territorial management among the various sectors and contribute to achieving multiple objectives, including sustainable productivity, enhanced resilience to climate variability and change, and climate change mitigation. This will contribute to the development of more effective synergies among sectoral interventions and identify trade-offs that need to be addressed by all stakeholders.

Figure 2.1
Land degradation severity in the Kagera river basin

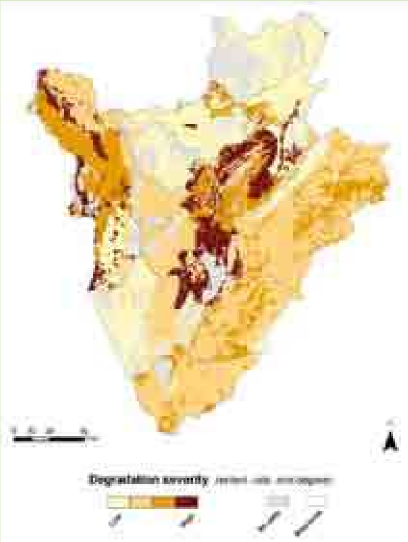
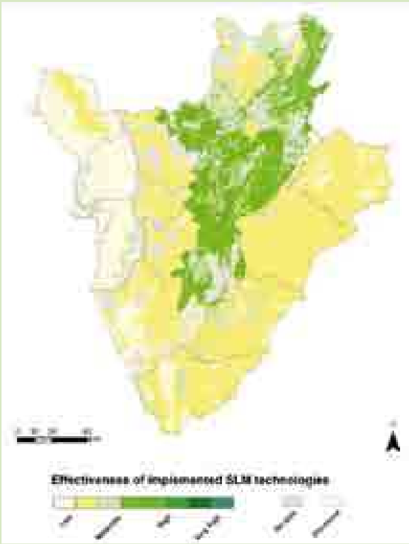


Figure 2.2
Land degradation caused by climate in the Kagera river basin

Figure 2.3
Effectiveness of SLM in the Kagera river basin



Case study 2.8
Planning and management for the hydrological balance of the South American continent – the role of the tropical Andes

Contour terraces in the Peruvian Andes

Introduction

Most of the watersheds of the South American continent, including the Amazon and La Plata river basins, originate in the tropical Andes mountain range. Water places the tropical Andes in a position of strategic importance for the environmental stability of the entire South American continent.

Climate change is a significant threat to the functioning of the tropical Andes' ecosystems. Throughout rural Latin America, and particularly in the tropical Andes and its related continental watersheds, agriculture and livestock production are the main livelihoods of most rural populations. As they are currently practiced, agriculture and livestock production have a huge impact on the hydrological regime and water quality downstream.

The landscape approach

At the farm level, shifting to climate-smart practices, improving market access, and protecting vegetation cover on the landscape level to stop soil erosion, are some of the key measures that need to be taken across the tropical Andes to avoid environmental damage and strenthen rural livelihoods.

Policy and institutional reforms are needed to ensure that the high-altitude ecosystems of the topical Andes are managed to ensure hydrological stability. Planning, development and management of water resources must be governed by an integrated local and continental perspective, and encompass climate change adaptation, disaster risk management and natural resource management. Institutions should be adapted to serve the resource, not the other way around.

On the continental scale, a South American plurinational agency that works to clarify roles and responsibilities in relation to the sustainable water management of the region´s watersheds could be an important positive force for long-term water security of the region.

On the national level, a basin perspective is often lacking. State authorities usually work in isolation, and there is a repeatedly acknowledged absence of national policies for water resources in the region. To a large degree, the solutions involve public policies that encourage the adoption of environmentally sustainable agricultural practices. These practices should be measured by their ability to achieve high yields per hectare and supported by public investments in physical infrastructure that is built by local populations. Institutional strengthening is needed especially at the municipal level to improve services. This could be addressed by municipal taxes. Currently, citizens only pay national taxes, and funds to municipalities are allocated by the central government. This situation leads to a lack of accountability by municipal officials towards local populations. Policies for municipal strengthening can enable the active involvement of local populations in policy design, implementation, monitoring and evaluation, which is important to ensure the effectiveness of efforts on the national scale.

On the subnational level, municipal structures, families, farmers, rural producers and community organizations are key institutions that need to be engaged to restore the Andean highlands and prevent hydrometeorological emergencies. Because farmers determine land use and land-use change, they need to play an influential role in constructing institutional arrangements at all levels of government. This can be done by establishing producer cooperatives (large and small) that can give farmers a voice and a collective market influence. Cooperatives need to be supported by municipalities. Municipal government is the appropriate institution to provide a link between the government and civil society organizations in the region, as they are the only public institutional figures in many remote locations and have a cross-sector organization.

For communities, the key determinant for improved livelihoods is a strong physical connection to markets. Good road access to nearby rural towns and cities is paramount. Once road access is available, communities can participate in markets with products for which they have a competitive advantage. A second important intervention that needs to be planned and organized on the landscape scale is technology and knowledge transfer for more climate-smart and profitable practices. The adoption of modern sustainable agro-ecological practices (e.g. drip irrigation and micro irrigation systems, soil fertilization with organic manure, production of food for domestic use in home orchards) and the revival of traditional sustainable practices (e.g. pre-Hispanic terrace rehabilitation, construction of water infiltration ditches, insect repellent plants, native Andean crops) contributes to the resilience of landscapes and family farms. These practices are also part of successful strategies for managing disasters (e.g. protection against soil erosion and soil recuperation, prevention of hydro-meteorological emergencies). Communities are better positioned to ensure that sustainable practices are undertaken, as it is only through the full participation of all community members that damage to the vegetation cover can be avoided.

Planning processes for watershed management involving multiple stakeholders, including municipal and regional governments, can be institutionalized in the tropical Andes using an integrated watershed perspective. This was done in Peru, where the National Plan for climate change adaptation and disaster risk management (2012-2021) was developed jointly with regional governments using a watershed approach. Watershed committees (comisiones de cuencas), inter-municipal commissions (mancomunidades de municipios) and watershed users' organizations involving rural populations as well as urban and industry stakeholders can play key roles in such processes. At the landscape level, watersheds can be favourably managed by intermunicipal commissions that create a chain of municipalities following the flow of water.

Previously, lack of public funding was a major issue for local governments in South America. Money is now flowing in, but it usually comes with constraints set by the funding source. Most local governments in Latin America heavily depend on fiscal transfers from central governments that exercise substantial influence over how finances are distributed. Funding is also commonly available from other sources, such as conditional cash transfer programmes, but these funds are not targeted to promote sustainable rural livelihoods and natural resources management. Fiscal autonomy of municipal governments would empower them to finance their own development and should be a long-term goal.

PES schemes (for more information see Module 14 on financing) is a financial mechanism that is playing a leading role in the improvement of livelihoods of upstream smallholders in the tropical Andes. An example is the Napo Province in Ecuador where a GEF project is supporting the implementation of a water fund that is operating a PES scheme for the appropriate management of páramos and catchment areas upstream so that downstream users have enough water for drinking and producing hydroelectricity. Another financial instrument that can empower citizens and focus public funds on sustainable natural resource management is participatory budgets, which allow citizens to participate in the planning and allocation for all or part of the municipal budget. Community involvement in municipal planning and budgeting strengthens local institutions and can overcome administrative inertia and improve the transparency and accountability of the elected officials.

Lessons learned and recommendations

1. Water is the linking thread which connects the tropical Andes to most watersheds in South America, not only those flowing west to the Pacific Ocean that provide water for cities, such as Lima, Quito and Guayaquil, but also east to the Atlantic Ocean, by way of the Amazon river basin and the La Plata River basin. As such, the hydrological stability of most of the continent depends on services provided by micro-ecosystems located above 4 000 metres above sea level (páramos, wetlands and glaciers).
2. A strategy for adaptation to climate change, risk management and natural resource management (in the case of South America) must be addressed with a regional approach that goes beyond national boundaries to become a strategy for natural resource management in the subcontinent of South America as a territorial unit. The territorial unity of the continent of South America is determined by hydrological dynamics which, according to the law of gravity, has its origin in the higher elevations of the Andes, downstream to the Pacific and Atlantic oceans.
3. Watershed committees allow for the governance of natural resources beyond the political boundaries that may run through the basin. However, watershed committes have sectorial limitations, as they act in matters only directly related to the basin. For that reason, it is essential that, whenever posible, watershed committees establish a close partnership with local government authorities, including municipalities. It is also important that municipalities establish intermunicipal alliances to overcome the administrative limits imposed by political borders and allow them to cover the entire transnational watershed.
4. Supranational feedback must begin from the communities located in the Andean plateaus, since they act as true guardians of the water recharge areas that feed the subcontinent's watersheds.
5. The focus on existing practices and local knowledge for adaptation to climate risk and conservation of agricultural biodiversity is the best guarantee for the sustainable management of Andean watersheds. Andean traditional farming practices, such as the construction of terraces, are well adapted to the conservation of soil organic content and water retention. The local knowledge of conservation practices in situ and the resilience of some crops and livestock products should be valued and included in the development of modern institutions.
6. The creation of synergies between producer organizations and local government institutions is a fundamental element because it provides the link between local governments and civil society organizations.

Conclusions

The landscape approach has an important role to play in transitioning to CSA. It is an integrated approach that aims at the sustainable management of natural and human-maintained processes in the landscape. Instead of separate and often counterproductive management of various sectors, it calls for the alignment of sectoral policies and their coordinated implementation. Adoption of participatory and people-centred approaches and management structures contributes to improving the resilisence of the agro-ecosytem and the livelihoods of the people who depend on it. Scaling up the landscape approach requires an enabling policy and market environment, adequate governance structures as well as improved knowledge management and heightened institutional capacity. Different landscapes require different approaches that will depend on the state and nature of the resources, current land-use dynamics, and social and economic conditions.

Notes

This module was written by Marja-Liisa Tapio-Bistrom (FAO), Anne Bogdanski (FAO) and Lisen Runsten (FAO) with contributions from Anni Arial (FAO); Nadine Azzu (FAO); Sally Bunning (FAO); Christina Seeberg-Elverfeldt (FAO); David Coates (CBD secretariat); Zhijun Chen (FAO); Cassandra De Young (FAO); Paolo Groppo (FAO); Marc Dumas Johansen (FAO); Damiano Luchetti (FAO); Sheila Mwanundu (IFAD); Matthias Reiche (FAO); Janie Rioux (FAO); Reuben Sessa (FAO); Kim-Anh Tempelman (FAO); Stephen Twomlow (IFAD); and Tiina Vahanen (FAO). Box 2.4 was written by Maria Nuutinen (FAO). Case Study 2.1 was written by Richard Hatfield (Natural Capital East Africa). Case Study 2.2 was written by David Boerma (FAO). Case study 2.3 was written by Doris Soto (FAO). Case Study 2.4 was written by Lisen Runsten (FAO) and Manuela Vollbrecht (FAO). Case Study 2.5 was written by Pieter Van Lierop (FAO) and Petteri Vuorinen (FAO). Case Study 2.6 was written by Wu Ning (ICIMOD) and Hans Joosten (University of Greifswald). Case Study 2.7 was written by Sally Bunning (FAO) and Monica Petri (FAO). Case Study 2.8 was written by Tomas LIndemann (FAO), Paola Palestini (FAO) and Daniela Morra (FAO).

Acronyms

CDM	clean development mechanism
COE	Council of Europe
CSA	climate-smart agriculture
EAFA	ecosystem approach to fisheries and aquaculture
FPIC	Free Prior Informed Consent
GEF	Global Environment Facility
GHG	greenhouse gas
ICIMOD	International Centre for Integrated Mountain Development
ICLEI	Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
ISRIC	International Soil Reference and Information Centre
LADA	Land Degradation Assessment in Drylands
NAMA	Nationally Appropriate Mitigation Actions
NAP	National Adaptation Plans
NAPA	National Adaptation Programmes of Action
MEA	Millenium Ecosystem Assessment
NGO	non-governmental organization
PFC	Project Facilitating Committee
PES	payment for ecosystem services
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SLM	sustainable land management
SPI	sustainable production intensification
TAMP	Transboundary Agro-ecosystem Management Project, for the Kagera River Basin
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNEP	United Nations Environment Programme
WHC	World Heritage Committee

References

Bai, Z.G., Dent, D.L., Olsson, L. & Schaepman, M.E. 2008. *Proxy global assessment of land degradation.* Soil Use and Management, 24: 223–234.

Bunning, S., McDonagh, J. & Rioux, J. 2011. *Land degradation assessments in drylands*. Rome, FAO.

Chen, H., Yao, S.P., Wu, N., Wang, Y.F., Luo, P., Tian, J.P. & Gao, Y. H. 2008. *Determinants influencing seasonal variations of methane emissions from alpine wetlands in Zoige Plateau and their implications*. Journal of Geophysical Research-Atmospheres. Vol. 113.

Chen, H., Wu, N., Gao, Y., Wang, Y., Luo, P. & Tian, J. 2009. *Spatial variations on methane emissions from Zoige alpine wetlands of Southwest China*. Science of the Total Environment, 407 (3): 1097-1104.

Council of Europe (COE). 2000. *The European Landscape Convention.* (available at http://www.coe.int/t/dg4/cultureheritage/heritage/Landscape/default_en.asp)

Conant, R. 2009. *Challenges and opportunities for carbon sequestration in grassland systems.* Technical report. Rome, FAO.

Critchley, W. 2010. *More people, more trees.* Practical Action Publications. International Institute for Environment and Development. (available at http://www.iied.org/sustainable-markets/blog/more-people-more-trees)

Ekstam, B. 1993. *Peatland restoration and ecosystem services: science, practice, policy.* Flora, structure and regeneration of wetland vegetation in Hongyuan, Sichuan, China. Report from Hongyuan Wetland Research Project prepared for Sichuan Institute of Natural Resources. University of Lund, Limnology: Department of Ecology. 47 pp.

FAO & International Soil Reference and Information Centre (ISRIC). 2008. *Global assessment of land degradation and improvement: identification by remote sensing.* Global Assessment of Land Degradation and Improvement (GLADA) report No. 5. Wageningen, Netherlands and Rome.

FAO. 2009. *Glossary on organic agirculture.* (available at http://termportal.fao.org/faooa/oa/pages/pdfFiles/OA-en-es-fr.pdf)

FAO. 2011a. *Potential effects of climate change on crop pollination.* Rome. (available at http://www.fao.org/docrep/014/i2242e/i2242e00.htm)

FAO. 2011b. *Framework programme on climate-change adaptation.* FAO Adapt. Rome.

FAO & Wetlands International. 2012. *H.* Joosten, M.-L. Tapio-Biström & S. Tol, eds. Peatlands— guidance for climate change mitigation by conservation, rehabilitation and sustainable use. Mitigation of Climate Change in Agriculture, Series 5.

Fischer, J., Lindenmayer, D.B. & Manning, A.D. 2006. *Biodiversity, ecosystem function and resilience: ten guiding principles for commodity production landscapes*. Frontiers in Ecology and the Environment, 4: 80–86.

Foley, J. A., Ramankutty, N., Brauman, K. A., Cassidy, E. S., Gerber, J. S., Johnston, M. & Zaks, D. P. M. 2011. *Solutions for a cultivated planet.* Nature, 478(7369): 337—342. (available at http://search.proquest.com/docview/907243114?accountid=41827)

Frison E. A. Frison, Cherfas, J. & T. Hodgkin. 2011. *Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security*. Sustainability, 3: 238–256.

Gao, Y., Schumann, M., Chen, H., Wu, N. & Luo, P. 2009. *Impacts of grazing intensity on soil carbon and nitrogen in an alpine meadow on the eastern Tibetan Plateau*. Journal of Food, Agriculture & Environment, 7: 749–754.

Geerlings, H., & Stead, D. 2003. *The integration of land use planning, transport and environment in European policy and research*. Transport Policy, 10(3): 187–196.

Holmgren, P. 2012. *Landscapes for sustainable development.* Center for International Forestry Research (CIFOR) Forests News Blog. (available at *http://blog.cifor.org/12517/landscapes-for-sustainable-development*)

Intergovernmental Panel on Climate Change (IPCC). 2001. *An Assessment of the IPCC.* Synthesis Report – Summary for policymakers. Cambridge, United Kingdom and New York, USA, Cambridge University Press.

IPCC. 2007a. *Climate change 2007: synthesis report.* Contribution of Working Groups I, II and III to the Fourth Assessment Report of the IPCC. Geneva.

IPCC. 2007b. *Agriculture.* In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge, United Kingdom and New York, USA, Cambridge University Press. (available at http://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter8.pdf)

Joosten, H. 2009. *The global peatland CO_2 picture: peatland status and emissions in all countries of the world.* Ede, Netherlands, Wetlands International. 10 pp. (available at http://tinyurl.com/yaqn5ya)

Jongman, R.H.G. 2004. *The new dimension of the European landscape, Dordrecht.*

Local Governments for Sustainability (ICLEI). 2013. *Ethekwini environmental services management plan/durban metropolitan open space system.* (available at: http://archive.iclei.org/index.php?id=1168)

Long, R. & Ma, Y.S. 1997. *Qinghai's yak production systems.* In D.J. Miller, S.R. Craig & G.M. Rana, eds. Conservation and Management of Yak Genetic Diversity. Kathmandu, Nepal. pp. 105–114.

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and human well-being: synthesis.* Washington D.C., Island Press. 155 pp.

Petter, M., Mooney, S., Maynard, S. M., Davidson, A., Cox, M., & Horosak, I. (2013). *A Methodology to Map Ecosystem Functions to Support Ecosystem Services Assessments.* Ecology and Society, 18(1).

Reiche, M., Azzu, N., Bogdanski, A., Braatz, S., Bunning, S., Evtimov, V. & Gordes, A. 2012. *Mainstreaming climate-smart agriculture into a broader landscape approach.* Background Paper for the Second Global Conference on Agriculture, Food Security and Climate Change. Hanoi, Vietnam. 26 pp. Rome, FAO.

Reij, C., Tappan, G. & Smale, M. 2009. *Re-greening the Sahel: farmer-led innovation in Burkina Faso and Niger.* (available at http://www.ifpri.org/book-5826/millionsfed/cases/innovation)

Sangha Group. 2008. *The 'Sangha guidelines' for landscape approaches.* Learning from Landscapes: The IUCN Forest Conservation Programme 2008. IUCN & Ecoagriculture Partners. Arborvitaespecial. (available at http://www.ecoagriculture.org/documents/files/doc_126.pdf)

Schaller, G. B. 1998*. Wildlife of the Tibetan Steppe.* University of Chicago Press.

Scherr, S.J., Shames, S. & Friedman, R. 2012. *From climate-smart agriculture to climate-smart landscapes.* Agriculture & Food Security, 1: 1–12. (available at http://www.agricultureandfoodsecurity.com/content/1/1/12)

Schumann, M., Thevs, N. & Joosten, H. 2008. *Extent and degradation of peatlands on the Ruoergai Plateau (Tibet, China) assessed by remote sensing*. Proc. Intern. Peat Congress Tullamore. Pristine Mire Landscape, 77–80 pp.

Shames, S., Scherr, S.J., Wallace, C. & Hatcher, J. 2011. *Integrating agendas for forests, agriculture and climate change mitigation: rationale and recommendations for landscape strategies, national policy and international climate action.* Ecoagriculture Discussion Paper No. 7. Washington D.C., EcoAgriculture Partners and Rights and Resources Initiative.

Steenbergen, F. V., Tuinhof A. & Knoop, L. 2011. *Transforming lives, transforming landscapes: the business of sustainable water buffer management.* Wageningen, Netherlands, 3R Water Secretariat.

Sunderland, T. 2012. *Landscape guidelines and principles.* Presentation at conference. Bogor, Indonesia, CIFOR.

Tsuyuzaki, S., Urano, S. I., & Tsujii, T. 1990. *Vegetation of alpine marshland and its neighboring areas, northern part of Sichuan Province, China.* Plant Ecology, 88(1): 79–86.

Victoria, R., Banwart, S., Black, H., Ingram, J., Joosten, H., Milne, E., Noellemeyer, E. & Bask, Y. 2012. *The benefits of soil carbon: managing soil for multiple economic, societal and environmental benefits.* UNEP: Yearbook 2012. (available at http://www.unep.org/yearbook/2012/pdfs/UYB_2012_CH_2.pdf)

Wang, G., Wang, Y. & Kubota, J. 2006. *Land-cover changes and its impacts on ecological variables in the headwaters area of the Yangtze River, China.* Environmental Monitoring and Assessment, 120: 361–385.

Wascher, D. M. Múgica, M. Gulinck, H. 1999. *Establishing targets to assess agricultural impacts on European landscapes*. Chapter: 6, CABI ebooks.

Wiener, G., Jianlin, H. & Ruijun, L. 2003. *The Yak*. 2nd ed. Bangkok, FAO. 460 pp.

World Heritage Committee (WHC). 1996. *World Heritage Committee, Information Document Glossary of World Heritage Terms.* Paris.

Wolfe, M.S. 2000. *Crop strength through diversity.* Nature, 406: 681-682.

World Bank. 2011. *Climate-smart agriculture: increased productivity and food security, enhancing resilience and reduced carbon emissions for sustainable development, opportunities and challenges for a converging agenda: country examples.* Washington D.C., The World Bank.

Yan, Z. & *Wu, N.* 2005. *Rangeland privatization and its impacts on the Zoige wetlands on the Eastern Tibetan Plateau.* Journal of Mountain Science, 2: 105–115.

Yang, Y. 2000a. *Mire conservation in China: the latest research progress and current viewpoints.* A. Crowe, S. Campeau & C. Rubec. Millennium wetland event - Programme with abstracts. 219 pp.

Yang, Y. 2000b. *The distribution, degeneration and formation mechanism of peatland in P.R.* China. In L. Rochefort & J.-Y. Daigle, eds. Sustaining Our Peatlands: Proceedings of the 11th International Peat Congress Quebec, 1: 162–169.

MODULE 3:
WATER MANAGEMENT

Overview

This module examines the overall development context in which water is managed in agriculture and provides an overview of the current status, trends and challenges. It also reviews the current state of knowledge of the impact of climate change on water for agriculture and the vulnerability of rural populations and farming systems to climate change. This is followed by an examination of possible response options for addressing these impacts. These options can be applied at various scales, on individual farms, in larger irrigation schemes, throughout entire river basins and at the national level. The module also presents criteria for prioritizing response options, examines conditions for climate change adaptation and reviews opportunities for climate change mitigation.

Key messages

- Most of the impacts of climate change on agriculture are expected to result from changes in the water cycle. Because of this, the design of climate-smart agriculture (CSA) strategies will need to be viewed though a 'water lens'.
- Climate change will affect both rainfed and irrigated agriculture through increased crop evapotranspiration, changes in the amount of rainfall, and variations in river runoff and groundwater recharge. The impact of climate change on water use in agriculture must be considered within a wider context in which a number of issues are taken into account including: increased water demand by all sectors; the degradation of water quality; and heightened competition for water at various levels (community, river basin and aquifer).
- Climate change adaptation in water includes a range of response options related to policies, investments, water management, and institutional and technical factors. These options will need to be applied at different scales: on fields and farms; in irrigation schemes; in watersheds or aquifers; in river basins and at the national level.
- Climate-proofing will have to become central in the design of future investment plans in water for agriculture. It will become necessary to maintain a clear perspective on resilience when screening water development programmes. When designing development policies it will be necessary to systematically consider how the policies may be affected by climate change. In many cases, the challenge will be to combine more efficient use of water with increased resilience of production systems.

Contents

List of Figures

List of Tables

List of Boxes

3.1 Introduction

It is commonly acknowledged that most of the impacts from climate change will relate to water (UN-Water, 2010). How water is managed will be at the centre of climate change adaptation strategies. This is particularly true in rural areas and in the agriculture sector, where water plays a critical role in crop and animal production (including fish), and the management of ecosystems, including forests, rangeland and cropland. There is also scope for climate change mitigation actions in water management for agriculture.

The most immediate impact of climate change on water for agriculture will be through the increased variability of rainfall, higher temperatures, and associated extreme weather events, such as droughts and floods. In the medium to long term, climate change will affect water resources and reduce the availability or reliability of water supplies in many places already subject to water scarcity. This impact must be considered in the bigger picture of water scarcity and agricultural development in which other factors are driving changes in water use at a much faster pace than climate change. Climate change is expected to bring additional burdens on already stressed systems.

Addressing risks associated with climate change requires an understanding of the potential water-related impacts of climate change and the vulnerability of rural populations. Vulnerability, sensitivity, adaptability, resilience and exposure vary depending on the agricultural system and the importance of agriculture for the national economy. These two factors are reviewed below as a basis for action.

There is a range of possible response options to adapt to climate change. These options can be related to policies, investments, water management, and institutional and technical factors, both within the water and agriculture sectors and beyond. To have optimal impact, these options must be used in combinations that are tailored to different contexts. Focus should be placed on major systems at risk. However, there is also a need to assess the vulnerability of different categories of rural people to identify priority actions.

3.2 Water management in agriculture: status and trends

Although agriculture is highly dependent on climate, so far evidence of observed changes related to regional climate changes, and specifically to water, has been difficult to find. One of the reasons for this is that agriculture is strongly influenced by factors unrelated to climate, especially management practices, technological advances, market prices and agricultural policies. These factors have more immediate impacts on water than those induced by climate change (Bates *et al.*, 2008). For this reason, it is important to understand the current status of water management in agriculture before assessing the potential impact of climate change.

Over the last 50 years, heightened demand for food, fibers and other agricultural products has been met mostly by an increase in agricultural productivity. The expansion of agricultural land has remained relatively limited. Total cultivated land increased by only 12 percent between 1961 and 2009, but productivity more than doubled. The amount of land needed to produce food for one person has decreased from 0.45 hectares in 1961 to 0.22 hectares in 2009. During the same period, the extent of irrigated land has more than doubled, increasing from 139 to 301 million hectares (FAO, 2011a). By providing farmers with access to water, irrigation has been a key factor in agricultural intensification. The expansion of irrigated land is expected to continue in the future as farmers will increasingly look for greater control over production factors.

With the doubling of irrigated area, water withdrawal for agriculture has been rising sharply. Globally, agricultural water withdrawal represents 70 percent of all withdrawals. However, as water resources are very unevenly distributed, the impact of these withdrawals varies substantially between countries and regions. An increasing number of the world's river basins have reached conditions of water scarcity through the combined pressure of agriculture and other sectors. FAO (2011a) estimates that more than 40 percent of the world's rural population lives in river basins that are classified as water scarce.

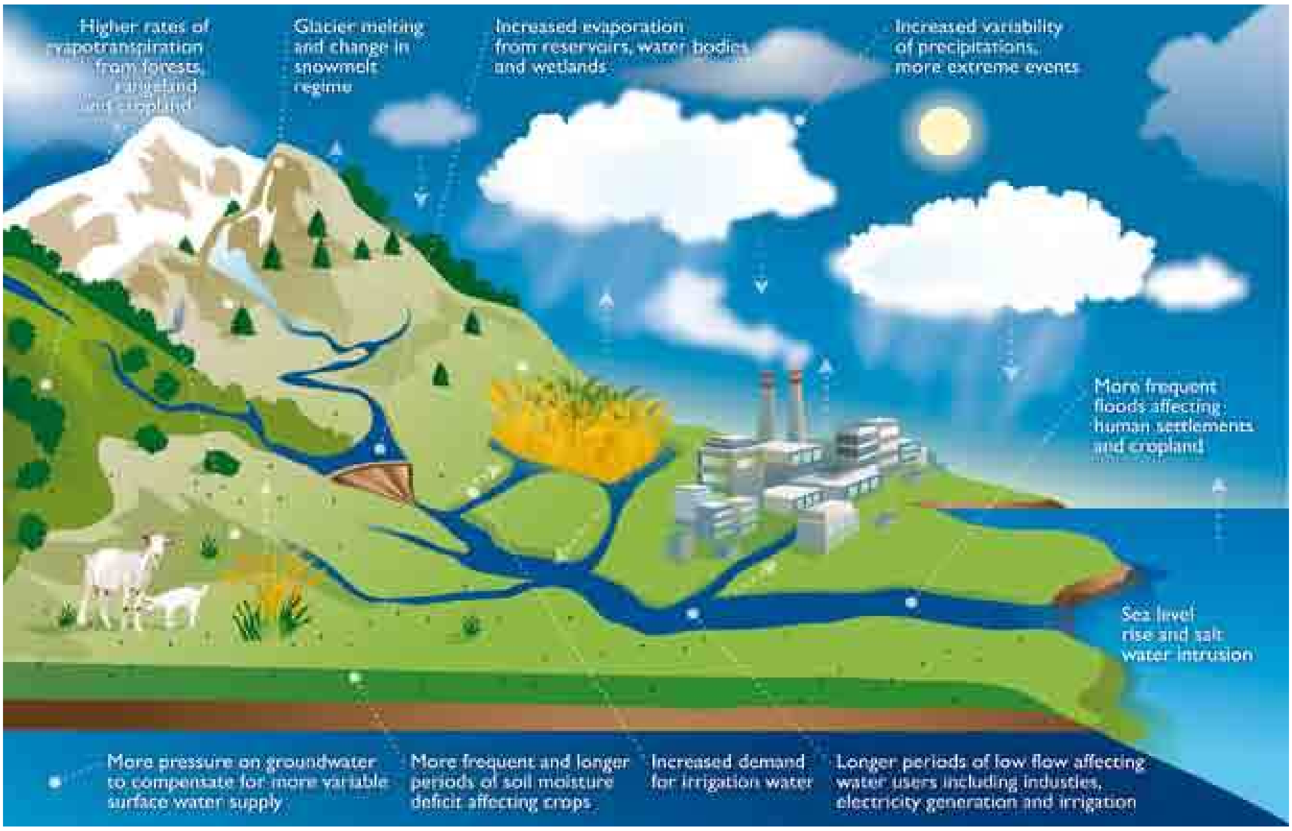
The high level of pressure on water resources has had serious impacts on water users and the environment. Competition over water use is growing in river basins where there are no measures in place for arbitrating conflicts. Evidence shows that biodiversity is declining more rapidly for freshwater-dependent species than for species from other types of ecosystems (Comprehensive Assessment, 2007). The large-scale public surface irrigation systems built during the green revolution dominated the landscape until the early 1980s and had a profound impact on the flow of many rivers. Over the last 30 years, private investments, stimulated by the availability of cheap pumps and well drilling capacity, have been directed to tapping groundwater. Consequently, aquifers are being depleted in countries with key agricultural production systems, including China, India, and the United States.

Water demand from cities and industries has been booming as a result of rapid economic growth in emerging countries. This growth has put pressure on irrigation schemes to release water for urban and industrial users. Pollution from agriculture, cities and industries has affected rivers and aquifers and further reduced the amount of water available for use. The trends towards an increasing demand for water from all sectors is expected to continue in the coming decades as the population reaches 9 billion people in 2050 and economic growth increases the consumption of food and manufactured goods.

The role climate change will play with regards to water in agriculture must be considered in this context of rapid increases in water withdrawals, the degradation of water quality and the competition for water at all levels. The following sections look at the current state of knowledge about climate change impacts on water resources and the demand for these resources. These impacts are framed within the overall perspective of the current status, trends and challenges of water management in agriculture. Of particular interest are aspects of change that are specific to climate and as such require specific responses.

3.3 Potential impacts of climate change on water in agriculture

Figure 3.1
How climate change affects all the elements of the water cycle and its impact on agriculture



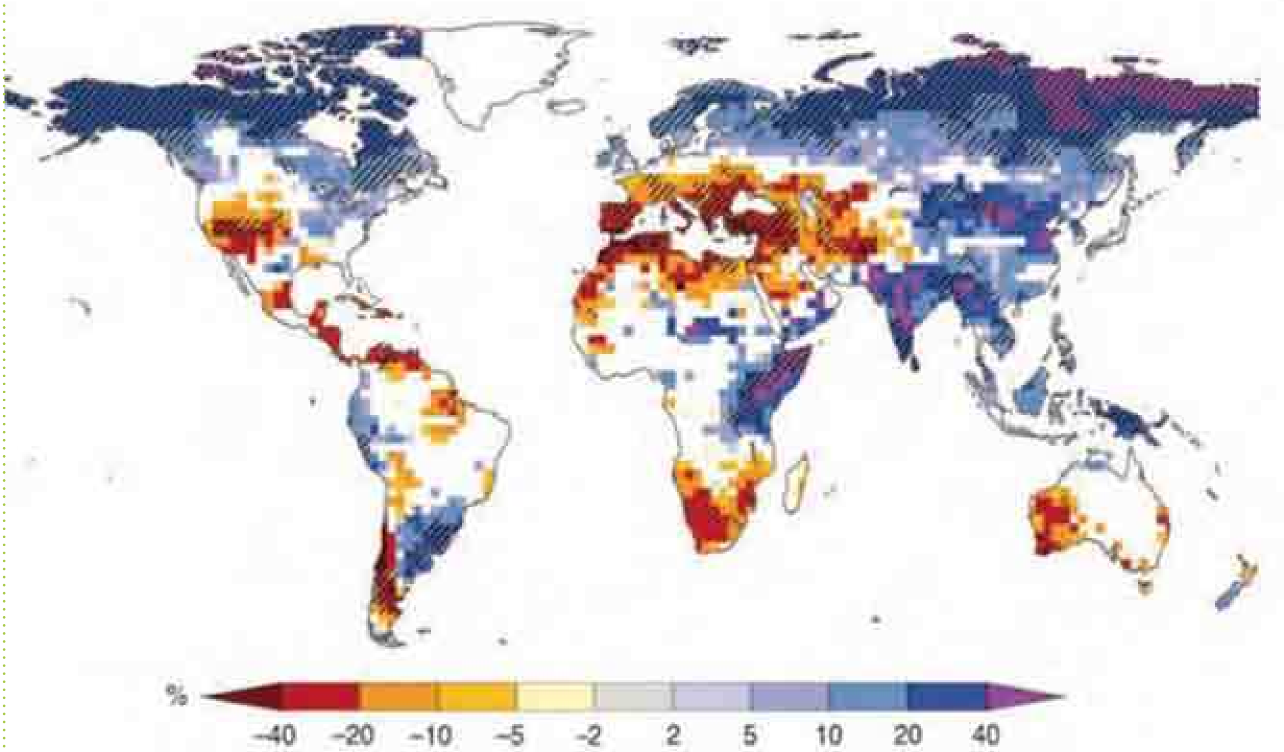
Water is the prime channel through which the impacts of climate change on the world's ecosystems and on the livelihoods of societies will be felt. Climate change will have an impact on every element in the water cycle (UN-Water, 2010). Agriculture will be affected by increased evaporative demand, changes in the amount of rainfall and variations in river runoff and groundwater recharge, the two sources of water for irrigation (Figure 3.1). These impacts are described in more details below.

Impact on water supply and demand

A global increase in atmospheric temperatures is predicted to affect agricultural productivity. Particularly affected will be areas in low latitudes, where temperatures are already high. In these areas, heat waves will affect both crops and animals. An increase in temperatures will trigger increased demand for water for evapotranspiration by crops and natural vegetation, and will lead to more rapid depletion of soil moisture. This scenario, combined with changes in rainfall patterns (see below), may lead to more frequent crop failures.

The hydrological cycle is expected to accelerate as rising temperatures increase evaporation from land and sea (Turral *et al.*, 2011). Predictions about the patterns of change of annual precipitation are still in their infancy, but models tend to agree that there will be substantial changes at the regional level, including a sharp reduction of precipitation in already water-scarce areas, including the Mediterranean, Southern Africa, the Western United States, Mexico and Australia (Figure 3.2).

Figure 3.2
Large-scale relative changes in annual runoff for the period 2090–2099, relative to 1980–1999



White areas indicate where less than 66 percent of the ensemble of 12 models agree on the sign of change (whether there will be more or less runoff). Hatched areas are where more than 90 percent of models agree on the sign of change.

Source: IPCC, 2008

Changes in the distribution of precipitation, with longer periods between rainfall events and more intense precipitation, are expected everywhere. This may lead to increased occurrence of extreme weather events, including floods and droughts. Dry spells, the short periods of rainfall deficit during the cropping season, are expected to increase in duration and frequency. This will directly affect soil moisture and the productivity of rainfed crops. Such changes will be felt mostly in areas already subject to climate variability, such as in the semi-arid and sub-humid areas of sub-Saharan Africa and South Asia, where, in the absence of alternative sources of water, the risk of increased frequency of crop failures is high.

Reductions of rainfall in arid and semi-arid areas will translate into a much larger reduction in river runoff (in relative terms). In Cyprus, for example, analyses have shown that a 13 percent reduction in rainfall translates into a 34 percent reduction in runoff (Faurès *et al.*, 2010). In rivers receiving their water from glacier or snow melt (about 40 percent of the world's irrigation is supported by flows originating in the Himalayas), the timing of flows will change, with high flows occurring earlier in the year. However, the mean annual runoff may be less affected.

The impact of climate change on groundwater recharge is difficult to predict. Local recharge will depend on the characteristics of the aquifer, the recharging processes and changes in rainfall. It is likely, however, that aquifer recharge will be reduced in arid and semi-arid areas, where runoff will decline (Bates *et al.*, 2008; Turral *et al.*, 2011).

Finally, the expected rise in sea levels will affect agriculture in coastal areas, particularly river deltas. Higher sea levels combined with upstream changes (variations in runoff distribution, more frequent floods), will result in an increased incidence of floods and saltwater intrusion in estuaries and aquifers.

Combined effects of climate change and development

As mentioned above, rapid increases in water use for agriculture and other purposes has modified the water balance in many watersheds and aquifers. The combined effects of water withdrawal and pollution are affecting ecosystems and rural populations in an increasing number of places. The extent to which climate change will affect the water cycle and agriculture needs to be considered in light of these developments.

In arid and semi-arid areas, climate change will place additional burdens on already stretched water resources. However, agriculture will first need to respond to the challenges posed by increasing human pressures on these resources. In other places, climate change will be the main driver of change and will necessitate specific climate change-related responses. Table 3.1 is an attempt to present the relative importance of climate change and development on water supply and demand for agriculture. The relative impacts of climate change will vary from one agricultural system to another, but it is important that adaptation strategies take into account the overall context in which they are to be implemented.

Of particular relevance is the time frame for climate change and its relation to the speed of change driven by development. Annual changes in runoff and recharge due to climate change are expected to occur at a slower pace than changes caused by human demands for water. However, changes in variability and extreme events associated with climate change may already be having impacts and deserve particular attention for short- to medium-term responses.

Table 3.1
Climate change and development: how they influence water supply and demand

Elements of the water cycle	Impact from	
	Development activities	Climate change
Annual precipitation	No or minor impact	Expected to increase globally during the 21st Century, with potentially great spatial variations
Interannual variations in precipitations	No impact	Expected to increase everywhere
Seasonal variability of rainfall	No impact	Expected to increase everywhere
Soil moisture stress (droughts)	Limited impact: some agricultural practices can deplete soil moisture faster than natural vegetation	Moisture stress to generally increase as a result of increasing variability of rainfall distribution (longer periods without rain) and increasing temperatures
Floods	Moderate impact: flood intensity and impact can be exacerbated by changes in land use and unplanned development in alluvial plains	Increased as a result of increasing frequency and intensity of extreme rainfall events
Snow and glacier melt	Limited impact through deposit of pollutants and change in the reflecting power of the surface (albedo)	Rising temperatures lead to accelerated snow and glacier melt with initial increases in river flow followed by decreases
River discharge	High impact in water scarce areas, where reservoir construction and water diversion for agriculture and other uses are modifying runoff regimes and reducing annual flow. Large-scale water conservation measures also have an impact on river discharge	Increased variability as a result of changes in rainfall patterns. Changes in snow and glacier melt induce changes in seasonal patterns of runoff. Changes in annual runoff expected to vary from region to region (see Figure 3.2)
Groundwater	High impact: large-scale development of groundwater resources in many regions are already threatening the sustainability of aquifers in many dry areas	Varies as a function of changes in rainfall volumes and distribution. Impact is complex, with floods contributing to increasing recharge, and droughts leading to increased pumping
Evapotranspiration	Limited impact in agriculture: some crops have higher evapotranspiration rates than natural systems, other less	Increases as a function of temperature increases
Water quality (in rivers, lakes and aquifers)	High impact from pollution in highly developed areas	Moderate impact through temperature increases
Salinity in rivers and aquifers	High impact from water withdrawal in highly developed areas (mostly in arid regions)	Potentially high impact where sea water level rise combines with reduced runoff and increased withdrawal

Source: adapted from a comparative analysis of Turral et al., 2011; Comprehensive Assessment, 2007

3.4 Vulnerability to climate change and resilience: a variety of situations

The potential impact of climate change on agricultural systems and rural populations depends on a combination of exposure and sensitivity. It also depends on the level of resilience of these systems in relation to potential changes in water supply and demand. Climate change-related risk will vary substantially from one system to the other. The table in the Annex (A.3.1) presents the main agricultural systems at risk, their exposure to climate change, their sensitivity and adaptive capacity, as well as the elements of response strategies that would be needed as part of any programme designed to strengthen adaptation to climate change. The table is based on the section, 'Land and water systems at risk', from the State of land and water resources for food and agriculture (FAO, 2011a).

The table A.3.1 illustrates that a farming system's vulnerability is directly related to its relative dependency on elements of the water cycle, and in particular rainfall variability. With or without climate change, agricultural societies most at risk are those that rely exclusively on farming for their livelihood, have little scope for diversification and are highly exposed to climate variability. Most of the responses that are needed to increase the resilience of these farmers are not necessarily specific to climate change. Actions that build resilience include: better conservation of soil moisture (in particular through improved soil water holding capacity or access supplementary irrigation); better storage of grain; and better access to markets and to drought protection schemes. Climate change only represents an additional justification for actions that are already needed.

The distinction between rainfed and irrigated production systems will dictate the impacts and associated risks related to climate change. Rainfed systems in sub-tropics and semi-arid tropics will be mostly affected by changes in rainfall patterns and temperatures. These changes will lead to greater frequency of crop failures as a result of increased variations in soil moisture. In mountainous areas, rainfed farming in marginal areas will also be affected by the impact of extreme events, including intense rainfalls, floods and erosion. Pastoral areas will suffer from more frequent drying of water points and greater variability in available animal feed.

Irrigated systems are better protected against rainfall variability. But these systems will increasingly require greater storage capacity to respond to more frequent droughts and floods and changes in the annual distribution of runoff. For surface or groundwater systems already being over-exploited, climate change will add an extra burden to water management and generally lead to a reduction in the availability of water and greater competition for water resources.

Aquatic systems and capture fisheries will be affected by changes in quantity and quality of freshwater, which will have an impact on production. Many aquatic species depend on the timing of rainfall and flood events for important migrations (e.g. spawning and feeding). Changes in precipitation may disrupt these migrations or force these species to make adaptations in their life history patterns. Integrated irrigation systems (e.g. rice and fish) could see changes in system components as climate change alters the suitability of the environment, (e.g. more or less water may require different species of fish). Increased storage (i.e. more or larger reservoirs) could promote integration of fish farming through cage culture and enhance the fisheries production (see also Module 10 on fisheries and aquaculture).

3.5 Assessing risk, preparing responses

Many governments and development agencies have developed tools to assess the risk associated with climate change in relation to expected changes and populations' vulnerability (OECD, 2009). Examples include Opportunities and Risks of Climate Change and Disasters (ORCHID), Community-based Risk Screening Tool – Adaptation and Livelihoods (CRisTAL), and tools developed by CARE and the International Federation of Red Cross and Red Crescent Societies. These tools can be classified by the type of approach they use. There are two types of approaches: a *top down* approach focuses on potential changes in the water cycle as a result of climate change, and designs response options to anticipate and prevent the negative impacts of these changes. By nature, this approach favours long-term responses. The other approach consists in assessing the vulnerability of rural populations, and designing solutions that helps increasing their resilience to external shocks. This *bottom-up* approach is more generic, not specific to climate change (but to any shock or crisis) and usually considers short- to medium-term responses. Both approaches are necessary when designing water management responses in relation to climate change. An impact-based approach is needed to ensure that long-term investments such as irrigation development take into account expected changes in water supply and demand.

Water infrastructures generally have a lifetime of 30-50 years. New investments or rehabilitation of old infrastructures are therefore subject to changes in climate. This has serious consequences for people and finances. In particular, the changing frequency and intensity of droughts, floods, and heat waves will affect water supply and demand and call for better protection of land and socio-economic assets. Improving the resilience of water infrastructure to climate change-related shocks and extreme events is a vital part of any effective water investment planning. The concept of robust decision making in water planning (Groves, 2006) acknowledges that is it very difficult to predict the future, and makes extensive use of scenarios to work out decisions that are robust under a variety of alternative futures (Box 3.1). In practical terms, resilient coping strategies are those that have the potential to be reasonably effective under the largest possible range of scenarios. This should be complemented with the adaptive management of existing and future water infrastructures, which puts the emphasis on flexible responses and requires strong monitoring and information management systems that allow for periodic upgrading of management plans and activities (UNDP, 2004).

Box 3.1
Planning under uncertainty

The current level of uncertainty associated with the impact of climate change on water availability remains high. The downscaling of global circulation models and local and regional assessments of precipitation patterns produce large variations in the assessment of runoff and aquifer recharge. When combined with the different scenarios presented in the Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emission Scenarios, the range of results shows major uncertainties in the prediction of future runoff patterns. A risk-based approach that uses a wide range of scenarios is needed and must be systematically used in hydrological assessments.

Source: Strzepek and McCluskey, 2010

Bottom-up approaches give the opportunity to address vulnerable populations' needs for resilience and development. By acknowledging that resilience is closely linked to a population's state of development, level of economic diversification and the strength of their livelihoods assets, community-based climate change response programmes offer the opportunity to progressively build a capacity to reduce climate change-related risks. Most of the options that will be considered on the basis of bottom-up approaches will not differ from classical agricultural development options for reducing poverty and increasing the standard of living of rural populations. The challenge in this case is to avoid maladaptation (i.e. designing development actions that are excessively sensitive to climate change and will therefore increase the vulnerability of beneficiaries). The concept of 'climate-proof' investments is central to the design of programmes for reducing climate change-related risks. It will become necessary to maintain a clear perspective on resilience when screening water development programmes. When designing development policies it will be necessary to systematically consider how the policies may be affected by climate change (OECD, 2009).

3.6 Options for adaptation to climate change

Options for adaptation to climate change will necessarily combine investments, improved or adaptive management, and modifications in or development of policies, institutions and capacity development. Such options will need to be applied at different scales: on fields and farms; in irrigation schemes (particularly in large schemes); in watersheds or aquifers; in river basins (including transboundary river basins); and at the national level. Table 3.2 lists typical response options and indicates their relevance for different scales.

Table 3.2
Options for climate change adaptation in water at different scales

Options	Field/farm	Irrigation scheme	Watershed/ aquifer	River basin	National
1.Investments					
On-farm water storage: water harvesting	X				
Groundwater development	X				
Modernisation of irrigation infrastructure		X			
Breeding for resistance to droughts and floods	X				
Dam construction/enhancement		X	X	X	
Drainage	X		X	X	
Introduction of appropriate fish species	X		X	X	
2. Land, water and crop management					
Enhancing soil moisture retention capacity	X				
Changing cropping pattern and diversification	X				
Adapting cropping (and fish harvesting) calendar	X				
Supplementary irrigation	X	X			
Deficit irrigation		X			
Alternate wet and dry rice production system	X	X			
Drainage and flood management		X	X	X	
Irrigation scheme operation improvement		X			
Integrated water resources management				X	
Adaptation of dam operation rules				X	
Riparian habitat restoration or creation in rivers				X	
3. Policies, institutions and capacity building					
Climate proofing of I&D infrastructure		X	X	X	
Reallocation of water (between or within sectors)	X	X	X	X	X
Strenghtening land/water right access	X	X	X	X	X
Crop insurances	X				
Improved weather forecasting capacity	X	X	X	X	X
Improved hydrological monitoring			X	X	
Development of flood/droughts				X	X
Review of food storage strategies					X

Source: adapted from Turral et al., 2011

Most of these options are not new to development programmes. Options for on-farm water conservation have been promoted for a long time as a response to water scarcity and climate variability. Options to address increasing water scarcity through better co-management of water at the watershed, aquifer and river basin level are needed in many water-stressed areas. Although there are overlaps between climate change adaptation and development, activities with an explicit focus on adaptation and climate change will also be required. Box 3.2, adapted from OECD (2009) proposes four categories of responses, from development responses to reduce the overall vulnerability of rural communities to all types of shocks, to targeted climate change adaptation options.

Box 3.2
A continuum of adaptation activities: from development to climate change-specific actions

Adaptation activities that span the continuum from development to climate change can be organized in four categories. The first category includes activities that are fundamentally about fostering human development. These activities focus on reducing poverty and addressing factors that make people vulnerable to harm, regardless of the cause. The second category of activities focuses on building response capacity. Mostly of a capacity-building nature, these activities tend to involve institution-building and technological approaches adapted from development efforts. The third category involves activities to manage climate risk. Activities in this category focus specifically on hazards and impacts and follow the concept of climate risk management. The fourth category involves activities for confronting climate change. They focus almost exclusively on addressing climate change impacts. Activities in this category tend to target climate change-related risks that are beyond historic climate variability.

Source: McGray *et al.*, 2007 in OECD, 2009.

Coping with water scarcity

In many river basins, water scarcity is already the main challenge facing agriculture. In areas where water is scarce, climate change is expected to exacerbate tensions and increase competition for water. If agriculture is to continue meeting the demand for food and other commodities, efforts will be needed both on the supply side and on the demand side. Enhancing supply includes: increased access to and improved management of conventional water resources; habitat rehabilitation; dam operations; re-use of drainage water and waste-water; transfer of water between river basins; desalination; and pollution control. Demand management is defined as a set of actions that control water demand, either by raising the overall economic efficiency of its use as a natural resource, or operating intra- and intersectoral reallocation of water resources. Options to cope with water scarcity in agriculture can be seen as running a spectrum from the source of water to the end user (the farmer and fisher), and beyond, to the consumer of agricultural goods (FAO, 2012). A combination of technical, managerial, legal and investment options are needed to help farmers produce more with less water. These options need to be backed with a policy and incentive framework that alerts farmers to water scarcity and rewards more productive use of water at the farm level.

Increasing the reliability and flexibility of access to water for farmers is of prime importance. Many wasteful behaviours on farms are linked to the uncertainty associated with water distribution practices that do not allow farmers to optimize water application or raise the productivity of their crops. Water storage, and the combined use of groundwater and canal irrigation water, can go a long way towards improving the productivity of water used for irrigation. Economic incentives, in particular the use of subsidies for pumping, must be designed in a way that promotes the efficient use of water and avoids wastage of both energy and water resources.

Building resilience

From a livelihood perspective, building resilience involves reducing farmers' exposure or sensitivity to shocks, or increasing their capacity to respond. Of prime importance is the ability to increase the farming systems' buffering capacity in the face of more variable supplies of rainwater. This necessitates an increased capacity to store water in the soil, in surface reservoirs or in underground reservoirs. Any action that increases the capacity to access water when needed will increase resilience to climate variability. These actions include: on-farm water harvesting; the enhancement the soil's capacity to hold moisture (see also Module 4 on soils); on-farm water retention and enhanced infiltration; and, where possible, more systematic access to groundwater. Supplementary irrigation at critical periods of the cropping season can reduce losses and boost productivity.

Resilience is closely linked to improved access to land and water. The strengthening of land and water rights will have a positive impact on resilience as it will encourage farmers and other rural people to invest in their land and build the assets that are needed for increased productivity and diversification.

Adaptation at field and farm level

Many farm-level adaptations will be spontaneous and will be done in response to change but not necessarily designed for climate. Others adaptations will need to be planned, often with external support. Farmers will favour more efficient irrigation technologies that reduce evaporation losses. These actions can be combined with deficit irrigation approaches to maximize productivity per volume of water applied rather than per area of land. Crop selection and changes in crop calendars will help farmers adapt to new temperatures and rainfall patterns. The use of crops or varieties with better resilience to dry spells will be preferred. (It should be noted however that there is little prospect for breakthroughs in developing 'drought resistant' crops in the near future.) Increased agricultural diversification, including better integration of trees, crops, fish and livestock will reduce risk and increase the resilience of farming systems. In particular, the farming and fishing of aquatic species that do not require extensive migrations and that have wide environmental tolerances will help aquaculture and capture fisheries adapt to new climatic conditions. Farmers will also need to adopt more systematically measures to respond to increased frequency of floods and more intensive rainfalls. A combination of erosion control actions and better drainage capacities will be needed.

Adaptation at irrigation scheme level

Actions for adapting to climate change in irrigation schemes need to be considered in the overall context of irrigation modernization. Modern irrigation systems require better water allocation mechanisms, the clear transmission of alerts about water scarcity to farmers, and the adaptation of both infrastructure and management for more flexible and reliable delivery of water (FAO, 2007). Intermediate storage within the irrigation scheme and, where possible, access to groundwater are part of the options for building the resilience and reliability of water supply and must be considered in adaptation plans for irrigation schemes. Water pricing and the establishment of water markets are often advocated as demand management tools for promoting better water use and reducing water wastage. While these options have proven effective in some places, they are often difficult to apply for a combination of technical, institutional and policy reasons. There are other options, such as limiting seasonal allocations to users or to groups of users, that may be simpler and more effective for inducing more productive water use behaviour. Box 3.3 provides an example of a climate change adaptation programme of irrigation in China. It illustrates how adaptation activities are closely linked to overall irrigation modernization programmes.

Box 3.3
Adaptation to climate change in the Huang-Huai-Hai Plain of China

The Huang-Huai-Hai Plain of China is critical to the country's agricultural economy and to national food security. Future productivity in the area is being jeopardized by higher annual temperatures and reduced rainfall, which has led to more frequent spring droughts. Combined with increasing industrial and domestic water demands, climate change will mean that less water will be available for irrigated agriculture. In 2004, a project financed by the World Bank started working with farmers and technical experts to implement water-saving measures across five provinces. In 2006, a grant from the Global Environmental Facility (GEF) was added to mainstream adaptation activities into the project activities.

The overall aims of the project were to reverse the inefficient use of water for farming and increase farmers' profits. A range of irrigation-centred engineering, agronomic and management measures were implemented to improve water management in over half a million hectares and bring benefits to 1.3 million farming families. Research and demonstration activities focused on the testing of adaptation measures and advanced agriculture and water saving technologies. Experts also introduced new drought- and pest-resistant wheat varieties that were more closely matched to expected future growing conditions. New techniques were introduced through pilot programmes to better manage irrigation water and were widely adopted after farmers saw the benefits in terms of reduced irrigation costs, reduced groundwater depletion and especially increased water productivity. Critical to the project's success was the strong coordination and partnership with leading scientific and agricultural research institutions, as well as the efforts that were made towards creating joint ownership with farmers.

Source: Qun, 2011 in FAO and World Bank, 2012.

Adaptation at watershed, river basin and national levels

Climate change adaptation at higher levels will involve a combination of policy adjustments and investments in infrastructure and management. In river basins, increased frequency and intensity of extreme weather events will require adjustments in the storage capacity and management of dams and river protection works. More than in the past, flood management plans will need to combine infrastructure upgrades with non-structural, information-rich approaches that can better mitigate the impact of floods through a combination of land planning, early warning and insurance schemes. Similarly, there will be a need to shift from drought emergency response to drought management plans that include prevention, preparedness, relief and rehabilitation and long-term measures to mitigate the impacts of droughts (FAO and NDMC, 2008).

In all these cases, adaptation approaches to floods and droughts used by water managers and farming communities should be considered systematically. Examples include flood mitigation through the cultivation of varieties of rice that respond differently to different levels of flooding, or the combined cropping of bean varieties with varying resistance to droughts. Habitat engineering and rehabilitation will also be needed to reduce the severity of flood impacts and provide erosion control, nutrients, shade and oxygen. This will also create suitable environments for fish production.

Integrated water resources management in river basins will become more and more important as the combination of increased water use and the occurrence of extreme events will increase the interdependency of people and communities living in river basins, and as actions in one part of a basin will have repercussions for people further downstream. In places where climate change contributes to increased water scarcity, the whole package of supply enhancement and demand management options will need to be considered (FAO, 2012). Improved governance of land and water use will be required to accommodate the multiple uses of water, including for livestock and fish.

Improved weather forecasting and hydrological monitoring will become a critical element of modern adaptation strategies (Faurès *et al.*, 2010). Currently reliable weather forecasting is still limited to a few days. However, progressive improvements in the timing and reliability of seasonal forecasts offer new opportunities for farming communities (more on assessments in Module 12). As efforts focus on improving the accuracy of these forecasts, more emphasis should now be given to improving the way information is conveyed to farmers and building their capacity to make best use of climate information (Gommes *et al.*, 2010). Monitoring and early warning during the cropping season remain a priority to help farmers make informed decisions.

Insurances represent a potential solution that should also be systematically considered as part of adaptation strategies. There is a renewed interest in various types of crop insurance, as well as aquaculture and fishing insurances, that could be adapted to developing countries. National crop insurance schemes have been tested in some countries, but they face substantial challenges in terms of costs and institutional settings. So far, few commercial insurance companies have found it to be an attractive business opportunity. Roberts (2005) focused on the need to smooth tensions between insurance that is run as business for commercial profit and the protection of small farmers that is in the strategic national interest. Insurance companies need to be solid and well-backed. International reinsurance could play an important stabilizing role and provide backup for emerging national companies. The role of national governments in promoting crop insurances must reflect national interests and at the same time ensure the smooth operation of private insurance companies. This must be based on the concept of shared risk between producers, insurance companies and governments.

A type of insurance which has recently been applied in developing countries is known as index-based insurance. In index-based products, compensation is paid to the insured if the agreed threshold of an index is exceeded. The indices must be defined in such a way that they bear a direct relationship with the performance of the product insured. Index-based insurance is difficult to apply to small-scale hazards but seems to have good potential for hazards with regional impacts like hurricanes or droughts (Gommes *et al.*, 2010).

3.7 Prioritizing options with an eye on vulnerable categories of people

The combination of vulnerability assessments, impact assessments and screening of response options usually produces a long list of possible actions. USAID (2007) has proposed a screening process for these actions using a series of criteria. The effectiveness of an option needs to be assessed as a solution to a problem arising from climate change, and be measured in terms of its cost and the size of the beneficiary group. Where possible, actions with impacts on large groups, with low costs per beneficiary and high levels of effectiveness should be selected. Currently, such assessments are rarely done. Adaptation options are often discussed with no clear understanding of possible tradeoffs between costs and effectiveness. A much more systematic approach to adaptation will be needed in this field.

Criteria for assessing the impacts of climate change and adaptation options must also include considerations of equity. Particular focus should be placed on the most vulnerable categories of rural people. Women's access to water must be considered, both in terms of the impact of climate change and response options. Securing water rights in a way that is both effective and equitable will become increasingly important as water scarcity increases. In irrigation schemes, 'tail-enders', farmers located at the end of the irrigation canals, usually suffer more than other farmers during water shortages and floods. In river basins, downstream water users suffer from excessive water withdrawal from upstream users. Technologies and policies for climate change adaptation are not neutral in terms of equity. It is therefore important that they be analysed in terms of their impact on different groups of vulnerable people and that actions that would increase inequalities be eliminated from climate change adaptation programmes.

The adoption of a livelihood approach to water-related adaptation is a useful way to ensure that proposed actions will be beneficial to the people they are supposed to serve. Sullivan *et al.* (2008) consider four key dimensions of the water-related conditions of rural livelihoods: access to basic water services; crop and livestock water security; clean and healthy water environment; and secure and equitable water entitlement. Using such entry points to screen the impact of adaptation options ensures that they will be assessed in ways that are in line with the concerns and priorities of rural populations.

Ease of implementation considers possible barriers to the implementation of a given option that could delay or reduce its impact. Such barriers could be policy-related, structural, institutional or social. Social barriers are related to the acceptability of proposed actions by local stakeholders. Specific policy or technical assistance may be required to overcome these barriers. Other relevant criteria include technical feasibility and the time frame for implementation.

Adequacy for the current climate is an important criterion to consider. Here, possible options should be analysed in terms of their 'level of regret'. Low-regret or no-regret options are those options that are valid whether expected climate change impacts occur or not. In general, these options increase the resilience of rural populations and reduce their vulnerability to water-related shocks. Instead, many options, in particular options dealing with infrastructure, can be considered high-regret options: they would be valid for future climate scenarios but not necessarily for the current climate situation. They would therefore involve higher costs and have possible negative consequences under current climate conditions, and require careful consideration in terms of risk analysis.

All options must be considered in relation with the uncertainty associated with climate change predictions. Their robustness in terms of the above criteria (in particular effectiveness and adequacy for current climate) must be assessed against different climate change scenarios and global circulation models (see Module 18 on assessments and monitoring).

3.8 Conditions for successful adaptation

In developing countries, programmes designed to promote sustainable water management face the greatest number of barriers to the successful adoption of climate change adaptation practices. In most cases, the potential exists to adapt to climate change, improve the livelihood situation of rural communities and promote sustainable practices. Achieving these goals demands that a certain set of conditions be in place to remove constraints and build resilience and flexibility (FAO, 2011b), including: improvement of land tenure and secured access to water; strengthened and more collaborative land and water institutions; efficient support services (including knowledge exchange, adaptive research, rural finance); and changes in incentive frameworks that remove ineffective subsidies and focus on incentives that promote resilience, improve productivity and induce sustainable behaviours.

Climate change adaptation must be mainstreamed in both rural development and water scarcity programmes (FAO, 2011a; FAO, 2011b) and not carried out on a separate track. Water, land and food policies must be more aligned and viewed through the perspective of climate change. In particular, agriculture and rural development goals must be brought into water planning and take into consideration other water use sectors. Links must also be made with disaster risk management strategies, which are in a large part directly related to water management (see Module 15 on disaster risk reduction).

3.9 Water management for climate change mitigation

Irrigated agriculture accounts for only 20 percent of the area of global agriculture, but is more intensively managed. On average, irrigated agriculture uses greater amounts of inorganic fertilizer and other agrochemicals than most rainfed systems. Consequently, efforts to reduce greenhouse gases through improved crop management practices are likely to have more impact in irrigated lands than in rainfed areas.

Groundwater is used for irrigation on 38 percent of all irrigated land. The use of groundwater is expanding both in absolute and relative terms (Siebert *et al.,* 2010), and this is increasing the use of fossil fuels and raising the energy costs of water supply. At a regional level, energy consumption for groundwater irrigation can be significant. In China, energy consumption in this area is significant, accounting for 16–25 million tonnes of carbon emissions. In India, it is responsible for 4–6 percent of the national total emissions (Shah, 2009).

On balance, the options for direct climate change mitigation through irrigation are the same as those of agriculture as a whole. There is likely greater potential in areas of intensive groundwater irrigation. The possibilities are governed mostly by the increased intensity of irrigation, which will allow for a greater potential for carbon sequestration in tropical conditions and greater productivity, but may be offset by more intensive use of inputs (Turral *et al.*, 2011).

Agricultural methane (CH_4) emissions account for more than 50 percent of CH_4 emissions from human activities. One-third of these emissions come from flooded rice production (28-44 teragrams of CH_4 per year). More than 90 percent of global rice production is concentrated in the monsoon area of South and Southeastern Asia. Since the area of irrigated rice is growing relatively slowly, future increases in CH_4 emissions from rice fields are expected to be small. Furthermore, rice fields are converted at least partially from natural wetlands, which also emit CH_4, and extend over a much larger area at the global level. The effective net emissions growth from transforming wetlands into irrigated rice has not been well studied. However when emissions from natural wetlands are taken into account, gross emission estimates are probably substantially smaller than effective net emissions (HLPE, 2012).

Emissions during the growing season can be reduced by using various water management practices, such as cultivating aerobic rice and, where conditions allow, alternate wetting and drying. Avoiding water saturation when rice is not grown and shortening the duration of continuous flooding during the rice growing season are effective options for mitigating CH_4 emissions from rice fields. Currently, true aerobic rice yields tend to be poor (less than 2 tonnes per hectare), and this is a strong disincentive for adoption even when natural drainage conditions are favourable (Comprehensive Assessment, 2007). Promoted in many rice-producing countries, the System of Rice Intensification (SRI) is a practice that aims to increase the productivity of irrigated rice by changing the management of plants, soil, water and nutrients. Because SRI reduces the amount of flooding of irrigated rice, it is also likely to reduce CH_4 emissions. It also saves water and may possibly reduce nitrous oxide emissions (HLPE, 2012). However, well-quantified data on reductions in CH_4 emission are not yet available.

In inland fisheries and aquaculture, riparian habitat restoration or creation can be promoted to absorb carbon and create suitable environments for capture fish production. The modernization of fishing and aquaculture facilities also has the potential to contribute towards low impact fuel efficient (LIFE) systems (see Module 10 on fisheries and aquaculture).

Irrigated pastures are important in some areas of the world, and their importance is growing as demand for animal feed increases. Better pasture management, combined with the use of feed additives that suppress CH4 fermentation in ruminants, can reduce livestock CH_4 emissions substantially (Turral *et al.*, 2011).

3.10 Conclusions

Most of the impacts of climate change agriculture and rural livelihoods are expected to result from changes in the water cycle. Rainfall variability and the subsequent increase in frequency of extreme weather events, including droughts and floods, combined with an increasing acceleration of the water cycle through increased evapotranspiration, will have an impact on every element in agricultural ecosystems: crops, livestock, trees, fish, rural communities and physical infrastructure. For this reason, climate change adaptation strategies for agriculture will need to be viewed though a 'water lens'.

Many of the development activities for improving the socio-economic conditions in rural areas will have a positive impact on climate change adaptation as they reduce the vulnerability of local communities to shocks and increase their resilience. However, new programmes must become more strategic. The resilience of these populations to climate change must be assessed systematically to avoid maladaptation and increase the robustness of development programmes. In addition, specific climate change adaptation actions will need to be designed and mainstreamed into development programmes.

Given that most intensive agricultural practices with potential for climate change mitigation use some form of irrigation, there is some scope for mitigation actions addressing how water is managed in agriculture.

Notes

This Module was written by Jean-Marc Faurès (FAO) with contributions from Devin Bartley (FAO), Mohamed Bazza (FAO), Jacob Burke (previously FAO, now World Bank), Jippe Hoogeveen (FAO), Doris Soto (FAO) and Pasquale Steduto (FAO).

Acronyms

CARE	Cooperative for Assistance and Relief Everywhere
CH_4	methane
CRiSTAL	Community-based Risk Screening Tool – Adaptation and Livelihoods
CSA	climate-smart agriculture
GEF	Global Environmental Facility
HLPE	High Level Panel of Experts on Food Security and Nutrition
IPCC	Intergovernmental Panel on Climate Change
LIFE	low impact fuel efficient
NDMC	National Drought Mitigation Center
OECD	Organisation for Economic Co-operation and Development
ORCHID	Opportunities and Risks for Climate Change and Disasters
SRI	System of Rice Intensification
UNDP	United Nations Development Programme
USAID	United States Agency for International Development
WHO	World Health Organization

References

Bates, B.C., Kundzewicz, Z.W., Wu, S. & Palutikof, J.P. 2008. Climate change and water. Technical paper of the Intergovernmental Panel on Climate Change. Geneva, IPCC Secretariat. 210 pp.

Comprehensive Assessment. 2007. *Water for food, water for life: the comprehensive assessment of water management in agriculture, D.* Molden, ed. London, Earthscan and Colombo, International Water Management Institute.

FAO. 2007. *Modernising irrigation management – the MASSCOTE approach.* FAO irrigation and drainage paper No. 63. Rome.

FAO. 2011a. *The state of the world's land and water resources for food and agriculture (SOLAW) – managing systems at risk.* Rome, FAO and London, Earthscan.

FAO. 2011b. *FAO-ADAPT.* FAO's framework programme on climate change adaptation. Rome.

FAO. 2012. *Coping with water scarcity: an action framework for agriculture and food security.* Water report No. 38. Rome.

FAO & National Drought Mitigation Center (NDMC). 2008. *The Near East drought planning manual: guidelines for drought mitigation and preparedness planning.* Food and Agriculture Organization of the United Nations Regional Office for the Near East, Cairo and University of Nebraska-Lincoln, National Drought Mitigation Center.

FAO & World Bank. 2012. *Climate change adaptation in agricultural investment in East Asia and the Pacific: issues and options.* Summary report of an Expert Group Meeting jointly organized by the World Bank and FAO.

Faurès, J.M., Bernardi, *M.* & Gommes, R. 2010. There is no such thing as an average: how farmers manage uncertainty related to climate and other factors. International Journal of Water Resources Development, 26: 4, 523—542.

Groves, D.G. 2006. *New methods for identifying robust long-term water resources management strategies for California.* Pardee RAND Graduate School (PRGS) Dissertation Series. Santa Monica, USA.

Gommes, R., Acunzo, M., Baas, S., Bernardi, M., Jost, S., Mukhala, E. & Ramasamy, S. 2010. Communication approaches in applied agrometeorology, In K. Stigter, ed. Applied Agrometeorology, pp. 263–287, Heidelberg, Springer.

High Level Panel of Experts on Food Security and Nutrition (HLPE). 2012. *Climate change and food security.* A report by the HLPE of the Committee on World Food Security, Rome.

Intergovernmental Panel on Climate Change (IPCC). 2008. *Climate Change and Water.* B.C. Bates, Z.W. Kundzewicz, S. Wu & J.P. Palutikof, eds. IPCC Technical Paper VI. Geneva, IPCC Secretariat. 210 p.

McGray, H., Hammil, A. & Bradley, R. 2007. Weathering the storm: options for framing adaptation and development. Washington, World Resources Institute. In OECD, 2009.

Organisation for Economic Co-operation and Development (OECD). 2009. *Integrating climate change adaptation into development co-operation.* Policy guidance.

Quni, L. 2011. *Climate change impact assessment and adaptation in water resources and irrigated agriculture in 3H region of China.* Presentation made at FAO-WB Expert Group meeting on climate change adaptation in agricultural investment in East Asia and the Pacific. FAO and World Bank.

Roberts, J. 2005. *Insurance of crops in developing countries.* FAO Agricultural Service Bulletin 159. Rome, FAO.

Shah, T. 2009. *Climate change and groundwater: India's opportunities for mitigation and adaptation.* Environmental Research Letters No. 4. (available at http://www.iop.org/EJ/article/1748-9326/4/3/035005/erl9_3_035005.html)

Siebert, S., Burke, J., Faures, J. M., Frenken, K., Hoogeveen, J., Döll, P.& Portmann, F. T. 2010. Groundwater use for irrigation – a global inventory. Hydrology and Earth System Sciences, 14: 1863–1880.

Strzepek, K.M. & Mccluskey, A.L. 2010. Modeling the impact of climate change on global hydrology and water availability. Development and climate change discussion paper No. 8. Washington D.C., The World Bank.

Sullivan, C.A., Cohen, A., Faurès, J.M. & Santini, G. 2008. The rural water livelihoods index: a tool to prioritize water-related interventions for poverty reduction. Report for FAO-Water, Rome. (available at http://www.fao.org/nr/water/docs/FAOW_RWLI_paper.pdf)

Turral, H., Burke, J. & Faurès, J.M. 2011. Climate change, water and food security. FAO Water Report No. 36. Rome, FAO. (available at http://www.unwater.org/downloads/unw_ccpol_web.pdf)

United Nations Development Programme (UNDP). 2004. *Adaptation policy frameworks for climate change: developing strategies, policies and measures.* B. Lim, E. Spanger-Siegfried, I. Burton, E. Malone & S. Huq, eds. New York, UNDP. (available at http://www.preventionweb.net/files/7995_APF.pdf)

UN-Water. 2010. *Climate change adaptation: the pivotal role of water.* UN-Water policy brief. (available at http://www.unwater.org/downloads/unw_ccpol_web.pdf)

United States Agency for International Development (USAID). 2007. *Adapting to climate variability and change: a guidance manual for development planning.* Washington D.C. (available at http://pdf.usaid.gov/pdf_docs/PN-ADJ990.pdf)

Additional Resources

Parry, M.L., Canziani, O.F., Palutikof, J.P., van der Linden, P.J. & Hanson, C.E., eds. 2007. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change. New York, USA and Cambridge, United Kingdom, Cambridge University Press.

World Health Organization (WHO). 2010. *Vision 2030: The resilience of water supply and sanitation in the face of climate change, by G.* Howard & J. Bartram. Technical report.

Annex

A.3.1
A typology or major agricultural systems at risk and response options

Major agricultural systems	Sub-system and location	Vulnerability			Typical response options
		Main climate change exposure	Sensitivity	Adaptive capacity	
Highlands	Densely populated highlands in poor areas: Himalayas, Andes, Central American highlands, Rift Valley, Ethiopian plateau, Southern Africa	Rainfall variability, droughts, floods	High: mostly rainfed agriculture, marginal lands, poor soil moisture capacity	Low: high prevalence of poverty, limited options, knowledge, social safety nets and resources	Watershed management and on-farm water storage for water conservation; integrated water resources management in river basins; investment in social infrastructures
Semi-arid tropics	Smallholder farming in Western, Eastern and Southern Africa savannah region and in Southern India; agro-pastoral systems in the Sahel, Horn of Africa and Western India	High temperatures, rainfall variability, droughts	High: crop and animal sensitivity to high temperature and droughts, high population density on marginal lands	Low: high prevalence of poverty, limited options, knowledge, social safety nets and resources, limited capacity for water storage	On-farm water storage; crop insurance; increased productivity through better crop-livestock integration; integrated water resources management
Sub-tropics	Densely populated and intensively cultivated areas, concentrated mainly around the Mediterranean basin	Reduction in annual rainfall, increased rainfall variability, reduction in runoff and aquifer recharge, high temperatures, higher occurrance of droughts and floods	Variable, depending on the region and level on reliance on agricultural activities. Agricultural systems highly sensitive to changes in temperature and water availability.	Low adaptive capacity for agriculture in water scarce areas	Water conservation where possible; integrated water resources management; crop insurance; improved floods and drought management plans; shifting out of agriculture
Temperate areas	Highly intensive agriculture in Western Europe. Intensive farming in United States, Eastern China, Turkey, New Zealand, parts of India, Southern Africa, Brazil	Increased rainfall variability, reduced water availability in places.	Medium to low. Some high yielding varieties more sensitive to temperature and water stress	Possibilities to compensate water stress through supplemental irrigation in many regions; low capacity in water scarce areas	On-farm storage for supplemental irrigation; integrated water resources management at river basin level
Rice-based systems (irrigated)	Southeast and Eastern Asia, Sub-Saharan Africa, Madagascar, Western Africa, Eastern Africa	Increased rainfall variability, increased rainfall, increased occurrence of droughts and floods	Medium, depending on the capacity to cope with floods and droughts	Medium, depending on the capacity to invest in protection against droughts and floods	Increased water storage for flood control and for second and third crop; alternate wet-dry rice production systems where feasible
Large irrigation systems in dry areas (mostly canal irrigation)	Colorado River, Murray Darling, Krishna, Indo-Gangetic plains, Northern China, Northern Africa and the Middle East	Change in seasonality of runoff and groundwater recharge and progressive reduction in runoff in snowmelt systems; reduction of rainfall and runoff in Northern Africa and Middle East, higher occurrence of droughts and floods	High sensitivity to variations and reduction in water supply as most areas are already under water stress	Low due to already heavy pressure on water resources. Limited possibilities in places through increased storage and increased water productivity through conservation measures	Increased water storage and drainage; improved reservoir operations; changes in crop and land use; improved soil management; water demand management including groundwater management and salinity control; revision of flood management plans

Major agricultural systems	Sub-system and location	Vulnerability			Typical response options
		Main climate change exposure	Sensitivity	Adaptive capacity	
Groundwater-based irrigation systems in interior arid plains	India, China, central USA, Australia, North Africa, Middle East and others	Complex interactions between climate change and groundwater leading to possibilities of increase or decrease of aquifer recharge	High sensitivity to variations and reduction in water supply as most areas are already under water stress	Low due to overexploitation of aquifers and competition with other sectors. Limited possibilities in places through increased water productivity.	Increased productivity where possible; better groundwater management through controlled pumping
Rangelands	Pastoral and grazing lands, including on fragile soils in Western Africa (Sahel), North Africa, parts of Asia	High temperatures, rainfall variability, droughts	High sensitivity due to reliance on biomass and water for livestock	Very low: high prevalence of poverty, limited options, knowledge, social safety nets and resources	Where possible, better integration of water supply and grazing land management; reduction of livestock density
Deltas	Nile delta, Red River delta, Ganges/ Brahmaputra, Mekong, ect. and coastal alluvial plains: Arabian Peninsula, Eastern China, Bight of Benin, Gulf of Mexico	Sea level rise and salinisation of aquifers and estuaries. Higher frequency of cyclones (E/SE Asia); increased frequency and intensity of floods	Usually high, depending on population density and the capacity to cope with floods, droughts and salinity levels	Variable	Minimise infrastructure development; better conjunctive use of surface water and groundwater; integrated flood management plans; improved management of coastal aquifers
Small islands and coastal alluvial plains	Including Caribbean, Pacific Islands	Hurricanes, sea-level rise, floods, changes in aquifer recharge	High sensitivity due to fragile aquifers, saltwater intrusion	Variable	Improved management of coastal aquifers; disaster risk reduction plans; water conservation
Peri-urban agriculture	Everywhere	Depending on location	Relatively low	Highly adaptive and dynamic systems	Climate change is rarely the prime source of risk. Actions would focus on competition for water and land with cities, pollution control and health issues

MODULE 4:

SOILS AND THEIR MANAGEMENT FOR CLIMATE-SMART AGRICULTURE

Overview

This module looks at soil management in the context of climate change. It begins with an overview of some of the principles of soil health and the way soils interact with the atmosphere and with terrestrial and freshwater ecosystems. Sustainable soil management options are presented as "win-win-win" strategies that sequester carbon in the soil, reduce greenhouse gas (GHG) emissions and help intensify production, all while enhancing the natural resource base. The module also describes practices that contribute to climate change adaptation and mitigation, and build the resilience of agricultural ecosystems.

Key messages

- Knowing the status and condition of soils and their properties is fundamental for making decisions about sustainable soil management practices that contribute to climate-smart land use.
- Soils that have been degraded are at much greater risk from the damaging impacts of climate change. Degraded soils are vulnerable due to serious losses of soil organic matter (SOM) and soil biodiversity, greater soil compaction and increased rates of soil erosion and landslides. In addition, land degradation is itself a major cause of climate change.
- Management practices that increase soil organic carbon (SOC) content through organic matter management rather than depleting it will bring win-win-win benefits. These practices will maintain productive soils that are rich in carbon, require fewer chemical inputs and sustain vital ecosystem functions, such as the hydrological and nutrient cycles.
- The sound management of the interrelations among soils, crops and water can increase SOM, improve the soil's capacity to retain nutrients and water, and enhance soil biodiversity. Integrated management practices can create optimal physical and biological conditions for sustainable agricultural production (including food, fibre, fodder, bioenergy and tree crops, and livestock).

Contents

List of Figures

List of Tables

List of Boxes

4.1 Principles of soil health, key functions and soil: plant-water interrelations

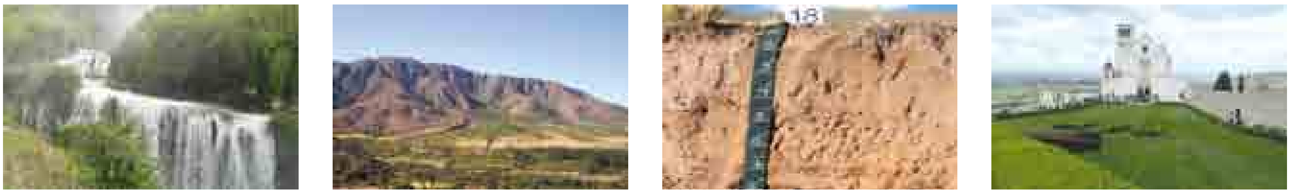
Soils are formed over long periods of time. They are made up of differing proportions of weathered rock, decayed plant and animal matter and a diversity of living plants and animals. Due to differences in local geology, topography, climate, vegetation and human management often over thousands of years, soils are highly variable, both across landscapes and in depth. The diversity and abundance of life that exists within the soil is greater than in any other ecosystem. A handful of soil can contain billions of different organisms that play a critical role in maintaining soil health and ensuring the soil carries out its functions.

Figure 4.1
Definition of soil. Soils contribute to a range of vital ecosystem services and functions[1]

Soil is the thin layer of material (organic and inorganic) on the Earth's surface. It is the foundation on which plants establish themselves and grow, and the basis for crop, forest and livestock production. Soil provides nutrients and water that are taken up through plant roots and contribute to the regulation of water and atmospheric gases.

[1] Ecosystem functions and services are the processes by which the environment produces resources critical to the good functioning of the Earth's life-support system and that contribute to human welfare.

Figure 4.2
Provision of ecosystem services and functions by soils



Life support services

- The soil renews, retains, and delivers plant nutrients and provides physical support to plants.
- It sustains biological activity, diversity and productivity.
- The soil ecosystem provides habitat for the dispersion and dissemination of seeds, which ensures the continued evolution of the gene pool.

Provision services

- Soil is the basis for the provision of food, fibre, fuel and medicinal products that sustain life.
- It holds and releases water for plant growth and water supply.

Regulating services

- The soil plays a central role in buffering, filtering and moderating the hydrological cycle.
- Soils regulate the carbon, oxygen and plant nutrient cycles (e.g. nitrogen, potassium, phosphorus, calcium, magnesium and sulphur) that affect plant production and the climate.
- Soil biodiversity contributes to regulating soil pests and diseases. Soil micro-organisms process and break down wastes and dead organic matter (e.g. manure, remains of plants, fertilizers and pesticides) preventing them from building up to toxic levels and entering the water supply as pollutants.

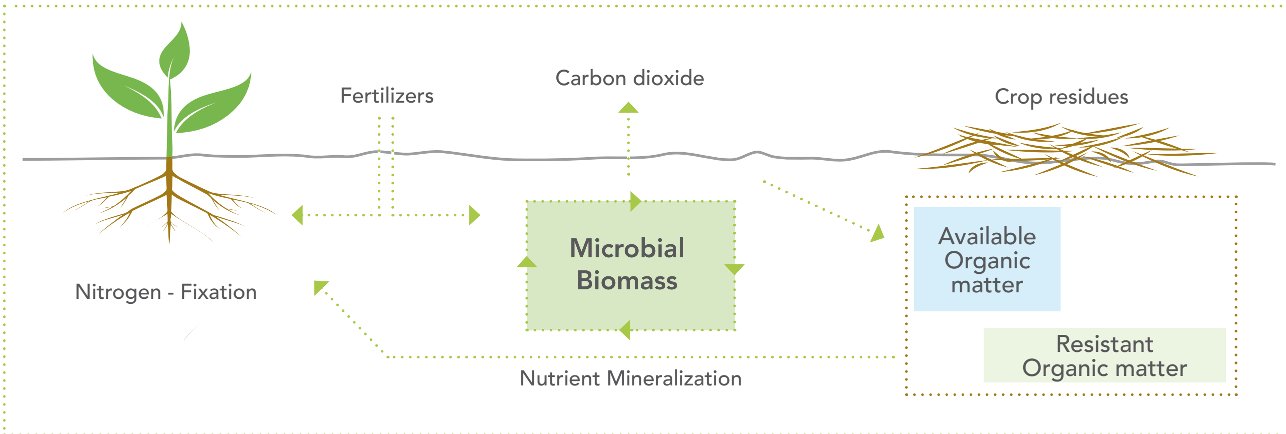
Cultural services

- Soil provides the foundation for urban settlement and infrastructure.
- Soils and their wider ecosystems provide spiritual or heritage value.
- Soils are the basis for landscapes that provide recreation.

©Vargas, 2012

Soil health is a function of its capacity to provide the basic services for supporting plant growth and contributing to the regulation of nutrient, water, carbon and gaseous cycles. Soil health is widely linked to soil biodiversity. Soil organisms mechanically (comminution) and chemically (mineralization) break down the organic matter so they can use it as food. Excess nutrients are released into the soil and used by plants. The recalcitrant (indigestible) fraction of the organic matter is reorganized into SOM, which is less decomposable than the original plant and animal material (Figure 4.3). In turn, SOM content, especially the more stable humus, increases the soil's capacity to store water and sequester carbon from the atmosphere (Bot and Benites, 2005).

Figure 4.3
Organic matter turnover



Source: Gupta *et al.*, 1997

A soil's productivity depends on its physical, chemical and biological properties. Of particular importance are its mineral composition, organic matter content, soil life and associated biological activity. Sandy soils are the least productive as they do not have the capacity (unlike clay soils and silty soils) to retain moisture and nutrients through chemical attraction (electrical charge). However, sandy soils can be managed productively even in hot, dry climates if there is access to required water, organic materials and fertilizers to nourish plant growth.

4.2 Challenges of climate change to soils

With global warming, rainfall levels are expected to decline in many places, and/or to occur in more intense events, and evaporation and transpiration rates are projected to increase. These changes will reduce the availability of soil moisture for plant growth. The higher temperatures will also increase the rate of SOM decomposition (mineralization), especially near the soil surface, which will affect the soil's potential capacity to sequester carbon and retain water. In the scientific literature, there is common consensus that the effect of higher concentrations of carbon dioxide (CO_2) in the atmosphere and increases in temperature on photosynthesis and net primary production, and hence on carbon fixation in the biomass, will not be sufficient to counterbalance the GHG emissions due to the mineralization of SOM.

In cropping, grazing and forest systems, in particular, climate change and variability may affect soil health for plant growth through:

- reduced or erratic rainfall and more frequent and severe periods of drought that lower the capacity of soils to make water and nutrients available to plants;
- more intense rainfall and storms that increase the risk of soil erosion by water and wind (through rain splash, accelerated runoff, strong winds); and
- increased soil surface temperatures and greater rates of mineralization of SOM.

Some soil properties, such as soil texture[2], cannot be changed. Others can be modified and enhanced to enable land users to adapt to climate change and mitigate the effects of global warming by increasing the soil's capacity to store water, supply nutrients to plants, sequester carbon and reduce GHG emissions.

- The soil properties and functions that are most important with regard to climate change are: soil structure[3] and texture, organic matter content, nutrients, soil organisms, pH and cation exchange capacity. These properties allow soils to fulfil their productive functions, especially their capacity to retain water. Soil texture is the relative share of the different sizes of mineral particles (sand, silt and clay). It influences the soil's capacity to retain water and its ability to retain and exchange nutrients. Soil structure is the arrangement of those particles into aggregates and the soil pores between them. Soil porosity depends on both soil structure and texture and is very important for soil permeability. Unlike texture, soil structure can be modified by tillage or traffic.

  Different soil types and textures have different degrees of water permeability and provide different levels of protection or bonding for SOM (Six *et al.*, 2002). Sandy soils are highly permeable due to larger sand grains and pore spaces. Consequently, they have low water retention capacity and offer limited protection to organic matter compared to soils with a higher proportion of silts and clays, which attract and retain water and nutrients.

[2] Soil texture indicates the relative content of particles of various sizes, such as sand, silt and clay in the soil.

[3] Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. When single particles assemble they are called aggregates. Aggregation of soil particles can occur in different patterns, resulting in different soil structures.

- SOM is the organic fraction of the soil that is made up of dead plant and animal materials in various stages of decomposition. It does not include fresh and undecomposed plant materials lying on the soil surface which is known as litter. SOM primarily contains organic carbon (on average 58 percent), but also macro- and micronutrients essential for plant growth and some inorganic carbon. Soil organic carbon (SOC) has an impact on the overall biological resilience of agro-ecosystems. It is also important for the soil's physical properties (e.g. aggregation, water holding capacity, water infiltration and aeration) and chemical fertility (e.g. nutrient availability). SOC also acts as a sink for atmospheric carbon. In addition, SOC enhances soil structure by binding the soil particles together as stable aggregates. Part of the biomass that is returned to the soil through processes of decay is converted into carbon compounds that stay in the soil for a long time (i.e. humus and related organo-mineral complexes). The amount of this stable fraction of SOM varies depending on the quantity and quality of the biomass and is higher in ecosystems with high biodiversity (Charman and Roper, 2000). The greater the SOM content, the greater the soil biodiversity and its activity in breaking down dead and decaying organic matter into humus and in making nutrients available for plant growth.

- Soil carbon stabilization. In most soils, young and unstable macro-aggregates are formed by biological processes (e.g. growing roots, fungal, bacterial and faunal activity have a primary role in mixing fresh organic matter with soil particles and root exudates [a complex of compounds secreted from growing roots and root hairs]). Young macro-aggregates physically protect carbon and nitrogen from mineralization by microbial enzymes, but need to be further stabilized for long-term carbon accumulation. In the carbon stabilization process, micro-aggregates are first formed within the unstable macro-aggregates. These macro-aggregates are then broken down further with the liberation of the micro-aggregates. The processes for the stabilization of aggregates mainly involve biological factors (such as ageing[4], as well as the growth of roots that exert pressure, remove water and produce exudates that have a role both as cementing agents and as substrate for further microbial activity). Some climate-dependent factors (such as wet-dry cycles) are also part of stabilization processes. As mechanical soil disturbance (i.e. ploughing) disrupts these important biological processes, it is particularly detrimental for the build up of SOM.

- Soil nutrients and organisms. While decomposing SOM, the multitude of any organisms in the soil food web release nitrogen (in the form of ammonia ions), potassium, calcium, magnesium and a range of other nutrients necessary for plant growth. Many of these plant nutrients exist in the soil in the form of positively charged ions (i.e. cations). The negative charges on the surfaces of clay particles and SOM attract cations and thus provide a nutrient reserve available to plant roots. Only a small percentage of the essential plant nutrients remains 'loose' in the soil water and directly available for plant uptake. Plants obtain many of their nutrients from soil by 'cation exchange', whereby root hairs exchange hydrogen ions with the cations adsorbed on the soil particles. Clay soils have a higher cation exchange capacity and a structurally greater potential fertility than silty and sandy soils.

- Nitrogen is a nutrient that deserves special attention as it plays a key role in plant metabolism and growth but it can also be a cause of pollution when it leaches in the form of nitrates into the water table. Also, nitrogen can be released from the agro-ecosystem in form of nitrous oxide (N_2O) – a serious GHG that affects global warming. The atmosphere contains 78 percent nitrogen by volume. But it is the lack of this element that most often limits plant growth because plants cannot use gaseous nitrogen from the atmosphere. However atmospheric nitrogen can be converted into nitrate and ammonium ions in the soil through nitrogen fixation by certain soil micro-organisms (symbiotic Rhizobia bacteria associated with the roots of legumes and non-symbiotic bacteria *Clostridium* and *Azoterbacter*, which are free-living in the soil).

[4] Ageing is the deposition of polysaccharides and other organic cementing agents by microbial activity.

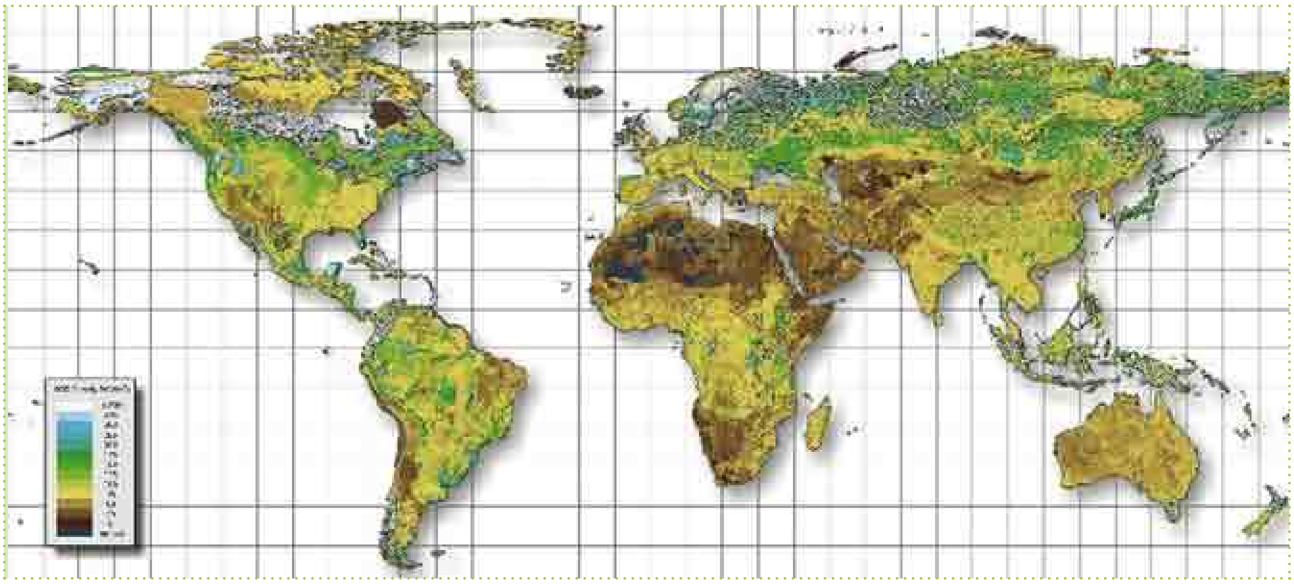
- Potassium is important in various plant physiological processes, and most crops require it in larger amounts than any other mineral element, with the exception of nitrogen. The potassium content of different soils is highly variable and depends on the parent material (the underlying bedrock or superficial deposits from which soils are formed). Unlike nitrogen and phosphorus, potassium is more dependent on the type and content of minerals than on organic matter. However, usually only less than one percent of the total potassium is present in water-soluble and exchangeable forms, and readily available for plant uptake. Potassium uptake by plants is positively related to increasing (yet not exceeding optimum levels of) soil moisture, aeration and temperature. Suggested management practices for potassium vary with the type of crop and the potassium status of soils. This status should be regularly monitored with either plant analysis or routine soil testing procedures. A positive response to potassium fertilization can be expected when soil test values are in the low range.

- Soil pH influences soil nutrient availability and biological activity. A soil pH level of 4 to 7 is acidic, while a soil pH level from 7 to 9 is alkaline. More fertile soils are usually between pH 6.0 and 7.0. Acidity reduces bacterial activity and consequently the decomposition of organic matter and nutrient release. Nitrogen-fixing *Rhizobia* and legumes generally do not do well in acidic soils. Also, strongly alkaline soils have suppressed biological activity and as a result fewer nutrients are available for plants. Strongly alkaline soils are also at risk of SOM decomposition, salinity, soil crusting and the accumulation of toxic levels of sodium and other minerals. Soil salinization is affected by climate change in that higher temperatures and evaporation rates increase the accumulation of salts (including sodium, phosphorus, calcium and magnesium) in the surface soil layers through capillary action. In addition, climate change may lead to higher rainfall, which will contribute to leaching out accumulated salts through increased drainage. Salinization is one of the progressive causes of soil degradation that threatens to limit plant growth and reduce yields on productive agricultural lands. High levels of soil salinity can only be tolerated if salt-tolerant (halophytic) plants are grown. Recent data show that globally about 11 percent of irrigated land is salt-affected, and about 53 percent of the global groundwater is also saline. In almost every irrigated area in the world, the groundwater is affected to some extent by salinity (Palaniappan and Gleick, 2009; FAO, 2011b). When the sodium ion predominates, soils can become sodic. This presents particular challenges because sodic soils tend to have very poor structure that limits or prevents water infiltration and drainage, and exacerbates the risk of erosion.

4.3 Soil principles for climate change adaptation and mitigation and enhancing resilience in different contexts

Sustainable crop, grazing and forest systems can sequester substantial and variable amounts of carbon from the atmosphere and store it in soils and vegetation as indicated in Figure 4.4 (see also Modules 7 on crops, 8 on livestock and 9 on forests). The carbon sequestration potential of any soil depends on many variables. When assessing carbon sequestration, rates should always refer to specific carbon pools, as each carbon category has a very different turnover rate. For instance, carbon accumulated in the first ten years is young and highly oxidizable. Soil carbon becomes more stable over time. In addition, to assess the effects of management practices on soils, it is necessary to have some reference base for similar soil types under the same climatic conditions. Undisturbed soils under natural vegetation should be used as a benchmark and used when comparing soils disturbed by human activities. In addition, data analysis should be carried out at the level of agro-ecological zones (Corsi *et al.*, 2012) to take into account the effects of climate.

Figure 4.4 Estimates of global soil organic carbon (t/ha of carbon) from amended Harmonized World Soil Database

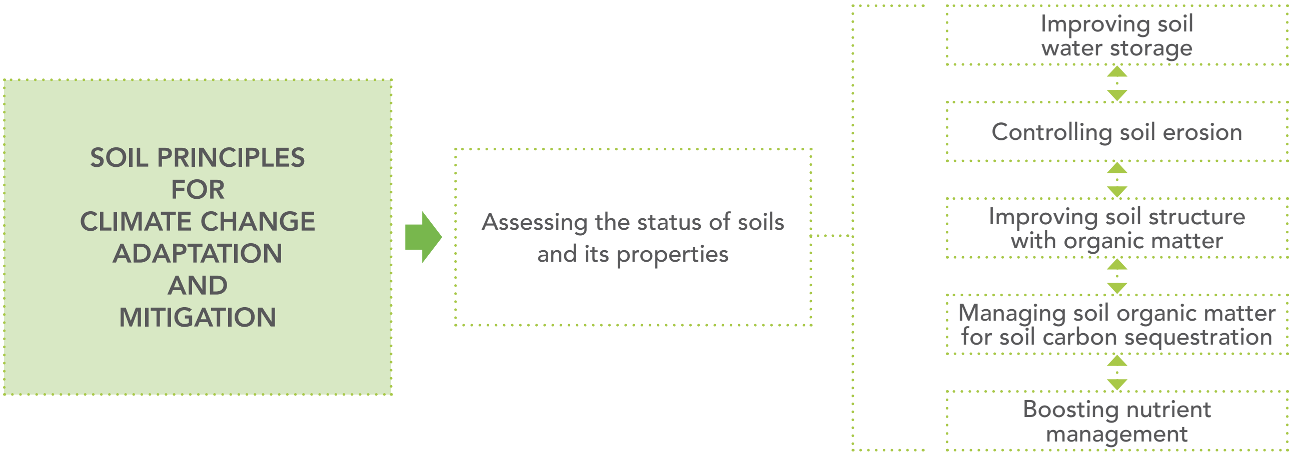


Source: Hieder and Kocky, 2011

Carbon sequestration will not only stabilize climate but will also make agricultural production more sustainable, increase the overall resilience of agro-ecosystems and maintain the ecosystem services that are supported by soils.

There are already proven soil management practices that can help farmers adapt to the likely adverse effects of increasing weather variability and climate change. These practices also often reduce GHG emissions from agriculture[5] and build resilience in farming systems (see Annex A.4.1). Widespread adoption of these practices has the potential to make major contributions to the achievement of national food security and development goals. There is a need to assess and provide incentives for the adoption of systems with the greatest production, mitigation and adaptation potential (win-win-win). The following figure (Figure 4.5) provides the basic soil principles for climate change adaptation and mitigation.

Figure 4.5
Soil principles for climate change adaptation and mitigation, and enhancing resilience



©Vargas, 2013

[5] While other GHGs may be affected, most agricultural land management activities target only one of the three major gases: CO2, by sequestering carbon in the soil; N_2O, by reducing emissions; and methane (CH_4) by reducing emissions or increasing their uptake in the system (Eagle *et al.*, 2012).

Assessing the status of soils

Knowing the status and condition of soils and their properties is fundamental for making decisions about sustainable soil management practices that contribute to climate-smart land use. In this respect, it is crucial to carry out soil assessments and undertake the analysis and mapping of data and information through soil surveys, including in-situ visual soil assessments (FAO, 2008). These surveys should involve land users and be supported by technical experts. In addition, they need to be backed up by laboratory testing for specific properties. Various conventional and digital mapping tools should be used to extrapolate the findings across a range of soil and terrain units, vegetation types, and/or agro-ecological zones. Ideally, soil information will be made available as continuous maps that emphasise soil's attributes. Visual soil assessments should also involve land users and be supported by technical experts to assess physical properties (texture, structure, water holding capacity, dispersion) and chemical properties (ph, nutrients, salinity). For quantitative chemical characterizations soil test kits are available in many countries or can be ordered through the internet. For example, the United Sates Department of Agriculture has developed a soil quality test kit for nine soil parameters (USDA and NRSC, 1998). However, the kit does not include any for the labile SOC fraction – the parts of soil organic carbon with most rapid turnover through oxidation by microbial activity which releases CO_2 into the atmosphere. These labile fractions of SOC are important to study in their own right as they fuel the soil food web and greatly influence nutrient cycles and biologically-related soil properties. The use of dilute, slightly alkaline potassium permanganate and calcium chloride and a colorimeter represents a simple method of estimating changes in biologically active SOC that can be conducted in the field and may provide an early indication of soil degradation or how management practices are affecting soil quality (Weil *et al.*, 2003; FAO, 2012).

Preventing land conversion and protecting vulnerable lands to high SOM losses

Intensive land uses are expanding into areas where SOC stocks are less resilient. For example, semi-arid savannas and grasslands, tropical rainforests and peat lands are all being converted to arable land at an increasing rate. Temperate humid grasslands lose about 30 percent of their SOC after 60 years of cultivation (Tiessen and Stewart, 1983; Guo and Gifford, 2002). Soil carbon stocks in semi-arid environments can decrease by 30 percent in less than five years when native vegetation or pastures are converted to cropland (Zach *et al.*, 2006; Noellemeyer et al., 2008). Pastures established on cleared Amazon rainforest emit between 8 and 12 tonnes of carbon per hectare (Fearnside and Barbosa, 1998; Cerri *et al.*, 2007). Cultivation of tropical forest soils causes losses of more than 60 percent of original SOC stocks in just a few years (Brown and Lugo, 1990).

Tropical peatlands converted to cropland or plantations are a hotspot of carbon emissions (see examples of peatland management also in Module 2 on landscape approach). Draining peat soils to introduce commercial production systems in tropical environments causes ongoing losses of up to 25 tonnes of carbon per hectare per year (Jauhiainen *et al.*, 2011). In boreal peatlands, emissions from cropland are around 7 tonnes of carbon per hectare per year (Couwenberg, 2011). Although drylands[6] have lower mitigation potential per hectare than humid lands, their overall contribution could be highly significant since dry and sub-humid lands cover 47 percent of the Earth's land surface. Moreover, many dryland regions affected by land degradation and are sub-optimally managed could rapidly respond to improvements in management (Farage *et al.*, 2007).

Assessments of land resources are needed to understand trends in land conversion; the type, extent and severity of various land degradation processes; and the extent and effectiveness of existing improved or sustainable land management measures. Such assessments will identify hotspots and bright spots in terms of land degradation (soil, water and biodiversity) and climate change. Land use planning can then be used to determine suitable land uses and provide policy support or incentives to reduce land conversion and promote the adoption of sustainable practices, with particular attention given to peatlands and drylands that are more vulnerable to climate change.

[6] Drylands are areas characterized by lack of water, which constrains their two major interlinked services of primary production and nutrient cycling (FAO, 2005).

Preventing and mitigating land degradation

Soils that have been degraded are at much greater risk from the damaging impacts of climate change. Degraded soils are vulnerable due to serious losses of SOM and soil biodiversity, greater soil compaction and increased rates of soil erosion and landslides. In addition, land degradation is itself a major cause of climate change. It is estimated that overall, land use and land use changes account for around 31 percent of total human-induced GHG emissions (Scherr and Sthapit, 2009b). In the 1990s, 56 percent of the world's cropland (65 percent in Africa, 38 percent in Asia and 51 percent in Latin America and the Caribbean) and 73 percent of rangelands were estimated to be degraded (Oldeman, 1992; Dregne and Chou, 1992). About 22 percent of these lands have been degraded since the 1950s.

Various sources suggest that about 5-10 million hectares are being lost annually to severe degradation. Declining yields (or increased input requirements to compensate) can be expected over a much larger area. These losses results from: physical degradation by water and wind, crusting, sealing and waterlogging; biological degradation due to the depletion of organic matter depletion and loss of soil flora and fauna; and chemical degradation by acidification, nutrient depletion, pollution from excessive use of pesticides and fertilizers or human and industrial waste.

Unsustainable land management practices that are degrading soils include: continuous cropping with reductions in fallow and rotations, repetitive tillage and soil nutrient mining; overstocking, overgrazing and burning of rangelands; and the overexploitation or clearance of wooded and forest lands. During a time of rising demand for food, fibre, fuel, freshwater, fodder, timber and household energy, these practices are reducing the productive capacities of the world's croplands, rangelands and forests.

There is a need for greater policy support and investment in identifying and promoting appropriate production systems and management practices that simultaneously reverse or minimize degradation, conserve above- and below-ground biodiversity, sequester carbon, reduce GHG emissions and at the same time ensure sustained productivity.

Controlling soil erosion

Soil erosion is a widespread and serious degradation process. Intense rains can cause devastating soil erosion on cultivated lands on moderate to steep slopes where runoff rates are high and the ground has inadequate vegetative cover. Studies have identified tillage-induced soil erosion as the major cause of the severe soil carbon loss and soil translocation on upland landscapes (Lobb et al., 1995; Lobb and Lindstrom, 1999; Reicosky *et al.*, 2005). Even on gradual slopes, alkaline soils may suffer from dispersion or crusting that will increase soil erosion risk. Runoff and resulting soil erosion can be substantially reduced through the adoption of minimum to no-tillage techniques combined with optimizing soil cover (cover crops, residues, mulch). On steeper slopes, soil erosion can also be reduced by planting cross-slope vegetation; using soil and water conservation structures, such as terraces, earth bunds and tied ridges to optimize water capture and infiltration; and creating grassed waterways to convey excess water safely off the slopes.

Increased incidence of windstorms could also accelerate soil erosion as the blown sand may be deposited on productive land or sand dunes may encroach on these lands. Measures to reduce erosion by wind include optimizing vegetation cover with drought-resistant species, using rotational grazing to sustain rangeland vegetation quality, and planting windbreaks perpendicular to the prevailing winds.

Improving water storage

Water storage in the soil depends on many factors, including rainfall, soil depth, soil texture (clay content) and soil structure. Soil management can influence rainwater infiltration and the capacity of the soil to reduce soil water evaporation and store water in the soil. Groundcover management can have highly beneficial effects on soil surface conditions, SOM content, soil structure, porosity, aeration and bulk density. Improvements in these properties influence infiltration rates, water storage potential and water availability to plants. These improvements also increase the effectiveness of rainfall and enhance productivity. They also reduce rates of erosion, the dispersion of soil particles and the risks of waterlogging and salinity in drylands.

Within the soil matrix, stable forms of organic carbon, such as humus, can hold up to seven times their own weight in water. Table 4.1 gives an example of how changes in SOC modifies the soil's capacity to store water. An increase of 14.4 litres (almost two buckets) of extra water could be stored per square metre in the top 30 cm of soil for every 1 percent increase in the level of SOC. On one hectare that is equivalent to an additional 144 000 litres of water.

Table 4.1
Capacity of a soil with a bulk density of 1.2 g/cm^3 to store water as affected by SOC content to 30 cm soil depth.

The calculation of these figures was based on a conservative estimate that one part of SOC retains four parts of soil water.

Change in SOC content	Extra SOC	Extra water		CO_2 sequestered
[%]	[kg]	[litres/m2]	[litres/ha]	[t/ha]
1	3.6	14.4	144 000	132
2	7.2	28.8	288 000	264
3	10.8	43.2	432 000	396

Source: Jones, 2006 a and b

Sandy soils are inherently permeable and in hot, dry areas, evaporation rates are high and organic matter breaks down very quickly. For these reasons in drylands and coarse-textured soils the accumulation rate of organic matter is expected to be lower (Zingore *et al*., 2005; Chivenge *et al*., 2006). Crop management systems that reduce soil disturbance (e.g. ploughing and hoeing) and bring about a high accumulation of organic matter should be introduced. Mulching is a simple technique that buffers soil temperature and helps the soil-crop system reduce evaporation and the mineralization of organic matter. Mulching also counteracts the nutrient loss.

Precision farming is a more sophisticated management strategy based on observing and responding to intra-field variations to optimize returns on inputs while preserving natural resources. For example, precision agriculture is used to optimize the quantities of water and nutrients required by providing these inputs directly to the plant when needed through scheduled sprinkler irrigation or drip irrigation systems. Implicit in this type of management is an increased level of knowledge of crop requirements and local soil, terrain and climatic conditions (e.g. soil, slope, aspect).

Improving soil structure with organic matter

Many clay or loamy soils are compacted due to repetitive hoeing or ploughing. In mechanized systems, soil compaction is caused by the passing of heavy machinery through the fields for tillage. In grazing lands, soil is compacted by the trampling of livestock or wildlife. Compaction reduces airspaces in the soil and decreases the penetration of plant roots. Only stronger roots are able to penetrate the soil. The growth of lateral roots or fine root hairs, which are important for moisture and nutrient uptake, is restricted. Compacted soils and shallow soils are seriously affected by dry spells that limit root growth and the plant's access to moisture and nutrients. Subsoiling[7] to break up compacted layers can have a huge beneficial effect on root growth and soil productivity.

Box 4.1
Carbon and SOM

The top metre of the world's soils holds some 2 200 gigatonnes of carbon, two-thirds of which is in the form of SOM (Batjes, 1996). This is more than three times the amount of carbon held in the atmosphere.

[7] Subsoiling, or ripping, is soil preparation treatment done with tined implements to break up hardpans without turning the soil upside down (see FAO, 2012c for more details).

Prevention measures should be adopted to avoid soil compaction. An example is controlled traffic systems that minimize traffic and keep compaction in wheel tracks out of the crop area. Another example is minimum-tillage in combination with a plant or litter cover. This provides organic matter that enhances the activity of soil fauna (e.g. earthworms and termites). The burrowing of these soil organisms breaks up compacted layers and incorporates SOM from the surface into the soil. Also, specific cover crops with strong roots such as radish or pigeon peas can be used to penetrate and break up compacted soils layers. In time, practices such as conservation agriculture (that combine minimized soil disturbance with increased soil cover and crop diversification) will allow SOM to build up and increase the soil's resilience to climate change. Such practices build up a cover of protective vegetation or litter that foster the biological-tillage activity of macro-fauna (such as earthworms) that burrow and make channels for air and water. These practices also incorporate and break down organic matter in the soil.

Managing soil organic matter for soil carbon sequestration

Soil carbon stocks and the mitigation potential they provide depend on the agroclimatic zone, the land use type and the intensity of use. The rate of SOM decomposition and turnover depends primarily on the combined effects of the soil biota, temperature, moisture and its chemical and physical composition. It is also affected by the previous land use and natural resource management practices (particularly the mechanical disturbance of the soil).

Tillage-based agricultural practices over the last 50 to 100 years, which are associated soil degradation, have caused SOC levels in many regions to decline by one to three percent. As shown in Table 4.1, a three percent loss in SOC not only represents a significant loss of water storage (432 000 litres per hectare) but also represents nearly 400 tonnes of extra CO_2 per hectare emitted into the atmosphere. Loss of SOC and water holding capacity is associated with practices such as the elimination of perennial groundcover, repetitive cultivation or continuous grazing, bare fallows, removal of crop residues and grassland burning.

The monoculture of cash crops and the high use of external inputs have been an approach farmers have adopted to achieve the highest possible yields with minimal labour. However, fossil fuel prices have increased, and the production of energy-intensive mineral fertilizers and pesticides is a major source of GHG emissions. Moreover, when incorrectly applied, these inputs leach into water resources and the resulting water contamination has serious deleterious effects on ecosystems and human health. Diversified crop rotations and improved techniques for the management of fertilizer, seeds and pesticides can make the application of inputs more efficient. This reduces the wastage of external inputs and thereby reduces the amount of inputs needed. Greater efficiency in this area can also potentially lower GHG emissions. By improving soil structure and increasing soil biodiversity, no-till cultivation and the control of soil compaction will also reduce GHG emissions, which result mainly from anaerobic soil conditions.

Boosting nutrient management

With agricultural intensification, organic fertilizers (manure, compost and plant residues) are increasingly supplemented by inorganic or synthetic fertilizers, which provide required crop nutrients, including:

- Macronutrients (e.g. nitrogen, phosphorus, potassium, calcium, magnesium and sulphur); and
- micronutrients (e.g. boron, chlorine, copper, iron, manganese, molybdenum, zinc and nickel).

Mechanized systems emit considerable GHG emissions as does the manufacturing and processing of synthetic nitrogen fertilizers. In 2007, the global emission of GHGs from the production and application of nitrogen fertilizers amounted to 750 to 1 080 million tonnes of CO_2 equivalent, or about one to two percent of total global GHG emissions (Niggli *et al.*, 2009). The fertilizer industry recognizes that it contributes directly and indirectly to emissions of GHGs, particularly CO_2 and N_2O, through the production, distribution and use of fertilizers. The industry is encouraging clean technologies and greater efficiencies in the manufacture and application of fertilizers (IFA, 2009).

Nitrogenous fertilizers are the most widely used fertilizers and deliver huge benefits in terms of productivity, especially in nutrient-depleted soils. However, these fertilizers also have a high potential for environmental damage in terms of GHG emissions and nitrate pollution:

- Through the activity of soil micro-organisms, organically-bound nitrogen in soil is mineralized as ammonia (NH_3) and ammonium ions (NH_4-) and then transformed (nitrified) into nitrates (Jiang and Bakken, 1999). Nitrate ions are not attracted to clay and SOM particles (both of which are negatively charged) so they move freely with the soil water and can be leached from the soil through drainage.
- In addition, in oxygen-limited soils, denitrifying organisms will reduce nitrate to nitrous oxide, a GHG with about 300 times the warming effect of CO_2.
- Finally, cultivation (ploughing and hoeing) disturbs the soil and the formation of new aggregates, which encourages microbial activity and the rapid mineralization of SOM.

Between 79 and 98 percent of the nitrogen loss from agricultural soils is largely determined by the nitrate content of the soil just before the rainy season starts (i.e. resulting from the mineralization of organic nitrogen in the post-harvest season when temperatures are high, not from unused fertilizer applied earlier in the year). It is estimated that fertilized soils release more than 2 billion tonnes (in terms of CO_2 equivalents) of GHGs every year (Scherr and Sthapit, 2009b).

These GHG emissions can be reduced by achieving greater efficiencies in fuel use for mechanical field operations and irrigation; making changes in the rates, timing and type of nitrogen fertilizer applications; using slow release fertilizers that control the formation of nitrates; and adding nitrification inhibitors containing ammonium to fertilizer. These practices will help synchronize the demand and supply of nitrogen.

Agronomic management can also control the biological processes that cause nitrate leaching and produce GHG emissions. Cropping patterns should provide enough structural carbohydrates (e.g. lignin) along with nitrogen to allow the nitrogen produced from decaying surface residues to be released slowly and contribute to the growth of the following crop while minimizing losses (Huggins *et al.*, 1998; Gregorich *et al.*, 2001; Gál *et al.*, 2007).

There is common consensus that zero tillage and conservation agriculture systems will considerably reduce nitrate leaching (Macdonald *et al.*, 1989). This is because, unlike mechanical tilling practices, zero tillage and conservation agriculture leave the soil undisturbed, which decreases mineralization and the subsequent production of nitrates. Cover crops take up the nitrogen and reduce its loss from the soil. At the same time, unused mineralized nitrogen remains distributed within smaller pores and is not washed out of the soil (Bergström, 1995; Davies *et al.*, 1996; Gors *et al.*, 1993). However, where no-till is used without cover crops and with herbicides to manage weeds, the effects on nitrogen uptake and reduced leaching, as well as on yields, may be less evident.

Box 4.2
Inorganic fertilizers

Current use of inorganic fertilizers is estimated at 102 million tonnes worldwide. Its use is concentrated in industrial countries and some irrigated areas of developing countries.

The positive effects of the above principles will be optimized and losses minimized by integrating soil-crop-water management practices, identifying the spatial variability within the given land area and fields, and using precision-farming techniques to apply fertilizer and water in ways that are highly efficient and site-specific. Below, Boxes 4.3 and 4.4 illustrate those principles.

4.4 Successful examples of soil management practices for climate-smart agriculture with a focus on resilience

Integrated soil-crop-water management

The sound management of soil-crop-water interrelations can increase SOM levels, improve the soil's nutrient retention capacity and enhance soil biota. This integrated management can provide optimum physical and biological conditions for crop production (food, fibre, fodder and trees).

In cropping systems, good management practices would include:

- Direct seeding (no-tillage); improved protective soil cover through cover crops, crop residues or mulch; and crop diversification through rotations (e.g. incorporating deep rooting plants and perennials pasture leys for integrated crop-livestock systems).
  Burning of crop residues should be avoided by all means.
- Integrated soil fertility management (inorganic and organic) to alleviate the problem of low nutrient retention capacity, which is more pronounced in tropical and subtropical soils where there is a quick turnover of SOM and organic compounds. Agronomic systems should be adopted that increase the protection of carbon and nitrogen from rapid mineralization. Integrated soil fertility management is a strategy used worldwide in intensified cropping systems to combine inputs of organic matter (mulch, compost, crop residues, green manure) with fertilizers to address or prevent macro- and micro-nutrient deficiencies.
- Precise management of nitrogen. The recycling of nitrogen on the farm by using manure and nitrogen fixing plants is the predominant technique used in organic and low external input agriculture to enhance soil quality and provide nutrients. When using this technique, proper timing and management are essential. Nutrients need to be delivered to the plant in times of peak demand. Organic and green manures, as well as nitrogen from legumes, can be managed very precisely through crop rotations that include cover and catch crops (for more details see Thorup-Kristensen *et al.*, 2003).
- Herbicides and other weed management options.
- Physical conservation structures (such as bunds, drainage).
- Irrigation, partial irrigation where needed or possible (see Module 3 on water management).
- Robust sources of information and extension that are tailored to local conditions.

In grazing systems, SOM can be increased through controlled grazing, which reduces vegetation degradation and restores grassland diversity. Reducing burning to the absolute minimum also increases SOM. However, in common property lands, burning is often a preferred strategy for enhancing phosphorus and encouraging young growth for grazing animals (also see Module 8 on livestock). Pasture cropping, a practice where an annual crop is grown out-of-phase with perennial pasture, builds soil at higher rates than perennial pastures alone. This is due to the year-round transfer of soluble carbon to the root-zone and the maintenance of the humification process in the non-growth period of the perennial (Cluff and Seis, 1997).

Box 4.3
Honduras: Quesungual Slash and Mulch Agroforestry System

Slash and burn is a traditional form of agriculture practiced by small-scale farmers on around 20 percent of the tropical land area. Despite the short-term benefits obtained from its use (e.g. firewood, nutrients for crop development and reduced incidence of pests and diseases), it is recognized as an environmentally unfriendly practice that does not guarantee food security and exacerbates natural resource degradation and climate change.

In southwest Honduras, in the early 1990s, experts from FAO identified native farming practices and worked together with farmers to develop a suitable production system to replace the slash-and-burn system. The 'Quesungual Slash and Mulch Agroforestry System' (QSMAS) is a smallholder production system that uses a set of technologies for the sustainable management of vegetation, soil, water and nutrients in drought-prone areas of the sub-humid tropics. QSMAS can be considered a model system that applies conservation agriculture principles to achieve sustainable food security and ensure the delivery of other ecosystem services in drought-prone hillsides that must deal with the impacts of land degradation and climate change.

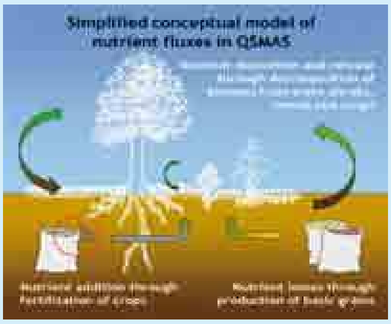
The basic Principles behind QSMAS success:

1 No Slash & burn
Management (partial, selective and progressive slash-and-prune) of natural vegetation.

2 Permanent soil cover
Continual deposition of biomass from trees, shrubs and weeds, and throgh crop residues.

3 Minimal disturbance of soil
No tillage, direct seedling and reduced soil disturbance during agronomic practices.

4 Efficient use of fertilizer
Appropriate application (timing, type, amount and location) of fertilizers.



Source: R. Vargas based on Castro *et al.*, 2008 and 2009

Water use efficiency and irrigation

As the climate changes, more attention should be placed on using water efficiently, reducing evaporation and enhancing infiltration and moisture retention in the soil profile through SOM management combined with the use of more drought-resilient species (see Module 3 on climate-smart water management).

Waterlogging from soil compaction, the over-application of irrigation water, inadequate drainage or soil puddling in paddy rice systems produces CH_4 emissions. Avoiding these emissions is particularly important as CH_4 is a much more powerful GHG than CO_2. After 20 years, CH_4 has a global warming potential 72 times higher than CO_2.

Irrigation increases crop and grassland productivity, particularly in drylands. The decomposition of roots and unharvested above-ground plant materials increases SOC, which delivers multiple benefits. The specific context will determine the most appropriate rainfed or irrigated system, as there are trade-offs that may need to be made. For example in irrigated systems, a trade-off may need to be made between reducing fossil fuel use and GHG emissions by using a gravity-fed irrigation and optimizing the efficiency of water use by using sprinkler or drip irrigation that emit more GHGs because they require fossil fuels for pumping water and transport. Addressing soil and water salinity in agricultural landscapes involves reducing salinity and using salt-affected soils and saline water through innovative soil and water management technologies and practices (Sakadevan and Nguyen, 2010). Integrated soil and water management practices for adapting to existing soil and water salinity and mitigating the potential development of salinity include: accurate irrigation scheduling (Howell, 2003); permanent raised bed (Akbar *et al.*, 2007); and soil conservation and management practices, such as reduced tillage, the incorporation of crop residues, gypsum and manure application, crop rotation and cover crops to increase soil organic matter, soil water holding capacity and infiltration.

Box 4.4
The traditional Minga system for drought management

Twenty-eight years ago, farmers from the Chiquitania region of Santa Cruz, Bolivia established a community adaption plan for climate change. As part of the plan, they have developed a practice for harvesting rainwater to cope with the greater fluctuations in rainfall, as well as the increased concentration and high variability of rains. Using a diversified production system, they grow maize, cassava, peanuts and organic coffee.

The practice consists in digging a row close to the plants, filling it with manure and then covering it with mulch or vegetation residues. According to the farmers, this technique has increased their yields and kept production stable even during droughts. The manure improves the soil structure, thereby increasing water storage. It also increases the soil's nutrient content. Currently, this technique is being spread by the Instituto Nacional de Innovación Agropecuaria y Forestal and FAO to other communities to help them cope with water scarcity resulting from climate change.


Community training


Preparing the manure


Digging the row


Filling the row with manure


Manure-filled row


Covering the surface with residues

Source: R. Vargas based on FAO-ICDS Bolivia, Photos Willy Barba

Restoring degraded soils for climate change resilience

The world's soils are estimated to have a high potential for carbon sequestration because SOC content can be effectively conserved and also readily restored or increased through appropriate land uses and agricultural management practices which can potentially be applied at landscape level (Corsi *et al.*, 2012). The widespread restoration of degraded soils is vital for carbon sequestration and can be achieved by increasing SOM content in the soil and reducing erosion and polluting factors. The highest potential for carbon sequestration is in degraded soils. However, initiating the process is slower on these soils because the soil microbial population that drives the SOC and nutrient cycles requires specific nutrient ratios that take time to achieve (Stevenson, 1986). Soil erosion by water (rainfall and runoff) or wind can be reduced by a range of soil and water conservation measures, including: maximizing vegetative cover, enhancing soil surface rugosity (clods, tied ridges); contour farming (bunds; diversion ditches); and reducing the degree and length of slopes (progressive and bench terracing). Tree planting can have win-win-win benefits in most systems (apart from light-sensitive crops). Planting trees introduces organic matter at a greater depth in the soil and can reduce wind erosion (see also Module 8 on forests). Soil carbon can be enriched by minimizing tillage, using cover crops or mulch, growing and incorporating green manures or applying biochar (see Box 4.5 below).

Green manures boost SOM and labile carbon, but they also disturb soil structure and do not maintain a protective litter, residue or plant cover.

More research is needed on the potential effects of biochar for reducing soil fertility in the longer term, binding and reducing the efficacy of some agricultural chemicals, and inhibiting microbial processes due to production of ethylene. In many contexts, because of the prohibitive cost of biochar, it is not an economically viable option.

Box 4.5
Biochar

Biochar is a stable, carbon-rich form of charcoal that can be applied to agricultural land as an element of agronomic or environmental management. It can be produced by pyrolysis, where biomass is heated with little or no oxygen (Sparkes and Stoutjesdijk, 2011). Possible biomass sources for biochar include: milling residues (e.g. rice husks, sugar cane bagasse); crop and logging residues; biofuel crops; municipal wastes; and animal manure. The suitability of the biomass for biochar production depends on its lignin content (Eagle *et al.,* 2012).

Biochar, because of its porous nature, high surface area and its ability to absorb soluble organic matter and inorganic nutrients is thought to have benefits for sustainable agricultural productivity. It increases biological activity and improves nutrient use efficiency, hence reducing NO_2 emissions and carbon sequestration. The use of biochar is new and more research is needed on the potential benefits and risks of its use in agricultural soils. There is a high variability in properties and its cost effectiveness depends on the biomass source and distance to the pyrolysis plant. Also, not all soils or crops show the same improvements when biochar is applied, and there may be risks associated with increased alkalinity.

Adaptive management capacity

Climate change impacts are complex and will affect natural resources and ecosystems in different ways in different places. It is important that communities understand the implications of these potential impacts in their own areas and are able to adapt. There is a need to build on farmers' knowledge and innovations and develop local capacity of land users to manage their soil systems so that they can build resilience and continue to innovate and adapt to a warming climate and changes in production systems. This requires building on practical farming skills, observation, personal experience, knowledge sharing and developing local capacity for adapting complex agro-ecosystems to change. Examples include breeding locally adapted seeds and livestock, producing organic fertilizers on farms (compost, manure, green manure), managing soil moisture and rainwater harvesting.

4.5 Conclusions

A healthy soil is fundamental for sustained agricultural productivity and the maintenance of vital ecosystem processes. To cope with climate change, the different types of production systems (crop, livestock and forest) and the specific practices used to manage them need to be adapted to take into account the diversity and current status of soils (e.g. sand, loam and clay soils, peat soils, sodic soils, shallow soils, nutrient depleted soils) and terrain (e.g. steep and flat lands, wetlands) and climatic conditions (e.g. short rainy seasons, erratic rains, high temperatures, storms).

Diversified production systems and land uses will conserve the diversity of plant and animal species and varieties in the agro-ecosystem; provide diverse habitats for beneficial predators and pollinators; and reduce farmers' risk and vulnerability if one or more crops fail or if other farming enterprises collapse. Management practices that do not deplete SOC content, but rather increase it from year to year through organic matter management, will bring win-win-win benefits. They will create productive soils that are rich in carbon, require fewer chemical inputs and maintain vital ecosystem functions, such as the hydrological and nutrient cycles. There is a need to shift away from specialized high-input systems towards the design and adoption of more integrated production systems (crop-livestock, agroforestry, agropastoral) that will reduce inorganic fertilizer use and the resulting GHG emissions. Integrated production systems also diversify farm outputs, sustain yields and reduce vulnerability to climate change and other shocks.

Notes

This module was written by Sally Bunning (FAO), Sandra Corsi (FAO) and Ronald Vargas (FAO).

Acronyms

C	carbon
CEH	Centre for Ecology and Hydrology
CH_4	methane
CO_2	carbon dioxide
GHG	greenhouse gas
IFA	International Fertilizer Industry Association
INIAF	National Institute of Agricultural and Forestry Innovation
IPCC	Intergovernmental Panel on Climate Change
ISFM	integrated soil fertility management
N	nitrogen
NH_3	ammonia
NH_4-	ammonium ions
N_20	nitrous oxide
NRSC	Natural Resources Conservation Service
SCCC	Soil Conservation Council of Canada
SOC	soil organic carbon
SOM	soil organic matter
SRI	Systems of Rice Intensification
USDA	United States Department of Agriculture

References

Akbar, G., Hamilton, G., Hussain, Z. & Yasin, M. 2007. Problems and potentials of permanent raised bed cropping systems in Pakistan. Pakistan Journal of Water Resources, 11(1): 11–21.

Altieri, M.A., Marcos, L.A., Bittencourt, H.V., Kieling, A.S., Comin, J.J. & Lobsyo, P.E. 2011. Enhancing crop productivity via weed suppression in organic no-till cropping systems in Santa Catarina, Brazil. Journal of Sustainable Agriculture, 35 (8): 1□15. Taylor & Francis Group, LLC.

Batjes, N.H. 1996. *Total carbon and nitrogen in soils of the world.* European Journal of Soil Science, 47 (2): 151–163.

Bergström, L. 1995. *Leaching of dichlorprop and nitrate in structured soil.* Environmental Pollution, 87: 189–195.

Bot, A. & *Benites, J.* 2005. The importance of soil organic matter key to drought-resistant soil and sustained food production. FAO Soils Bulletin. No. 80, Rome.

Bouman, B.A.M., Peng, S., Castañeda, A.R. & Visperas, R.M. 2005. *Yield and water use of irrigated tropical aerobic rice systems*. Agricultural Water Management, 74: 87–105.

Brown, S. & Lugo, E. 1990. *Tropical secondary forests*. Journal of Tropical Ecology, 6: 1–32.

Campbell, C.A. 1998. *Possibilities for future carbon sequestration in Canadian agriculture in relation to land use changes.* Climate Changes, 40: 81–103.

Castro, A., Rivera, M., Ferreira, O., Pavón, J., García, E., Amézquita, E., Ayarza, M., Barrios, E., Rondon, M., Pauli, N., Baltodano, M.E., Mendoza, B., Wélchez, L.A., Cook, S., Rubiano, J., Johnson, N. & Rao, I.M. 2008. *Dynamics of nitrogen and phosphorous in Quesungual Slash and Mulch Agro-forestry System*. Cali, Colombia.

Castro, A., Rivera, M., Ferreira, O., Pavón, J., García, E., Amézquita, E., Ayarza, M., Barrios, E., Rondon, M., Pauli, N., Baltodano, M.E., Mendoza, B., Wélchez, L.A., Johnson, N., Rubiano, J., Cook, S. & Rao, I.M. 2009. *Improving the efficiency of rain water use on hillsides in the sub-humid tropics: agricultural & environmental benefits of Quesungual system*. Cali, Colombia.

Cerri, C.E.P., Easter, M., Paustian, K., Killian, K., Coleman, K., Bernoux, M., Falloon, P., Powlson, D.S., Batjes, N.H., Milne, E. & Cerri, C.C. 2007. *Predicted soil organic carbon stocks and changes in the Brazilian Amazon between 2000 and 2030*. Agriculture, Ecosystems and Environment, 122: 58–72.

Charman, P.E.V. & Roper, M.M. 2000. Soil organic matter (SOM). In P.E.V. Charman & B.W. Murphy, eds. Soils: Their Properties and Management. 2nd Ed. Oxford University Press. 260–270 pp.

Chivenge, P.P., Murwira, H.K., Giller, K.E., Mapfumo, P. & Six, J. 2006. *Long-term impact of reduced tillage and residue management on soil carbon stabilization: implications for conservation agriculture on contrasting soils.* Soil Tillage Res., 94: 328–337.

Cluff, D. & *Seis, C.* 1997. *Should farmers and graziers be garmers and fraziers?* In Landcare Best Practice: 22–23. Landcare Changing Australia National Conference, Adelaide.

Cole, C.V., Paustian, K., Elliott, E.T., Metherell, A.K., Ojima, D.S. & Parton, W.J. 1993. *Analysis of agroecosystem carbon pools.* Water, Air and Soil Pollution, 70: 357–371.

Conant, R.T, Paustian, K., Del Grosso, S.J. & Parton, W.J. 2005. *Nitrogen pools and fluxes in grassland soils sequestering carbon*. Nutrient Cycling in Agroecosystems, 71: 239–248.

Corsi, S., Friedrich, T., Kassam, A., Pisante, M. & Sà, J.M. 2012. *Soil organic carbon accumulation and carbon budget in conservation agriculture: a review of evidence*. Vol. 16. FAO Integrated Crop Management.

Couwenberg, J. 2011. *Greenhouse gas emissions from managed peat soils: is the IPCC reporting guidance realistic?* Mires and Peat, 8: 1–10. (available at http://www.mires-and-peat.net/)

Davies, D.W., Garwood, T.W.O. & Rochford, A.D.H. 1996. *Factors affecting nitrate leaching from a calcareous loam in east Anglia.* Journal of Agric. Science, 126: 75–86. Cambridge University Press.

Derner, J.D. & Schuman, G.E. 2007. *Carbon sequestration and rangelands – a synthesis of land management and precipitation effects*. Journal Soil and Water Conservation, 62: 77–85.

Dormaar, J.F. & Carefoot, J.M. 1998. *Effect of straw management and nitrogen fertilizer on selected soil properties as potential soil quality indicators of an irrigated Dark Brown Chernozem.* Canadian Journal Soil Science, 78: 511–517.

Dregne, H.E. & Chou, N.T. 1992. *Global desertification dimensions and costs.* In Degradation and Restoration of Arid Lands, H.E. Dregne, ed. USA, Lubbock Texas Technical University.

Duiker, W. & Lal, R. 2000. *Carbon budget study using CO_2 flux measurements from a no till system in central Ohio.* Soil and Tillage Research, 54: 21–30.

Eagle, A.J., Olander, L.P., Henry, L.R., Haugen-Kozyra, K., Millar, N. & Robertson, G.P. 2012. *Greenhouse gas mitigation potential of agricultural land management in the United States: a synthesis of the literature.* Technical Working group on Agricultural Greenhouse Gases Report. Durham, USA, Nicholas Institute for Environmental Policy Solutions, Duke University.

FAO. 2008. *Visual soil assessment (VSA).* Field Guides for Annual crops, Olive orchards, Orchards, Vineyards and Wheat. Rome. (available at http://www.fao.org/docrep/010/i0007e/i0007e00.htm)

FAO. 2011b. *The state of the world's land and water resources for food and agriculture: managing systems at risk.* Rome.

FAO. 2012. *LADA local level manual for the assessment of land degradation and sustainable land management (in publication).* Rome. (available at www.fao.org/nr/lada)

Farage, P., Ardö, J., Olsson, L., Rienzi, E., Ball, A. & Pretty, J. 2007. *The potential for soil carbon sequestration in three tropical dryland farming systems of Africa and Latin America: a modelling approach.* Soil and Tillage Research, 94(2): 457–472.

Fearnside, P.M. & Barbosa, R.I. 1998. *Soil carbon changes from conversion of forest to pasture in Brazilian Amazonia.* Forest Ecology and Management, 108: 147–166.

Fließbach, A. & Mäder, P. 2000. *Microbial biomass and size density fractions differ between soils of organic and conventional agricultural systems.* Soil Biology and Biochemistry, 32: 757–768.

Follett, R.F. & Reed, D. 2010. *Soil carbon sequestration in grazing lands, societal benefits and policy implications.* Rangeland Ecology & Management, 63: 4–15.

Friedrich, T. & Kassam, A. 2009. *Adoption of conservation agriculture technologies: constraints and opportunities.* Invited paper at the IV World Congress on Conservation Agriculture. New Delhi, India.

Gál, A., Vyn, T.J., Michéli, E., Kladivko, E.J. & Mcfee, W.W. 2007. *Soil carbon and nitrogen accumulation with long-term no-till versus moldboard plowing overestimated with tilled-zone sampling depths.* Soil and Tillage Research, 96: 42–51.

Gors, M.J., Howsc, P.W., Lane, P.W., Christian, D.G. & Harris, G.L. 1993. *Losses of nitrate-nitrogen in water draining from under autumn-sown crops established by direct drilling or mouldboard ploughing*. Journal of Soil Science, 44(1): 35–48. (available at http://onlinelibrary.wiley.com/doi/10.1111/j.1365-2389.1993.tb00432.x/abstract)

Gregorich, E.G., Drury, C.F. & Baldock, J.A. 2001. *Changes in soil carbon under long-term maize in monoculture and legume-based rotation.* Canadian Journal of Soil Science, 81(1): 21–31. (available at http://pubs.aic.ca/doi/abs/10.4141/S00-041)

Guo, L.B. & Gifford, R.M. 2002. *Soil carbon stocks and land use change: a meta analysis.* Global Change Biology, 8(4): 345–360.

Gupta, V.V.S.R., Neate, S.M. & Leonard, E.C. 1997. *Life in the soil.* Cooperative Research Centre for Soil & Land Management.

Hiederer, R. & Kochy, M. 2011. Global soil organic carbon estimates and the harmonized world soil database, 79 p. JRC Scientific and Technical reports. Publications office of the European Union. (available at http://eusoils.jrc.ec.europa.eu/esdb_archive/eusoils_docs/other/EUR25225.pdf)

Howell, T.A. 2003. *Irrigation efficiency.* Encyclopedia of Water Science. New York, USA, Marcel Dekker, Inc. 1076 pp.

Huggins, D.R., Clapp, C.E., Allmaras, R.R., Lamb, J.A. & Layese, M.F. 1998. *Carbon dynamics in corn-soybean sequences as estimated from natural carbon-13 abundance*. Soil Science Society of America Journal, 62: 195–203.

IFA (International Fertilizer Industry Association). 2009. *Fertilizers, climate change and enhancing agricultural productivity sustainably.* White paper, Paris. (available at www.fertilizer.org/ifa/content/download/23000/329421/)

Intergovernmental Panel on Climate Change (IPCC). 1997. *Revised 1996 IPCC guidelines for national greenhouse gas inventories.* Reference Manual, Vol. 3. J.T. Houghton, L.G. Meira, L.G. Filho, B. Lim, K. Treanton, I. Mamaty, Y. Bonduki, D.J. Griggs, B.A. Callender, eds.

Jauhiainen, J., Hooijer, A. & Page, S.E. 2011. *Carbon dioxide emissions from an Acacia plantation on peatland in Sumatra, Indonesia.* Biogeosciences Discussions, 8: 8269–8302.

Jiang, Q.Q. & Bakken, L.R. 1999. *Comparison of Nitrosospira strains isolated from terrestrial environments.* FEMS Microbiol Ecol., 30: 171–186.

Jones, C.E. 2006a. *Soil carbon's impact on water retention.* In, Soil, Carbon and Water blog. Border Rivers-Gwydir CMA, Grain & Graze 'Practical clues for pasture cropping' workshops. (available at http://soilcarbonwater.blogspot.it/)

Jones, C.E. 2006b. *Aggregate or aggravate?* Creating soil carbon. In, Soil and Carbon Credits blog. YLAD Living

Soils Seminars. (available at http://soilcarboncredits.blogspot.it/2006_03_01_archive.html)

Lal, R. 2004. *Soil Carbon Sequestration Impacts on Global Climate Change and Food Security.* Science, 304: 1623–1627. (available at http://www.sciencemag.org/content/304/5677/1623.abstract)

Lobb, D., Kachanoski, R.G. & Miller, M.H. 1995. *Tillage translocation and tillage erosion on shoulder slope landscape positions measured using 137Cs as a tracer.* Canadian Journal of Soil Sci., 75: 211–218.

Lobb, D. & Lindstrom, M.J. 1999. *Tillage translocation and tillage erosion.* Poster Presentation at Manitoba Soil Science Society Meeting. Winnipeg, Canada.

Macdonald, A.J., Powlson, D.S., Poulton, P.R. & Jenkinson, D.S. 1989. *Unused fertiliser nitrogen in arable soils-its contribution to nitrate leaching.* Journal of the Science of Food and Agriculture, 46: 407–419.

Nair, P.K.R. & Nair, V.D. 2003. *Carbon storage in North Amercian agroforestry systems.* In J.M Kimble, L.S Heath, R.A. Birdsey, & R. Lal, eds. The potential of US forests to sequester carbon and mitigate the greenhouse effect. pp. 333-346. CRC Press. Boca Raton.

Niggli, U., Fließbach, A., Hepperly, P. & Scialabba, N. 2009. *Low greenhouse gas agriculture: mitigation and adaptation potential of sustainable farming systems.* Rev. 2. FAO. (available at ftp://ftp.fao.org/docrep/fao/010/ai781e/ai781e00.pdf)

Noellemeyer, E., Frank, F., Alvarez, C., Morazzo, G. & Quiroga, A. 2008. *Carbon contents and aggregation related to soil physical and biological properties under a land-use sequence in the semiarid region of Central Argentina.* Soil & Tillage Research, 99: 179–190.

Nyborg, M., Solberg, E.D., Malhi, S.S. & Izaurralde, R.C. 1995. *Fertilizer N, crop residue, and tillage alter soil C and N content in a decade.* In R. Lal, J. Kimble, E. Levine & B.A. Stewart, eds. Soil Management and Greenhouse Effect, pp. 93–99. Boca Raton, USA, Lewis Publishers, CRC Press.

Oldeman, L.R. 1992. *The global extent of soil degradation.* Biannual report. Wageningen International soil reference and information centre (ISRIC).

Palaniappan, M. & Gleick, P.H. 2009. *Peak Water*. In, P.H. Gleick, ed. The World's Water 2008–2009. The Biennial Report on Fresh Water Resources, 16 p.

Reicosky, D.C., Lindstrom, M.J., Schumacher, T.E., Lobb, D. & Malo, D.D. 2005. *Tillage induced CO_2 loss across an eroded landscape.* Soil and Tillage Research, 81 (2): 183–194.

Reij, C. & Smaling, E. M. A. 2007. *Analyzing successes in agriculture and land management in Sub-Saharan Africa: is macro-level gloom obscuring positive micro-level change?* Land Use Policy, 25: 410–420.

Rice, C.W. & Owensby, C.E. 2001. *The potential of U.S. forest soils to sequester carbon and mitigate the greenhouse effect*, J.M. Kimble, R. Lal, R. Birdsey, & L.S. Heath, eds. Lewis Publishers.

Sakadevan, K. & Nguyen, M.L. 2010. *Global response to soil and water salinization in agricultural landscapes.* Valencia, Spain, Global Forum on Salinization and Climate Change. (available at http://www.uv.es/jorba/GF-SCC2010).

Scherr, S.J. & Sthapit, S. 2009a. *State of the world: into a warming world.* The World Watch Institute.

Scherr, S.J. & Sthapit, S. 2009b. *Sustainable land management in Africa*. TerrAfrica Climate Briefs No. 1 & 2.

Washington D.C., Ecoagriculture Partners and World Bank.

Six, J., Conant, R.T., Paul, E.A. & Paustian, K. 2002. *Stabilization mechanisms of soil organic matter SOM: implications for C-saturation of soils: a review*. Plant and Soil, 241: 155–176.

Soil Conservation Council of Canada (SCCC). 2001. *Global warming and agriculture: fossil fuel.* Factsheet, 1 (3).

Solberg, E.D., Nyborg, M., Izaurralde, R.C., Malhi, S.S., Janzen, H.H. & Molina-Ayala, M. 1997. *Carbon storage in soils under continuous cereal grain cropping: N fertilizer and straw*. In R. Lal, eds. Management of carbon sequestration in soil. Boca Raton, USA, CRC Press.

Sparkes, J. & Stoutjesdijk, P. 2011. *Biochar: implications for agricultural productivity.* ABARES technical report, 11 (6). Australian Bureau.

Stevenson, F.J. 1986. *Cycles of soil.* New York, USA, John Wiley and Sons Inc.

Stoop, W.A., Uphoff, N. & Kassam, A. 2002. *A review of agricultural research raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers.* Agricultural Systems, 71: 249–274.

Tiessen, H. & Stewart, J. W. B. 1983. *Particle-size fractions and their use in studies of soil organic matter: II. Cultivation effects on organic matter composition in size fractions.* Soil Science Society of America Journal, 47(3): 509–514.

United States Department of Agriculture (USDA) & Natural Resources Conservation Service (NRSC). 1998. *Soil quality test kit guide.* Lincoln and Washington D.C., USA, Soil Quality Institute, NRSC, Agricultural Research Service & USDA.

Weil, R., Islam, K., Stine, M., Gruver, J.B. & Samson-Liebig, S. 2003. *Estimating active carbon for soil quality assessment: a simplified method for laboratory and field use.* American Journal of Alternative Agriculture, 18(1): 3–17.

Yang, X.M., Bouman, B.A.M., Wang, H., Wang, Z., Zhao, J. & Cehn, B. 2005. *Performance of temperate aerobic rice under different water regimes in North China*. Agricultural Water Management, 74: 107–122.

Zach, A., Tiessen, H. & Noellemeyer, E. 2006. *Carbon turnover and carbon-13 natural abundance under land use change in semiarid Savanna soils of La Pampa, Argentina*. Soil Science Society of America Journal, 70(5): 1541–1546.

Zingore, S., Manyame, C., Nyamugafata, P. & Giller, K.E. 2005. *Long-term changes in organic matter of woodland soils cleared for arable cropping in Zimbabwe*. European Journal of Soil Science, 56: 727–736.

Additional Resources

Centre for Ecology and Hydrology (CEH). 2011. *Soil Natural Capital & Ecosystem Services.* (available at http://www.ceh.ac.uk/sci_programmes/soil-capital-ecosystem-services.html)

FAO. 2005. *El sistema agroforestal quesungual: una opción para el manejo de suelos en zonas secas de ladera.* 49 p. Honduras, Sistema de Extensión Lempira.

FAO. 2011a. *Chapter 3, soil health.* In, Save and Grow. (available at http://www.fao.org/ag/save-and-grow/en/3/index.html)

FAO. 2012c. *Machinery, tools and equipment.* Agriculture and Consumer Protection Department: Conservation Agriculture. (available at http://www.fao.org/ag/ca/3e.html)

INIAF (National Institute of Agricultural and Forestry Innovation) & FAO. 2011. *Captura de agua para cultivos diversificados.* Módulo de conocimiento y comunicación. Serie Agroforesteria para pequeños productores. Rome.

Morris, G.D. 2004. *Sustaining national water supplies by understanding the dynamic capacity that humus has to increase soil water-holding capacity.* University of Sydney. (MA thesis)

Pauli, N., Barrios, E., Conacher, A.J. & Oberthür, T. 2011. *Soil macrofauna in agricultural landscapes dominated by the Quesungual slash-and-mulch agroforestry system, Western Honduras*. Applied Soil Ecology, 47: 119–132.

Seis, C. 2005. *Pasture cropping: a land management technique with potential to farm carbon.* Proceedings of Managing the Carbon Cycle Forum, Armidale, Australia. 37–39 pp.

Thorup-Kristensen, K. 2003. *Catch crops and green manures as biological tools in nitrogen management in temperate zones.* Advances in Agronomy, 79: 228–301. (available at http://www.sciencedirect.com/science/article/pii/S0065211302790056)

Annex

A.4.1
Soil management for sustained crop productivity and climate change adaptation and mitigation

Conventional practices	Practices to enhance Productivity and Adaptation	Practices to enhance mitigation
Soil tillage for annual crops: Hoeing or ploughing improves the seedbed and uproots weeds. However, it disturbs microbes, destroys soil drainage created by soil fauna (e.g. earthworms), speeds decomposition of organic matter and releases CO_2. It may develop a compacted layer or hardpan which impedes plant root growth and rainwater percolation.	Conservation agriculture systems are practiced on around 125 million hectares of land worldwide. It involves three principles: • Minimizing soil disturbance (no-tillage) through digging sticks or jab planter to plant seeds or mechanized direct drill systems (mechanized systems have been developed to drill the seed through a vegetative layer and may use herbicides to manage weeds). • Keeping the soil covered with a protective layer of mulch or crop residues which reduces weed growth, reduces moisture loss, keeps the soil cooler, reduces erosion by water and wind and restores soil carbon (C) through decomposition. • Rotating and diversifying crops to reduce crop pests and diseases and use leguminous species to replenish soil nutrients. In Paraná, Brazil, no-till plots are reported to yield a third more wheat and soybean than conventionally ploughed plots and reduce erosion by up to 90% (Altieri et al., 2011).	The sequestration potential after adoption of improved management practices follows a sigmoid curve: it attains a maximum level of sequestration rates in 5 - 20 years (Cole et al., 1993; Nyborg et al., 1995; Solberg et al., 1997; Campbell, 1998; Dormaar and Carefoot, 1998; Duiker and Lal, 2000; Six et al., 2002; Lal, 2004) and continues at decreasing rates until SOC stocks reach a new equilibrium in 20 - 30 years (IPCC, 2007). Emissions reductions are smaller but a perpetual benefit is achieved. Conservation agriculture practices reduce fossil fuel emissions from tractor use, although there may be slight negative GHG impacts from application of additional chemical herbicides for weed control instead of weed control by tillage.

Conventional practices	Practices to enhance Productivity and Adaptation	Practices to enhance mitigation
Fertilizer use: A shortage of any one of the nutrients required for plant growth can limit crop yields. Increased productivity is needed to meet current and future food demand. However, fertilizer use efficiency tends to decrease with increasing applications as a great part of the nutrients are not taken up by the crop but released into water bodies and emitted into the atmosphere. Fertilizer manufacture releases GHG into the atmosphere.	**Integrated soil fertility management (ISFM)** aims to make available required soil nutrients by balancing different on-farm soil organic sources (amendments) with nutrients from mineral fertilizers (to address deficiencies) and reducing nutrient losses through soil and water conservation. It aims to: • Maximize the use of organic matter that provides nutrients, sequesters C and enhances water storage (e.g. compost, animal manures or green manures). • Enhance nutrient efficiency through crop rotations or intercropping with nitrogen-fixing crops and judicious/ precision use of inorganic fertilizer to reduce losses. • Minimize GHGs emissions (reduced traffic and tillage and efficient use of organic and inorganic fertilizers). • The timely provision of micronutrients in "fortified" fertilizers is a potential source of enhanced crop nutrition where deficiencies occur (FAO, 2011a). • Leguminous species can fix nitrogen (N) through symbiotic Rhizobium, however, they have a lower C/N ratio than cereals and grasses and breakdown fast, providing little cover to protect soils from erosion.	Nitrous oxide emissions are significantly related to use of organic and inorganic N fertilizer and legume-derived N. Nitrate leaching from overuse of mineral fertilizers also increases the potential for off-site nitrous oxide emissions. Options to reduce N losses and emissions include: • change the N fertilizer source from ammonium-based to urea, or switching to slow-release fertilizers; • placement of fertilizer N near the zone of active root uptake; • synchronise timing of N fertilizer application with plant N demand to reduce N losses; • improve manure application rates, applying solid rather than liquid manure, and to dry rather than wet areas when air temperatures are low; • use nitrification inhibitors.

Conventional practices	Practices to enhance Productivity and Adaptation	Practices to enhance mitigation
Crop specialization and annual harvesting: Many crop production systems progressively decrease SOC as most plant growth is above ground and is removed at harvest. In intensive systems mono-cropping of cereals use high levels of fertilizers and pesticides to replace restorative fallows and rotations with perennial leys or legumes. Often crop residues are removed for fodder, fuel or industrial applications or are burned for pest control (e.g. cotton). The global potential of N availability through recycling and N fixation is far greater than the current, affected by the highly energy-intensive production of synthetic N.	**Organic agriculture systems** do not use inorganic fertilizers or pesticides but use crop rotations and mixed farm strategies, with mulch / composts / animal manures /green manures to replenish soil C, improve nutrient cycling and use by plants and suppress weeds. The enhanced biodiversity reduces pest outbreaks and severity of plant and animal diseases. **Increasing the use of perennial crops and maintenance of shrubs and trees** in the farm landscape improves soil resilience and provides diverse products (food, fuel, fibre, timber, etc.) while supporting ecosystem services. **Agroforestry systems** that integrate compatible leguminous shrubs and trees with crops restore SOM and N through the leaf litter, help fix N through symbiotic Rhizobium, they enhance diversity, build healthier soils, enhance crop and fodder production. Some species provide fruits, timber and fuelwood or bioenergy. They can also reduce erosion and provide water quality and habitat benefits through shade and deep rooting, hence enhancing resilience to climate change.	Decisions to irrigate should factor in the consideration of the cost and GHG implications of mechanized systems. Perennial crops and trees can sequester substantial amounts of C and can store C for longer periods than annuals in the biomass of roots as well as in stems and branches. The frequency of tillage is reduced, protecting SOC and other soil functions. Other soil management options in cropping systems include **breeding deep rooted crops and managing fallow periods** to increase soil C stocks. The C sequestration potential of agroforestry varies widely, depending on the specific practice, individual site characteristics and the time frame.

Conventional practices	Practices to enhance Productivity and Adaptation	Practices to enhance mitigation
Soil crusting and degradation in drylands: This is a severe problem in the Sahel due to wind erosion and loss of SOM due to high temperatures and burning. When rain falls it can no longer infiltrate the soil and the region becomes increasingly barren and arid.	**Zaï Planting pits and Stone Bunds** in Burkina Faso, Niger and Zambia were used to rehabilitate bare, crusted degraded lands. The bunds capture rainfall and reduce runoff and manure in pits prior to planting, providing nutrients and retaining water. Despite the high labour costs (40-60 days/ hectare in Burkina) of establishment and the high recurrent costs for maintenance, production and transport of manure or compost, these practices were spontaneously adopted to expand cultivated area and reduce pressure on already-cultivated sandy soils (Reij and Smalling, 2007).	

Conventional practices	Practices to enhance Productivity and Adaptation	Practices to enhance mitigation
Soil puddling in rice paddy systems: Creates anaerobic conditions and increases emissions of GHGs. Flooded rice fields globally represent one of the main sources of methane.	Systems of Rice Intensification (SRI), which are further elaborated in the column on the right, bring benefits also in terms of productivity and adaptation, e.g. by improving the growth and performance of rice crops and subsequently increasing yields.	New technologies to reduce the use of water and GHG emissions in rice cultivation are now available: • One is SRI, an approach that requires compliance with the following: i) moist (but well drained and aerated) soil conditions; ii) transplanting rice seedlings at a very young age; iii) wider spacing of plants; iv) use of organic matter (i.e. compost made from any available biomass and manure if available) and chemical inputs; and v) frequent weeding. • Another approach is interrupting the flooding: conventional irrigated rice systems with high yielding modern rice cultivars in soils with alternate wetting or drying and with high external inputs can achieve medium to high yields (Stoop et al., 2002; Bouman et al., 2005; Yang et al., 2005). However, only timely flooded rice or rainfed lowland rice in flooded fields with periods of non-submergence can help to save water and reduce CH_4 emissions, but they seem to have the potential to increase the release of N_2O. Given that irrigated aerobic rice and SRI do not require anaerobic conditions, it would appear that both practices can combine well with climate adaptation (Friedrich and Kassam, 2009).

Conventional practices	Practices to enhance Productivity and Adaptation	Practices to enhance mitigation
Grazing systems: Many extensive grazing systems are suffering from overgrazing and serious reductions in the biodiversity of the aboveground vegetation, due to the effects of declining availability of land and overstocking due to inadequate livestock management. This is resulting in a decline in the rangeland soil quality, with depletion of biomass, erosion of topsoil by water and wind, loss of SOC and reduction of ecosystem services. This results in losses of soil structure and resilience e.g. through loss of deep rooting species that can cycle nutrients and water from deep in the soil profile. Excessive trampling of livestock, in particular around watering points, further damages the soil structure and functioning.	• **Improved grazing management on pastures or rangelands** may involve reducing stocking rates, avoiding grazing during drought periods, and improving the duration and timing of grazing and its frequency. This increases the soil surface protection by living and decomposing vegetation, increases SOC status and supports wider soil ecosystem services. Applying fertilizer or other inputs can also increase annual net primary productivity. • **Altering plant species' composition** is usually beneficial for pasture soils, as a selective increase in biodiversity can increase the quality (and usually the quantity) of SOC, consequently the range of rooting depths, thus promoting improved nutrient and water cycling. Introducing leguminous species is particularly beneficial to fix atmospheric N and improve soil fertility. • **Rotational grazing** through regularly moving livestock between paddocks intensifies grazing pressure for a relatively short period of time (e.g. 1 - 3 days for ultra-high stocking density or 3 - 14 days for typical rotational grazing), leaving a rest period for re-growth in between rotations. • **Assisted natural regeneration**, leaving land ungrazed for a period of up to several years to allow tree seeds already in the soil seed bank to become established brings multiple benefits to rangeland soils; improving nutrient cycling as nutrients are drawn from deep in the soil, increasing soil organic carbon (SOC) to the soil surface as leaves drop and decompose / become incorporated into the soil. Trees also offer some protection to soils (as well as to people and livestock) from periods of intense heat, which are likely to become more frequent due to climate change. • **Fire management**. Periodic burns can promote the overall health and growth of rangelands; for example, in tall grass prairie, increased plant productivity after it's burnt more than compensates for the loss of plant carbon by ignition. Use of trees also increases production and adaptation.	Compared with more highly productive pasture, rangelands have low C sequestration rates on a per unit basis, but because of their vast area, they could capture 2 - 4 % of annual anthropogenic GHG emissions on a global basis (i.e. 20% of the CO_2 released annually from global deforestation and land-use change) (Derner and Schuman, 2007; Follett and Reed, 2010). The majority of this C capture (greater than 90 percent) is in the form of SOC. Fire management in rangelands is generally accepted to have a minimal to detrimental effect on GHG mitigation. Most studies found that SOC stays about the same or even decreases following repeated burns (Rice and Owensby, 2001). However, other negative co-effects (methane, smoke, aerosols) are also linked to climate change, making burning even less attractive as a GHG mitigation option. Through soil C and above-ground C storage, silvopasture (trees planted on grazing land) may have GHG mitigation potential on up to 70 million hectares of grazing land (Nair and Nair, 2003). However, with few field research data, the estimated soil C sequestration rates of 0.5-3.6 tonnes of CO_2 per hectare per year are largely based on expert opinions. Compared with conservation activities on harvested croplands, the above activities on pasture yield higher soil C sequestration rates. The difference is due to pastures' greater allocation of plant biomass C to below-ground soil C and the extended growing season, reduced soil disturbance and better utilization of soil water. The range in sequestration rates depends on characteristics such as soil composition, topography, climate and existing grass species. The net fluxes of GHGs are also affected by nitrous oxide, or methane cycles (Conant et al., 2005).

Conventional practices	Practices to enhance Productivity and Adaptation	Practices to enhance mitigation
Livestock wastes: While conventional stockless arable farms become dependent on the input of synthetic N fertilizers, manure and slurry from livestock farms become an environmental problem. In these livestock operations, nutrients are available in excess and over-fertilization may occur and leaching is likely to lead to water pollution and high emissions of CO_2, nitrous oxide and CH_4.	The concept of either mixed farms or close cooperation between crop and livestock operations—a common practice of most forms of sustainable farming, especially organic ones— can considerably contribute to mitigation and adaptation. In addition, different forms of compost, especially composted manure, are particularly useful in stimulating soil microbial processes and in building up stable forms of SOM (Fließbach and Mäder, 2000). On-farm use of farmyard manure (a practice increasingly abandoned in conventional production) needs to be reconsidered in the light of climate change.	

MODULE 5:

SOUND MANAGEMENT OF ENERGY FOR CSA

Overview

This section looks at the relationship between food and energy in a world where the climate is changing and competition for natural resources is increasing. This relationship is becoming stronger and more complex because the global agrifood system is almost entirely dependent upon fossil fuels and modern bioenergy is increasingly being looked to as an alternative to these fuels. Sound management of energy for and from the agrifood system could make a crucial contribution to making the transition to climate-smart agriculture and the achievement of food, climate and energy security. But this transformation can only happen if existing examples of energy-smart food systems can be scaled up significantly. Also required are adequate assessments of the effects of energy-based interventions in agrifood systems on sustainable development goals to guide decisions related to policy and practices.

Key messages

- In light of increasing and volatile fossil fuel prices, the dependence of agrifood systems on fossil fuels represents a major threat to food security and contributes significantly to climate change. The challenge of reducing this dependency on fossil fuels can be met by up-scaling of energy-smart food systems. These systems improve energy efficiency, increase the use and production of renewable energy, and broaden access to modern energy services in agrifood systems.
- More energy is generally used in post-harvest stages of the food supply chain, whereas most greenhouse gas (GHG) emissions occur in the pre-harvest stages. Nevertheless, there is greater synergy between energy-smart and climate-smart agricultural practices than may appear at first. This synergy can be created through resource-efficient farming practices that reduce pressures on land use change, lower emissions embedded in the production of agricultural inputs, lessen the reliance on fossil fuels and enhance the productivity and resilience of agro-ecosystems.
- Each intervention requires careful analysis. This must be done using a lifecycle analysis, which includes the intervention's indirect effects, to assess the synergies and trade-offs among the various sustainable development goals related to energy, climate, food security and water security.
- In developing countries, increased access to modern energy services in agrifood systems is often required to improve productivity and income, and advance economic and social development. However, an increase in energy consumption, even if based initially on fossil fuels, may result in lower absolute GHG emissions. For example, improved access and greater use of modern energy services may reduce deforestation as the demand for traditional wood fuels declines, or create new economic opportunities that displace unsustainable high-emission activities that are profitable only in the short-term, such as logging and charcoal production, or agricultural expansion. Increased access to energy is likely to reduce emissions per unit of food production or per unit of gross domestic product (GDP). The effect of increased energy access on climate change mitigation should be assessed according to a county's or community's current stage of development and the development model that is being followed. It should not be assumed that there is always a trade-off to be made between energy access and climate change mitigation.

Contents

List of Figures

List of Tables

List of Boxes

5.1 Introduction – Energy and the agrifood system

Global primary energy demand will increase by a third between 2010 and 2035, and today's developing countries will account for the majority of this demand (IEA, 2011a). Fossil fuels are expected to continue to meet the bulk of the primary energy requirements. However, the use of renewable energy is increasing and will continue to do so in the future.

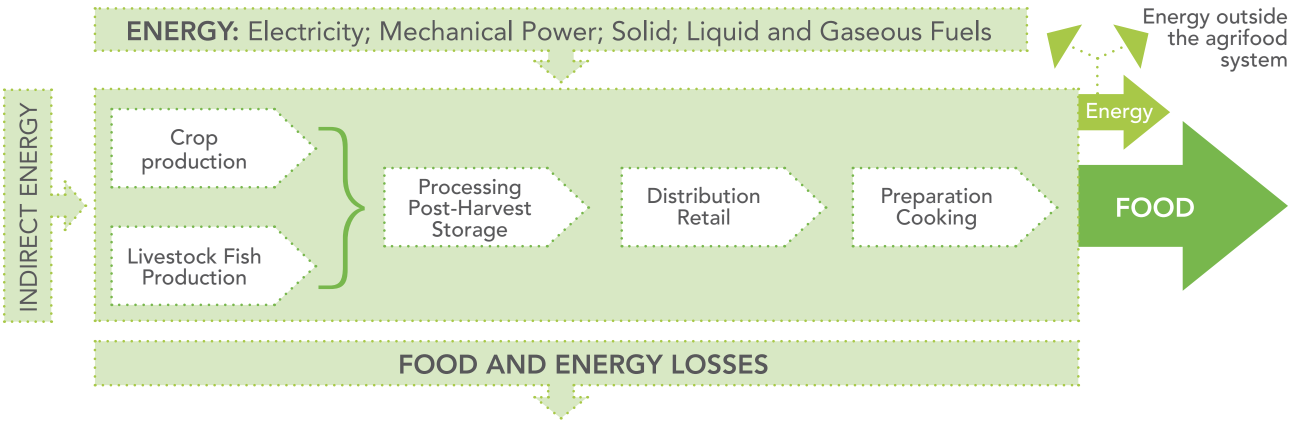
Over the last decade, crude oil prices have fluctuated around a generally steadily increasing trend line, from US$ 28 per barrel to US$ 120. There was one dramatic price spike in 2008. Conversely, the costs of renewable energy have been declining recently. This trend will continue in the coming decades, and renewable energy will become more and more competitive.

The gap between energy needs and access to energy is large, and demand will certainly increase as countries develop. The International Energy Agency (IEA) estimates that a fifth of the world's population lacks access to electricity and that two-fifths rely on traditional biomass for cooking. The use of biomass for cooking is a severe cause of high indoor air pollution, which has harmful health effects for rural households, especially for women (IEA, 2011a). Increasing energy access is essential if the poverty reduction targets set out in the Millennium Development Goals (MDGs) are to be met.

Agriculture and energy have always been closely interlinked. These linkages have changed and grown stronger over time. Agriculture, including forestry, has always been a traditional source of energy (through bioenergy), while fossil fuels have become a major input in modern agricultural production. The energy generated by the agrifood system can be partially used in the food supply chain or exported outside the system (e.g. through the sale of biogas produced on-farm to local households, or through the generation of electricity from residues to feed the national energy grid).

These two-way linkages between energy and agriculture - the energy **for** and **from** the agrifood sector, are illustrated in Figure 5.1.

Figure 5.1: Energy FOR and FROM the Agrifood System

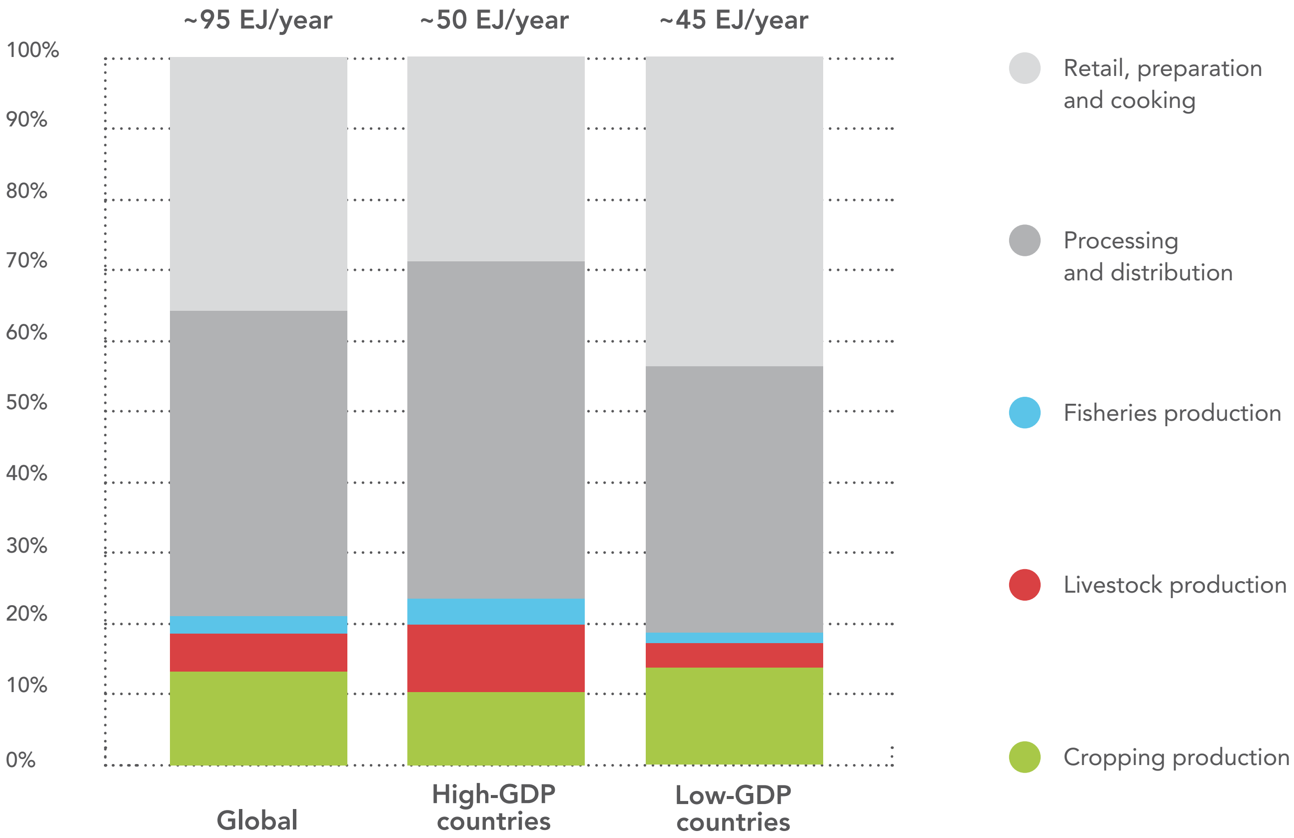


Source: Based on FAO's current work being done through the Energy-Smart Food for People and Climate Programme (see FAO, 2011a and b), the food sector[1] currently accounts for around 30 percent of the world's total end-use energy consumption.[2] More than 70 percent of that energy is used beyond the farm gate (Figure 5.2). Countries with a high GDP use a greater portion of this energy for processing and transport. In low-GDP countries, cooking consumes the highest share.

[1] In this context, food sector concerns only those parts of "agriculture" in the broad FAO sense (i.e. agriculture, forestry and fisheries) that produce food, as well as the food processing, distribution, retail, preparation and cooking phases.

[2] Energy includes direct energy used at the operational level primarily on farms and processing plants, for example for irrigation, land preparation and harvesting as well as indirect energy that is not directly consumed to operate farms, in fishing or processing plants but required to manufacture other inputs such as machinery, fertilizers and pesticides.

Figure 5.2
Indicative shares of final energy consumption for the food sector for high- and low-GDP countries



On the input side, the linkages between energy and agrifood systems have strengthened as agriculture has become increasingly reliant on chemical fertilizers, irrigation and machinery. Post-harvest activities, such as food storage, processing and distribution, are also energy-intensive. Consequently, higher and volatile energy costs have a direct impact on agricultural production costs and food prices. Over the last decades, the increased use of energy by the agricultural sector has significantly contributed to feeding the world. Energy from fossil fuels has increased farm mechanization, boosted fertilizer production and improved food processing and transportation. Between 1900 (when energy inputs were limited to low-level fertilization and rudimentary mechanization) and 2000, the world's cultivated area doubled, but the energy used in edible crops expanded six-fold. This greater productivity was made possible by an 85-fold increase in energy input per hectare (Smil, 2008). This transformation occurred in an area of cheap oil and where there were few concerns about climate change. However, since then times have changed.

Prices for nitrogen fertilizers and other fossil fuel-dependent inputs are closely related to the price of crude oil. Rising and volatile oil prices translate into higher and fluctuating food production costs. Farmers, in particular smallholder farmers, are the first to be affected. As a result, agrifood systems that are highly dependent upon fossil fuels pose serious challenges to development, and this could hamper food security in the future.

Food losses occur at all stages of the supply chain. About one-third of food produced is lost or wasted (Gustavsson *et al.*, 2011). The energy embedded in global annual food losses is thought to be around 38 percent of the total final energy consumed by the whole food chain (FAO, 2011 a and b).

As stated earlier, one of the greatest challenges the world now faces is to develop global food systems that can emit fewer GHG emissions, benefit from a secure energy supply, are be resilient to fluctuating energy prices, and continue to ensure food security and foster sustainable development. This calls for energy-smart food systems that:

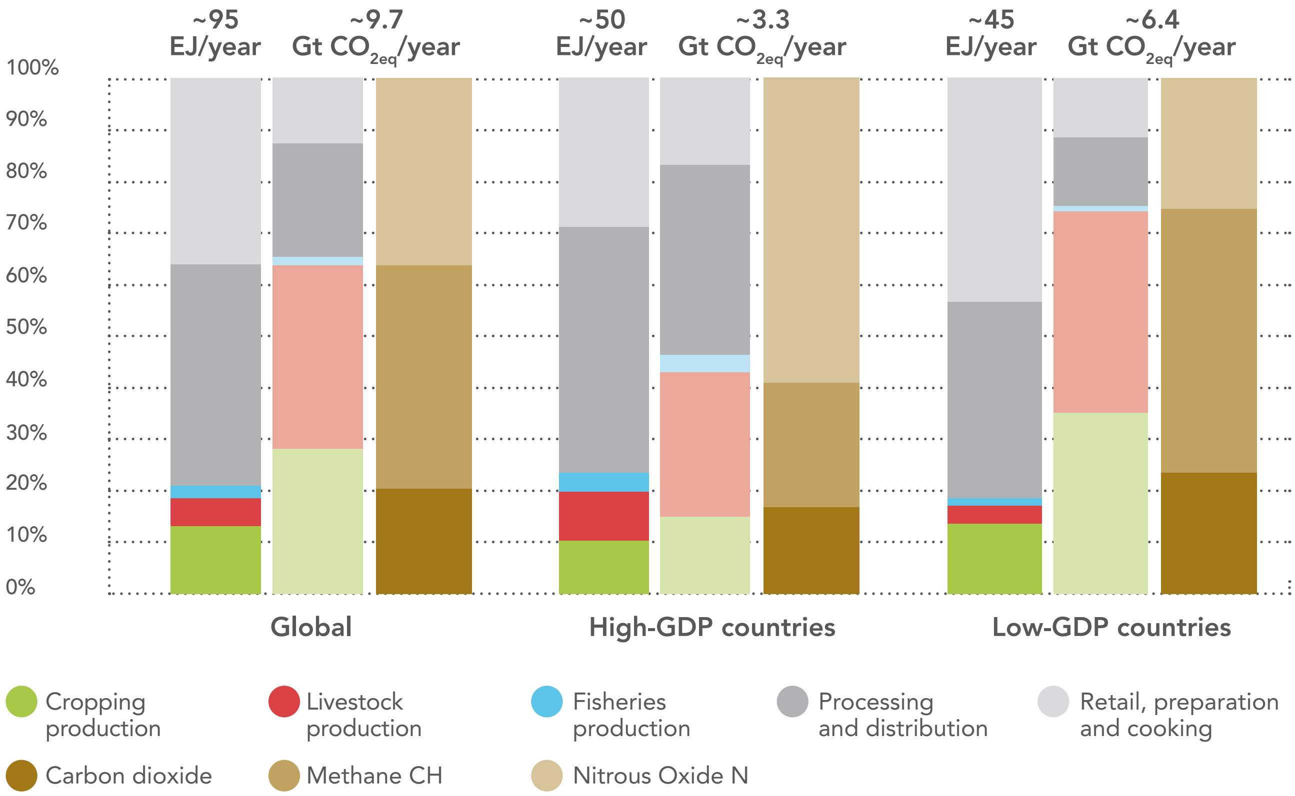
1. improve energy efficiency (measured in food output, preferably measured in nutritional units, per unit energy input) at all stages of the agrifood chain;
2. use diverse energy sources with an emphasis on renewable energy and contribute to renewable energy production through integrated food and renewable energy production; and
3. require improved access to modern energy services.

Bioenergy has a special role to play in relation to food security. Although biomass is often used in unsustainable ways, it is found almost everywhere and is currently, and for the foreseeable future, the most important source of renewable energy. It is used primarily for cooking and heating. In addition, agrifood systems not only use bioenergy, they also produce it. One instance is in integrated food-energy systems. However, putting bioenergy to use in an appropriate manner is more complex than with other types of renewable energy. If it is not well managed, bioenergy development may jeopardize food security and harm the environment. This is further discussed in Box 5.3.

5.2 Energy-smart food in the CSA context

The energy sector, which produces nearly 60 percent of carbon dioxide (CO_2) emissions, is the largest contributor to climate change (FAO, 2011a). The agrifood sector contributes over 20 percent of total GHG emissions, most of which originates from methane and nitrous oxide (see Figure 5.3). Globally, primary farm and fishery production[3] accounts for around 20 percent of the total energy demand for food, but produces 67 percent of the GHGs (FAO, 2011 a).

Figure 5.3
Shares of GHG emissions along the food supply chain with breakdown by energy consumption (by phase) and GHG emissions (by phase and by gas).



Source: FAO, 2011a

[3] Primary production here includes cropping, pastoral and intensive livestock, aquaculture and fishing.

It is important to point out that these facts and figures relate to the entire agrifood chain, from 'farm' to 'fork'. They do not account for emissions related to land-use change, international trade (transport) or food waste despite the fact that GHG figures related to agriculture usually concern only behind-the-farm-gate activities (excluding fuel combustion and sewage waste) and often include land-use change impacts.[4]

In the following three sub-sections, we explore the potential for energy-smart agrifood systems to also be climate-smart and examine how it can fit with each dimension of CSA.

CSA objective: sustainable increases in productivity and income

Energy-smart strategies that cover the diverse range of food management options are complex and can involve making trade-offs. In this regard, some key points relating to primary production management practices should be emphasized.

- Methods used to save on inputs that are fossil fuel-dependent but also lower productivity, such as cutting back rather than optimizing the amount of fertilizer applied, are rarely beneficial and should be avoided.
- High-external input production systems do not necessarily have high energy intensities (megajoules per kilogram (MJ/kg) of product), especially when they lead to increased yields. Conversely, low-input systems can have relatively high-energy intensities when they produce lower yields.
- In promoting energy-smart food, balance needs to be maintained between improving access to energy sources and increasing the efficiency of available energy, as well as increasing the proportion of renewable energy. This balance must be based on local conditions and the economic trade-offs between the different options. Box 5.1 illustrates these trade-offs made in the deployment of machinery systems for small farms in Bangladesh.

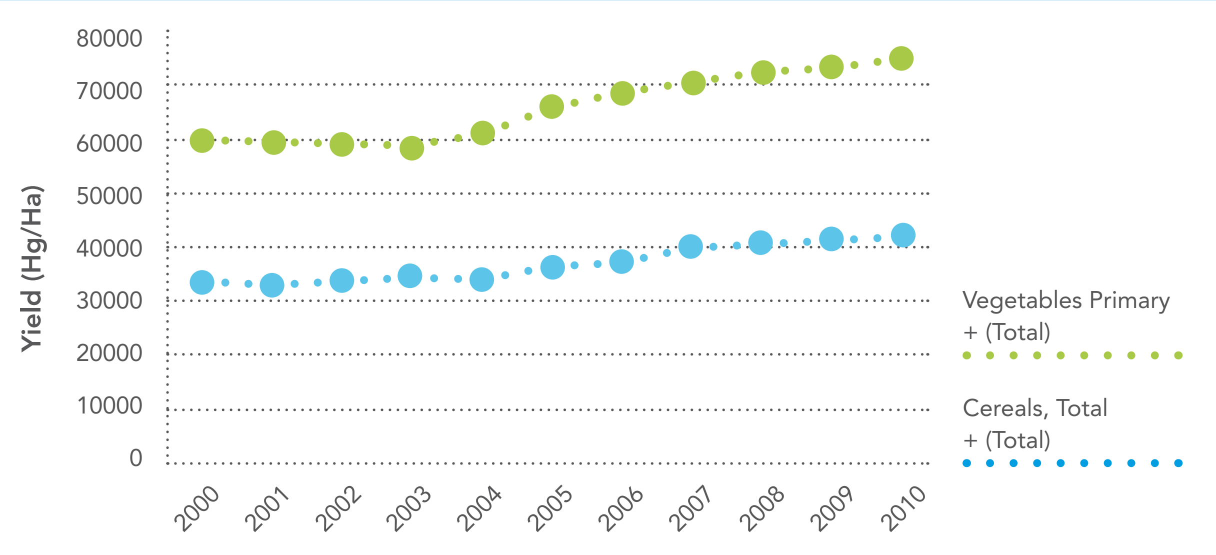
[4] Often LULUCF (land use, land use change and forestry) assumed emissions due to agricultural expansion are lumped together with agriculture sector emissions. In national GHG inventories prepared for reporting under the United Nations Framework Convention on Climate Change (UNFCCC), important pre-farm gate sources of emissions such as fertilizer production (industrial processes and energy sectors), on-farm fuel combustion (energy sector) or sewage waste (waste sector) are not included. But if the whole agrifood chain is considered, other sources of emissions must be added, such as those mentioned above and also post-harvest stages of the agrifood chain, in particular agro-industrial operations, food distribution, storage and preparation and the food waste component of landfill.

Box 5.1
Low-cost machinery systems for small farms in Bangladesh

The introduction in Bangladesh of small, mobile, diesel engines has increased food production (Steele, 2011). These demountable engines can be used for a range of applications, including powering small boats, tractors or trucks, generating electricity, and operating processing equipment and water pumps. Public policy changes enabled the import of innovative, Chinese-made, farm equipment. The diesel engines could be easily repaired by local mechanics and were less expensive than more sophisticated and more fuel-efficient machinery manufactured in India. The introduction of inexpensive Chinese technology led to the 'agrotractorization' of Bangladesh.

The extent of mechanization in Bangladesh can also be measured as the level of energy input. The available power in agriculture over the period of 1960 to 2007 increased by almost 500 percent: from 0.24 kilowatt per hectare (kW/ha) in 1960, to 0.61 kW/ha at the end of the 1990s, to 1.17 kW/ha in 2007 (Islam and Shirazul, 2009). The available power gradually increased from 0.24 kW/ha in 1960, grew moderately until the 1980s and then rose sharply in the '90s, reaching 1.17 kW/ha in 2007. Most of the agricultural machinery used in the country is either imported or locally manufactured. Farm machinery, such as weeders, threshers, winnowers and centrifugal pumps are developed and manufactured locally with local materials (APCAEM-ESCAP, 2010).

Figure 5.4
Cereals and vegetables yield increases in Bangladesh from 2000 to 2010



Source: FAOSTAT, 2012

In the early 1970s, when Bangladesh was characterised as a 'basket case' by some international development specialists, no one was forecasting that by 2010 the country would have one of the most mechanized agricultural economies in South Asia (Islam and Shirazul, 2009). Today 80 percent of primary tillage operations are mechanized. These operations are performed mainly by 300 000 small two-wheel tractors and a few (3 000) four-wheel tractors. There is a highly developed market for servicing tractors, pumpsets, threshers and other machinery derived from the use of small engines (Biggs and Justice, 2011).

The figure above indicates that from 2000 to 2007 external energy subsidies in agriculture increased by 60-70 percent for cereals and vegetables (per kg of product). However, yields (per unit of cultivated area) also increased by 20-25 percent. This made mechanized agriculture more profitable and gave farmers more time for other activities.

The Bangladesh private sector (as compared to the private sector in Nepal or India) focused on the imports of smaller-scale machinery. Presently, there are over one million small horsepower diesel irrigation pumpsets and nearly 400 000 diesel two-wheel tractors. In Bangladesh, the import value of soil machinery is consistently higher and continues to increase compared to the values of agricultural machinery and equipment such as harvesters and threshers, milking and dairy machinery and agricultural tractors. In 2007 Bangladesh started exporting some agricultural machinery, but most machinery is manufactured locally for local use. Seeing these results, Nepalese and Indian farm machinery manufacturers have recognized a new business opportunity. Small engines are now being sold mainly into low-cost, farm machinery markets in rural communities. Farm services have expanded as a result of the versatility and transportability of this equipment.

It is essential to consider affordability and cultural issues when deploying new or improved energy technologies. Domestic stoves account for a major part of energy consumption in the food chain, especially in developing countries. The dissemination of improved designs of domestic stoves succeeds mainly when micro-finance is available for the necessary capital investments. Traditional biomass cooking stoves may be less energy-efficient, less healthy and more labour-intensive than solar or biogas designs, but they are often more affordable, which is a critical factor for impoverished rural communities (Geoghegan *et al.*, 2008; UNDP, 2009). New stove designs also need to be culturally acceptable. Compared with open fires, the use of more efficient biomass cooking stoves can reduce by half the demand for traditional fuelwood (Chum et al., 2011). However, not all programmes to introduce these more efficient stoves have succeeded. This lack of success is often due to the informal nature of the fuelwood supply chain and a poor understanding of local cultures and their cooking habits. For example, users may prefer to cook with fuelwood during the cooler evenings rather than cook in the heat of the day with a solar oven.

CSA objective: strengthened resilience to climate change and variability

As a result of climate change, some farming practices may become less reliable as sources of income. For some farmers diversification to on-farm energy generation could be a coping strategy. With high and volatile fossil fuel prices, energy-smart food systems which improve access to modern energy services and increase energy diversity, contribute to energy security. This is not a climate change adaptation strategy, but it strengthens resilience, which is the broader term used in the definition of CSA. Reliance on local energy sources does not automatically enhance resilience to climate change (see Table 5.1). Tapping into local energy sources can increase incomes and expand the diversity of energy sources. This increases resilience to climate change. The use of biogas cookstoves illustrates both types of adaptation. Biogas cookstoves and their liquid fertilizer by-product can help ensure self reliance in household energy and at the same time they can reduce the amount spent on woodfuel and chemical fertilizers, as well as make gathering firewood less time consuming.

Although renewable energy plays a key role in future low-carbon plans aimed at limiting global warming, its dependence on climate conditions also makes it susceptible to climate change. This is also true for energy-smart food systems. For example, climate change will affect many aspects of renewable energy production, including: the cultivation of biofuel crops; water availability and seasonality for hydropower; atmospheric conditions for wind and solar energy; and variations in needs of energy for heating and cooling. As these impacts will increase significantly, the energy sector will have to adapt. The energy supply needs to be 'climate-proofed' as much as possible to ensure that energy use in the agrifood system can be climate-smart. Table 5.1 presents examples of adaptation measures to reduce climate change-related losses and risks in the energy sector. Several of these measures are similar to those promoted for climate change adaptation in agriculture and are relevant to CSA. Furthermore, while the table shows adaptation measures for individual energy classes, it should be noted that a diverse energy portfolio could be a way to reduce climate risk to energy supply.

The World Bank's Energy Sector Management Assistance Program (ESMAP) has developed a web tool called the Hands-on Energy Adaptation toolkit (HEAT) to assess the vulnerability of the energy sector to climate change and other factors (ESMAP, 2013).

Table 5.1
Examples of adaptation measures to reduce losses/risks in energy systems

ENERGY SYSTEM		TECHNOLOGICAL		BEHAVIORAL		
		"Hard" structural)	"Soft (technology and design)	(Re)location	Anticipation	Operation and maintenance
Supply	MINED RESOURCES including oil and gas, thermal power, nuclear power	Improve robustness of installations to withstand storms (offshore), and flooding/drought (inland)	Replace water cooling systems with air cooling, dry cooling, or recirculation systems Improve design of gas turbines (inlet guide vanes, inlet air fogging, inlet air filters, compressor blade washing techniques, etc.) Expand strategic petroleum reserves Consider underground transfers and transport structures	(Re)locate in areas with lower risk of flooding/drought (Re)locate to safer areas, build dikes to contain flooding, reinforce walls and roofs	Emergency planning	Manage on-site drainage and runoff Changes in coal handling due to increased moisture content Adapt regulations so that a higher discharge temperature is allowed Consider water re-use and integration technologies at refineries
	HYDROPOWER	Build desilting gates Increase dam height Construct small dams in the upper basins Adapt capacity to flow regime (if increased)	Change water reserves and reservoir management Regional integration through transmission connections	(Re)locate based on changes in flow regime		Adapt plant operations to changes in river flow patterns Operational complementarities with other sources (for example natural gas)
	WIND		Improve design of turbines to withstand higher wind speeds	(Re)locate based on expected changes in wind-speeds (Re)locate based on anticipated sea level rise and changes in river flooding		
	SOLAR		Improve design of panels to withstand storm or reduced loss of efficiency due to higher temperatures	(Re)locate based on expected changes in cloud cover	Repair plans to ensure functioning of distributed solar systems after extreme events	
	BIOMASS	Build dikes Improve drainage Expand/improve irrigation systems Improve robustness of energy plants to withstand storms and flooding	Introduce new crops with higher heat and water stress tolerance Substitute fuel sources	(Re)locate based on areas with lower risk of flooding/storms	Early warning systems (temperature and rainfall) Support for emergency harvesting of biomass	Adjust crop management and rotation schemes Adjust planting and harvesting dates Introduce soil moisture conservation practices Apply conservation agriculture for better drought and flood management

ENERGY SYSTEM	TECHNOLOGICAL		BEHAVIORAL		
	"Hard" structural)	"Soft (technology and design)	(Re)location	Anticipation	Operation and maintenance
DEMAND	Invest in high-efficiency infrastructures and equipment Invest in decentralized power generation such as rooftop PV generators or household geothermal units		Efficient use of energy through good operating practice		
TRANSMISSION AND DISTRIBUTION	Improve robustness of pipelines and other transmission and distribution infrastructure Burying or cable re-rating of the power grid		Emergency planning	Regular inspection of vulnerable infrastructure such as wooden utility poles	

Source: Adapted from ESMAP, 2011

CSA objective: contribution to climate change mitigation

Given the facts and figures above, energy-smart food systems may not appear to be very important for the third pillar of CSA which is GHG emission reduction and carbon sequestration. Primary production is responsible for most agricultural emissions, but most of the energy used in the agrifood sector is not for primary production. This is also true regarding the direct energy used in the agrifood chain. However, there are additional links that make energy-smart food systems important for CSA. Many of these links become apparent when considering the mitigation potential rather than current GHG emissions and energy consumption. Reducing energy use in the food chain will reduce CO_2 emissions. Figure 5.2 shows that, globally, these do not represent the major share of GHG emissions from the agrifood chain. However, there are other considerations that should be taken into account.

- The situation differs between high- and low-GDP countries. In high-GDP countries, post-harvest operations contribute the most GHG emissions, largely as CO_2. In low-GDP countries, most GHGs, largely methane and nitrous dioxide, are emitted on the farm.
- There is a correlation between nitrous oxide (N^2O) emissions from fertilizer application and energy use (and hence CO_2 emissions) in the production of fertilizer. Precision agriculture, including a more efficient use of fertilizer, will lower CO_2 and N_2O emissions and reduce the consumption of fossil fuels. Methane emissions can be reduced by using manure for biogas, which may also improve energy access or reduce the use of fossil fuels on farms. Growing trees on farms for energy purposes can also sequester carbon and displace fossil fuels. However, increasing energy efficiency in agricultural production may also increase profits, which could lead to agricultural expansion. As such, the resulting land-use change would lead to higher GHG emissions (even per unit of production). These considerations indicate that there are many links between energy-smart food systems and CSA beyond the reduction of CO_2 emissions from fossil fuels.

Box 5.2
Examples of the importance of energy-related GHGs beyond the farm gate in high GDP countries

As shown in Figure 5.3, the energy component associated with CO_2 emission is most relevant in the agrifood chain's post-harvest operations, and accounts for the bulk of emissions in high-GDP countries.

A recent study from the United Kingdom (UK) has shown that around 52 percent of the emissions occur in the post-farm stages of UK food production (see Figure 5.5). Similar figures can be observed for the United States, where around 54 percent of GHGs are emitted after the farm-gate (see Figure 5.6).

These results are shaped by a number of factors, including the definition of the boundaries of the food system. The inclusion of dishwashing or international food trade could significantly change the overall picture. For example, the net food trade in the UK's food system is responsible for around 24 percent of total emissions of the food chain, which lowers the relative proportion of emissions attributable to farming to just 32 percent.

Source: FAO elaboration based on UK DEFRA, 2010.

Figure 5.5
GHG emissions along the agri-food chain in the UK

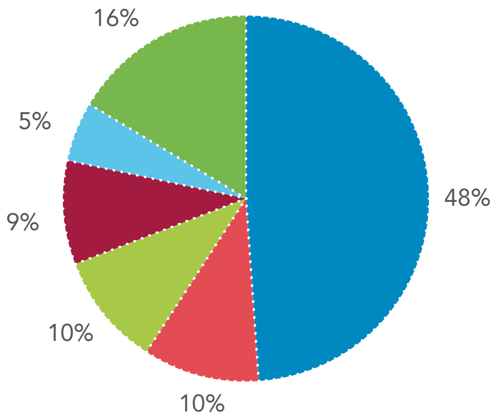
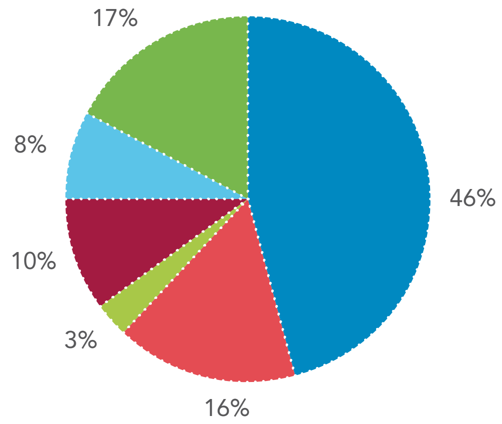


Figure 5.6
GHG emissions along the agri-food chain in the US



Source: FAO elaboration based on UK DEFRA, 2011

Source: FAO elaboration based on USDA, 2010 and US EPA, 2009

Efforts to achieve food and energy security in a climate-smart way will be accomplished through low-carbon approaches. This can be done either directly, through the increased use of renewable energy in the agrifood sector, or indirectly, through measures to increase energy efficiency (see Table 5.2). It is worth pointing out that many of these measures, in particular those that are carried out behind the farm gate, involve resource-efficient farming practices that are part and parcel of CSA. Implementing these measures would be a win-win solution from the point of view of both CSA and energy-smart food.

Table 5.2
Examples of energy efficiency improvements through direct or indirect technical and social interventions along the food chain

	Directly	Indirectly
Behind farm gate	Adopting and maintaining fuel efficient engines Precise water applications Precision farming for fertilizers Adopting no-till practices Controlled building environments Heat management of greenhouses Propeller designs of fishing vessels	Less input-demanding crop varieties and animal breeds Reducing soil erosion Reducing water demand and losses Using biofertilizers Efficient machinery manufacture Information and communication technologies to identify stock locations and markets
Beyond farm gate	Truck design and operation Variable speed electric motors Better lighting and heating Insulation of cool stores Minimizing packaging of food Improve efficiency of cooking devices and space heating	Improving road infrastructure Urban planning to reduce distances travelled to distribute and buy food Reducing food losses at all stages Changing diets away from animal products Lowering obesity levels Labeling of food products

Source: adapted from FAO, 2011a

Box 5.3
Can biofuels contribute to CSA?

Global liquid biofuel production has increased more than 500 percent since 2000. Production is projected to increase a further 50 percent by 2020 and increase even more by 2050.

Over the past five or six years policies have played a critical role in the rapid increase in liquid biofuel production, principally for transport purposes. Policy support for biofuels has been motivated by a desire to strengthen energy security, reduce GHG emissions, advance rural development and increase farmers' incomes. After the rapid introduction of new and expanded support measures, there is now a better evidence base for reviewing the impacts of increased biofuel production and reflecting on how policies might be adjusted to address changing goals and concerns.

Listed below are some possible contributions of biofuels to CSA objectives.

- Biofuels (in solid, liquid and gaseous forms) can help improve access to modern energy services for household and productive uses, which contribute to sustainable increases in productivity and income. A recent study on small-scale bioenergy initiatives (FAO, 2009) shows that this improvement can be achieved with minimum sustainability risks.
- Biofuels, especially small-scale production, can strengthen resilience to climate change and variability. However, they may also bring about their own climate risks by creating a link between energy security and crop yields. This risk is particularly high where feedstock diversity is low.
- The impacts on GHG emissions and carbon sequestration are more complex and the subject of much debate. Bioenergy is often considered to be CO_2-neutral because the generation of biomass by photosynthesis absorbs the same amount of CO_2 that is released by burning the biomass. However, this fails to consider the linkage between the carbon cycle and other natural cycles, including those of nitrogen, phosphorus and water. These elements are also required for photosynthesis and they are consumed whenever biomass is produced. Soil nutrients are consumed and need to be supplemented. These additions (e.g. fertilizer application) can result in GHG emissions, especially nitrous oxide. A full life cycle assessment has to be carried out that can take into account agricultural production and processing, as well as direct and indirect land-use changes.
- Some good practices that can improve the performance of biofuels in terms of climate change mitigation include:
    - agroecological zoning, to avoid biofuel development in high carbon areas (e.g. primary forests, peat land) and only promote it in areas of high land suitability;
    - the use of residues for biofuel production, as long as it does not affect their use for soil management or as animal feed; and
    - conservation agriculture, which is usually a low-carbon farming practice that can sometimes even sequester carbon.

More broadly, biofuel policies and programmes should act in synergy with programmes related to agricultural development rather than with policies that artificially support biofuel demand. A sound and integrated approach to bioenergy, particularly biofuel development, is required to reduce the risks and harness the opportunities related to bioenergy development. This approach requires:

- an in-depth understanding of the situation and the related opportunities and risks, as well as synergies and trade-offs;
- an enabling policy and institutional environment, with sound and flexible policies (e.g. targets and incentives) and means to implement these;
- implementation of good practices by investors and producers to reduce risks and increase opportunities, along with appropriate policy instruments to promote these good practices;
- proper impact monitoring and evaluation and policy response mechanisms; and
- capacity building and good governance in the implementation of the above.

To promote this sound and integrated approach, FAO has been developing a set of instruments which are part of FAO's Sustainable Bioenergy Toolkit: Making Bioenergy Work for Climate, Energy and Food Security (FAO, 2013).

Synergies and trade-offs between energy-smart food and climate-smart agriculture

As there are numerous synergies between CSA and energy-smart food, climate benefits can and do often accrue through the development of energy-smart food systems. However combining these objectives may also require some trade-offs. Table 5.3 presents examples of such potential synergies and trade-offs. It should be noted that this table presents a very broad picture and should be considered as a first approximation for summarizing the possible linkages between energy-smart food systems and CSA. These linkages are often quite complex and context specific, and as such, more research is needed in this area.

Table 5.3
Examples of possible synergies and trade-offs between energy-smart food and CSA objectives

		CSA objectives		
		Sustainable increases in productivity and income	Strengthened resilience to climate change and variability	Agriculture's reduced impact on climate change
Energy-smart food objectives	Increased energy efficiency	☑ General: Savings on energy costs (after up-front costs for technology have been paid) will result in increased profit if productivity is not excessively decreased Specific: Practices such as replacement of synthetic fertilizers with application of agricultural residues or manure, which require fewer external inputs and increase yields, can contribute to both increased energy efficiency and sustainable increases in productivity and income. Practices that reduce external energy inputs and (at least) maintain yields, such as reduced or zero tillage, will increase energy efficiency and sustainably increase income. If such practices are combined with others that increase yields (such as nitrogen-fixing cover crops or manure trees), this can contribute to both energy efficiency and sustainable increases in productivity and income. There is also much scope for enhanced post-harvest technologies and practices that contribute to both energy efficiency and sustainable increases in productivity and income, such as improved crop and food storage, packaging and distribution. Some high pressure drip irrigation systems may be less energy efficient than gravity irrigation for the same water efficiency: hence trade-offs between increased energy efficiency and water efficiency should be taken into account to ensure sustainability.	☑ General: Savings in energy costs will result in increased income available to enhance adaptive capacity Decreased dependence on energy inputs (especially fossil fuels) will tend to reduce vulnerability to shocks in energy prices Some "climate-proof" agricultural production and energy systems may result in lower energy efficiency Specific: Practices such as conservation agriculture that enhance crop cover, soil water retention and soil organic matter may increase resilience to drought and extreme weather events Irrigation tends to enhance resilience and may increase energy efficiency through its impacts on productivity	☑ General: Improvements in energy efficiency, whether due to lower embedded energy in inputs or on-farm fuel combustion, will reduce GHG emissions in the production chain However, increased energy efficiency may translate into greater profits, which may result in extensification of agriculture (so-called rebound effect), potentially bringing about CO_2 emissions from land use change that could even result in greater GHG emissions per unit of production Specific: Practices such as reduced or zero tillage, precision agriculture, replacement of synthetic fertilizers with agricultural residues or manure, elimination of pesticides through integrated pest management or enhanced distribution logistics that reduce fossil fuel combustion will generally lead to reduced GHG emissions, though full lifecycle assessment is required. Reduced or zero tillage, in combination with permanent crop cover, crop rotation and elimination of agrochemicals may also sequester carbon.

Energy-smart food objectives	CSA objectives: Sustainable increases in productivity and income	CSA objectives: Strengthened resilience to climate change and variability	CSA objectives: Agriculture's reduced impact on climate change
Increased production and use of renewable energy in agrifood systems, including through integrated food-energy systems)*	? General: On-farm production of renewable energy can allow farmers to sustainably increase income through the sale of renewable energy to the grid or of biogas to the local market or through reduced purchases of fossil fuels. Potential land-use competition (energy versus food: e.g. solar panels on farm land, biofuels) Use of renewable energy systems may result in more expensive energy inputs (i.e. fossil fuel might be cheaper than renewable energy) Specific: On-farm production of biogas can allow use of a biogas by-product as a liquid fertilizer, which can increase yields and reduce environmental pollution. Integrated food-energy systems such as intercropping with leguminous crops or agroforestry may sustainably increase farm productivity and also provide energy. Excessive use of agriculture and forestry residues for bioenergy can compete with their role in increasing soil organic matter and hence damage productivity. Biofuel production could lead to increased pressure on water resources, reduced agrobiodiversity (where monoculture is used) and introduction of invasive species.	☑ ? General: Renewable energy will lead to decreased dependence on fossil fuels, so less vulnerability to fossil fuel market shocks. On-farm renewable energy production can Increase income diversification, so reducing dependency on crop yields and demand. Carefully-designed diversified energy portfolio can reduce climate vulnerability, but some types of renewable energy (e.g. wind, bioenergy, hydro) are vulnerable to climate variability. The degree to which new energy services are climate resilient depends on the energy source (see table 5.1). Specific: Excessive use of agriculture and forestry residues for bioenergy can compete with their role in improving soil management, which could decrease resilience to extreme weather events. The use of residues for bioenergy rather than animal feed and/or soil conditioner could result in decreased soil quality.	☑ General: Energy diversification will tend to replace fossil fuels with renewable forms of energy, but in the case of bioenergy, will only reduce net GHG emissions subject to use of good practices. Specific: Excessive use of agriculture and forestry residues for bioenergy can compete with their role in returning carbon to the soil; different bioenergy technologies lead to different levels of nutrient availability in the soil. Indirect effects of biofuel demand such as indirect land-use change and price-induced intensification can lead to net GHG increases. The use of residues for bioenergy rather than for animal feed could act as an additional source of displacement and potential land-use change

* Integrated food-energy systems can be used to increase access to modern energy services (the third pillar of energy-smart food) as well as to increase production and use of renewable energy in agrifood systems (the second pillar) (Bogdanski *et al.*, 2010; Bogdanski, 2012).

Increased access to modern energy services	CSA objectives		
	Sustainable increases in productivity and income	Strengthened resilience to climate change and variability	Agriculture's reduced impact on climate change
Increased access to modern energy services	☑ ?	☑	☒
	General: Availability of energy for productive use (both for primary production and value-adding processing) and reduction of food losses (e.g. through improved processing, packaging and storage) can enable improved use of natural resources and increased productivity and profits. Provision of modern energy services through renewable forms of energy is likely to lead to sustainable increases in productivity and income (particularly where locally produced), whereas if fossil fuels are used there could be productivity and income benefits along with negative environmental consequences. Trade-offs need to be assessed in the local context and taken into account. More affordable energy services may be less energy efficient (e.g. cheaper tractors may be less efficient).	General: Increased access to modern energy services enables enhanced adaptive capacity through the ability to increase and diversify income, for example through adding value to primary production and through enhanced storage of products.	General: Increased access to modern energy services will generally lead to increased energy consumption. This will often lead to increased GHG emissions (although these could be insignificant for some renewable energy sources). However, in the case where access to modern energy services displaces unsustainable use of wood for energy, the resulting reduction in deforestation and forest degradation could lead to reduced GHG emissions. Increased access to modern energy services may or may not lead to increased energy efficiency – this depends in part on the stage of development and level of energy consumption of a country/agri-food system (see above cell for energy efficiency versus climate change mitigation). Specific: Bioenergy technologies that retain more nutrients (e.g. anaerobic digestion) versus those that retain less nutrients (e.g. gasification and combustion).

Legend:
☑ = Synergy between energy-smart food and CSA objectives
? = Synergy between energy-smart food and CSA objectives with some significant caveats
☒ = No clear trend

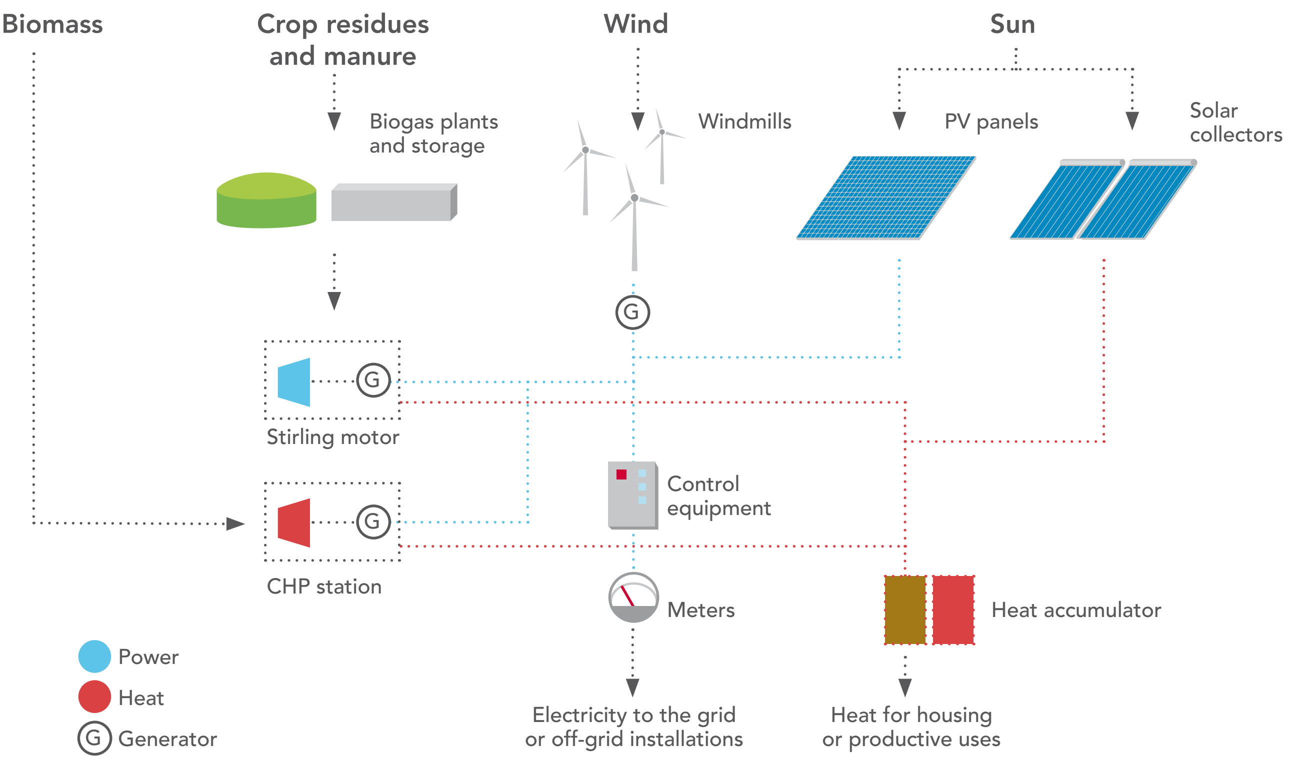
5.3 Moving forward – possible energy solutions for CSA

FAO projections to 2030 indicate that in developing countries the proportion of land cultivated by hand and with animal power will decrease. This shift in agricultural practices offers opportunities for increased productivity and reduced drudgery for farmers. However, expensive machinery and equipment are often unavailable to poor farmers. Innovative business and community models are required to ensure that smallholder farmers are able to access improved technologies (e.g. through rental schemes or cooperatives). The move to more highly mechanized farming systems is likely to reduce farm labour requirements and reduce employment opportunities in rural areas. Well-designed policies and programmes are required to create alternative employment opportunities along the agricultural value chain and in other non-agricultural rural livelihoods.

Technologies for energy-smart food and CSA

A mix of appropriate energy technologies, equipment and facilities in farming communities is necessary to make the gradual shift to energy-smart food systems. The nature of this mix will depend on natural conditions, infrastructure and skills available in the labour force. There are many technologies that can be part of energy-smart food systems, including: wind mills, solar collectors, photovoltaic panels, biogas production units, power generators, equipment for bio-oil extraction and purification, fermentation and distillation facilities for ethanol production, pyrolysis units, hydrothermal conversion equipment, solar-, wind or bioenergy-operated water pumps, renewable energy-powered vehicles, monitoring systems, information and communication technologies (ICT), cooking stoves, equipment for water supply, distribution and purification. These technologies add value to production near the source of raw materials. They can also be combined on the same farm in integrated food-energy systems as shown in Figure 5.7.

Figure 5.7
An integrated approach to renewable energy for farming systems



It is difficult to identify energy-smart food 'hot-spots' and intervention priorities with data that is currently available. Different food chains are subject to very different processes and require different types of energy inputs. In particular, more research is required on the relationships between energy use, yields and production costs in various agricultural systems and settings.

Field efficiencies[5] can be up to 90 percent in tilling and cultivating; 65-70 percent in fertilizing and grain harvesting. However, results depend on yields and plot size. Fuel consumption is typically 600-1 200 megajoules per hectare (MJ/ha) for mouldboard ploughing; 200-4 900 MJ/ha for disking; 80-160 MJ/ha for planting; 150-300 MJ/ha for ammonia application; 100-200 MJ/ha for cultivating; and 250-500 MJ/ha for grain harvesting (Smil, 2008).

Farming systems where there are typically low energy needs and extensive fields for farming and grazing, like those in Australia or New Zealand, can operate with energy requirement as low as two or three gigajoules per hectare (GJ/ha). The energy requirement for input-intensive agriculture in countries such as the Netherlands or Israel can reach up to 70-80 GJ/ha (Smil, 2008).

[5] The work obtained from energy invested.

On a per calorie of food output basis, China, with its high cropping ratio, extensive irrigation and intensive fertilization, now has a more energy-intensive agriculture sector than the United States or the European Union. After the farming reforms of 1978 in China, nitrogen (half of which comes from inorganic fertilizers) has provided about 60 percent of the nutrient in cropping. Over 80 percent of the country's protein requirement has been derived from crop production. The agriculture sector is highly dependent on fossil fuels, but has been able to feed about 8.5 people per hectare and up to 15 people in populous provinces. This result is also attributable to a national diet with little animal proteins.

Inefficient use of nitrogen fertilizers leads to losses that are usually above 50 percent and sometimes can amount to 60-70 percent of applied nutrients (Cassman *et al.,* 2002). In many areas, increasing the efficiency of fertilizer application so that it results in optimal plant growth with minimal inputs would significantly improve the energy balance of food production. It would also help protect the environment and cut costs for farmers. However, in some areas, such as in Africa, reaching optimal energy efficiency in food production may require the application of more fertilizer to increase yields. Curbing soil erosion could be another important method to reduce fertilizer losses.

Water efficiency is becoming a priority in irrigation. However, achieving greater efficiency in irrigation may require more energy. Drip irrigation, for example, which increases the efficiency of water use, requires energy to pressurize the water. Much of the energy needed for irrigation is often used for pumping operations. Extending irrigation in remote areas requires appropriate energy technologies, such as solar powered pumps that can save manual labour in off the energy grid rural areas. Irrigation efficiency can be as high as 95 percent; good field practices have average efficiency rates around 65-75 percent while furrow irrigation can only achieve 30-40 percent efficiency. In Asia, irrigation efficiency could potentially be doubled (Smil, 2008).

Liquid fuels are usually required for soil preparation. The amount of energy required for this is influenced by weather conditions (wet or dry soils), soil compaction and other factors. The single most energy-consuming operation in a cropping cycle is soil tillage for land preparation, particularly ploughing. Consequently, reduced tillage cropping systems, particularly no-till systems, have become particularly attractive in times of high energy costs. Practices, such as zero tillage used in conservation agriculture, have the potential to bring about significant energy savings that can even reach up to 40-50 percent (Doets *et al.,* 2000; SCCA, 2012). An example from Brazil of these potential savings from conservation agriculture is given in Table 5.4. Energy savings are primarily due to the reduction of external inputs, which are usually energy-intensive.

Table 5.4.
Total energy inputs per crop per hectare for conventional (regular) agriculture (RA) and conservation agriculture (CA) for the complete microcatchment of Lajeado São José, Brazil

	Conventional Agriculture				Conservation Agriculture			
	Maize	Soya	Beans	Wheat	Maize	Soya	Beans	Wheat
Herbicide input (MJ/ha)	1514	1018	254	0	603	603	603	0
Machinery input (MJ/ha)	525	693	227	604	404	513	77	483
Fuel input (MJ/ha)	1625	2167	1673	1450	645	709	454	470
Human labour input (MJ/ha)	0	28	71	0	0	28	71	0
Total input (MJ/ha)*	3664	3906	2226	2054	1653	1854	1205	953
Total input system (MJ/ha)**	2962				1416			

*= sum of energy inputs for herbicide, machinery and fuel

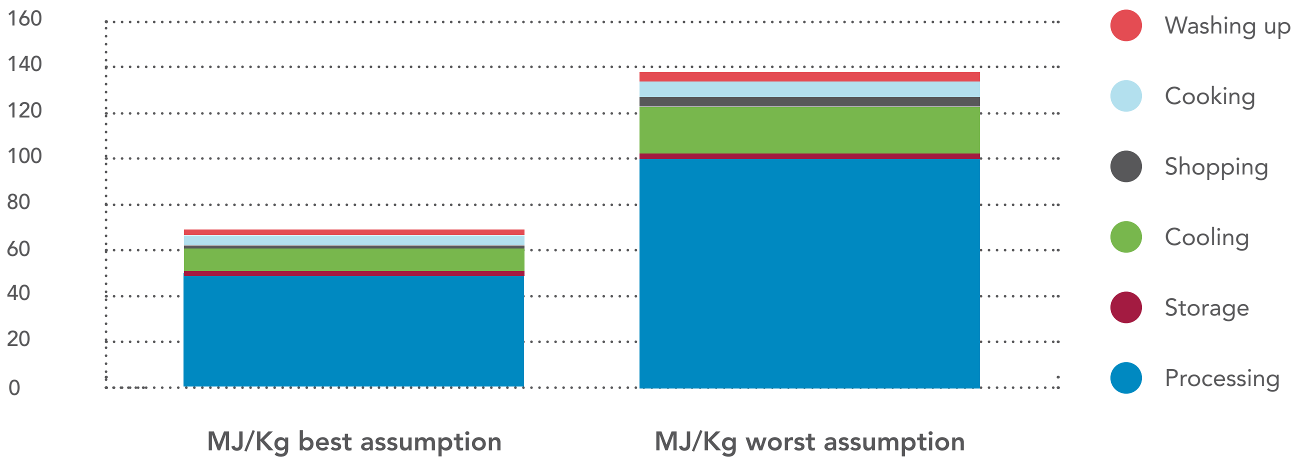
**= sum of energy inputs per average hectare

Source: Doets et al., 2000

A number of technological solutions exist to minimize energy use. These solutions include reducing the rolling resistance and slippage of combine harvesters (e.g. improving tractor tires). Energy conservation in greenhouses, animal houses and agricultural buildings is also a major area of intervention. Energy use can be minimized through a greater deployment of heat pumps (mostly of mechanical compression type, which are driven by electric motors) and heat recovery systems. Both of them can also provide dehumidification services and cooling. Air-to-water heat pumps or water-to-water heat pumps, possibly combined with geothermal energy sources can significantly increase energy efficiency in all operations that require heat. Pipe heating, heated floors, infrared heating and air heating are all technological options that can also be considered. The proper construction, insulation and correct ventilation of buildings and greenhouses are some of the most economic energy-efficient interventions.

A best and worst assumption of energy intensity per unit of produce can be made for all activities that are part of the agrifood chain. These activities are not included under the agricultural sector in the Intergovernmental Panel on Climate Change (IPCC) GHG accounting system but instead are under the industrial processes or energy sectors. These intensities are presented in Figure 5.8.

Figure 5.8
Best and worst assumption of energy intensities in the post-harvest stage of the food chain



Source: FAO, 2011a

Important opportunities for reducing energy dependency can be found in the drying, conditioning and storing of produce and in improving the fuel efficiency of field machinery. For grain drying, modern continuous flow dryers can be operated with much lower levels of energy than conventional dryers. Reduced energy use can also be achieved through the insulation of dryers, the recirculation of heat recovery of out-going air and improved instrumentation and automatic control. Combined (warm and cold air) dryers further reduce heat demand, but require a continuous and reliable electricity source for fans. Also available is dielectric heating technology, which can significantly reduce the energy needed for processing agricultural products. Typical rates of 600-750 kilojoule per kilogram (kJ/kg) of dried grain are needed to store products with 14 percent moisture, with liquefied petroleum gas (LPG) and electricity as the principal energizers. This rate goes up to 3-6 GJ/ha for corn (Smil, 2008).

Solar power (photovoltaic or solar heaters), wind and geothermal energy are all sources of energy that are available today for both large and small applications. They are particularly suitable for remote rural areas.

Worldwide, the use of biomass for heat and power could save significant amounts of carbon. However, the bioenergy would have to be carbon neutral, and there is debate as to whether this would be the case (see Box 5.3). Co-firing of biomass with coal could save nearly 0.5 gigatonne of carbon (GtC) per year at fairly modest costs (FAO, 2010). Savings in the traditional biomass and charcoal sectors could amount to another 0.5 GtC. Considerable efforts would be required in this sector to address the higher investments involved, the complex socio-economic and cultural issues, and the transaction costs associated with equipment and the reliable supply of biomass (FAO, 2010).

Examples of progress being made to realize the transformation towards energy-smart food include:

Behind the farm gate:

- Significant improvement in energy efficiency has been made through precision farming in industrial agriculture and through conservation agriculture.
- Renewable energy has been used on farms. The increased use of solar pumps in irrigation systems is one example. In addition, bioenergy is being used in integrated food-energy systems (Bogdanski, 2012). Examples include: biogas in integrated crop-livestock systems, particularly in Asia; intercropping with perennials such as pigeon peas to produce wood for on-farm energy purposes in Africa (Bogdanski and Roth, 2012); and more complex food-energy systems, such as the Tosoly farm in Colombia (see Box 5.4). Another example can be found in the use of suspended solar panels in agrophotovoltaic systems (see Box 5.5).

Beyond the farm gate (see also Module 11 on post-harvest management and food chains):

- Renewable energy is also being used in food processing activities. For example, in Sri Lanka woody biomass is used to dry spices. This innovation has diversified income streams and has increased revenue for a range of local operators in the spice market chain. In addition to selling by-product fuel wood from pepper plants to the dryer operators, small-scale growers are now able to sell mature spices that can be dried and preserved (FAO, 2009).
- The United Kingdom's 'war on food waste,' 'waste implementation programmes' (UK DEFRA, 2003) and similar initiatives have improved the energy efficiency in agrifood systems by reducing food losses.
- The promotion of clean cooking stoves in many parts of the world has made food preparation more energy efficient and healthy.

Box 5.4. An integrated food-energy system in Colombia

TOSOLY Farm in the Colombian foothills north of Bogotá, is a highly integrated farm that produces food and energy for family consumption and for sale in a crop and livestock system. The cropping is based on sugar cane (feed for pigs, food and energy), coffee and cocoa (food and energy), and multipurpose trees. Sugar cane is cultivated on 1.5 ha of the seven ha farm. Tree crops include coffee, cocoa, forage trees and forage plants for timber and fuel, including for shading the coffee.

The livestock and fuel components are chosen for their capacity to utilize the crops and by-products produced on the farm. The sugar cane stalk is fractionated into juice and residual bagasse. The tops, including the growing point and some whole stalk, are the basal diet for cattle and goats. The juice is the energy feed for pigs and the source of 'sweetener' for the farm family's cooking. The bagasse is the fuel source for a gasifier that provides combustible gas for an internal combustion engine linked to an electric generator. The goats are the means of fractionating the forage trees, consuming the leaves, fine stems and bark as sources of protein. The residual stems are an additional source of fuel in the gasifier. The goat unit has ten breeding does and two bucks. There are three pens for two crossbred cows and their calves, which are kept for the production of milk, meat and manure.

The pig unit has a capacity for 40 growing pigs and five sows. Forty hens and six ducks are raised for eggs and meat in foraging, semi-confined systems. Rabbit production, a new venture on the farm, applies the principles of 100 percent forage diets developed in Cambodia, Viet Nam, and the Lao People's Republic.

A horse transports sugarcane and forages. All high-moisture wastes are recycled through plug-flow, tubular plastic (Polyethylene) biodigesters. Pig and human excreta are the feedstock for four biodigesters. Waste water from coffee pulping, washing of dishes and clothes go to a fifth biodigester. Effluents from all eight biodigesters are combined and recycled to the crops as fertilizer. The pens for the goats and cattle have clay floors covered with a layer of bagasse to absorb the excreta. Periodically, this manure is applied to the crops as fertilizer and a source of organic matter.

Most of the energy on the farm (about 100 kilowatt hours per day [kWh/day]) is produced by gasification of the sugarcane bagasse and the stems from the mulberry and Tithonia forages. The 800 W installed capacity of photovoltaic panels are estimated to yield 8 kWh daily. The eight biodigesters produce 6m3 daily of biogas, two-thirds of which are converted to electricity (6 kWh/day) using it as fuel in the same internal combustion motor generator attached to the gasifier. The remainder is employed for cooking. Low-grade heat energy produced by the solar water heater and the wood stove are not included in the energy balance.

After deducting the electricity used to drive the farm machinery and to supply the house (11 kWh/day), the potentially exportable surplus is 104 kWh daily. At the current price of electricity (US$0.20/kWh), this would yield an annual return of US$7 600. Annually, the gasifier produces 4.4 tonnes of biochar, which is returned to the soil. Assuming that 65 percent of carbon in the biochar is not oxidized in the soil (Lehmann, 2007), then the effective sequestration of carbon dioxide is in the order of 11 tonnes annually.

Source: Preston, 2010

Box 5.5.
An agrophotovoltaic farm in Italy

In 2011, an agrovoltaic installation was inaugurated in Mantua, Italy. 'Agrovoltaic' technology is a production technique that uses and integrates existing technologies in new ways. It offers farmers the possibility to continue cultivating their lands while producing clean energy. This also allows farmers to partially shade their land, which permits the cultivation of a wider range of crops.

The agrophotovoltaic installation, which makes use of recycled and non-pollutant technologies and materials, consists of a series of photovoltaic panels suspended 5 meters above the ground. These panels produce renewable electricity with a power capacity of 2.4 megawatts (MW). The installation, realized by REM (Revolution Energy Maker), a group of Italian entrepreneurs who operate at the national and international level in the sector of electricity production, is also equipped with a series of accessories that offer additional useful options. One of these options is a wireless control system that lets users change the panels' inclination and monitor ground temperature and relative humidity.

The installation satisfies energy producers' needs for photovoltaic units to generate renewable energy and farmers' needs for arable land. It allows land-owners to diversify their incomes, and preserve and optimize the use of the landscape. By permitting an automatic and programmed management of water distribution and irrigation, this type of installation offers significant advantages for agriculture and the environment.

The system requires 4 to 5.5 hectares to produce a peak power of 1 MW to install and occupies at most two percent of the land. Thanks to the omnidirectional dual-axis tracking of the photovoltaic panels, the agrovoltaic system increases the production of clean energy by 30 percent, compared with fixed panels. The structure can integrate new automatic systems that support farming, such as systems for watering, the distribution of fertilizers and phytosanitary inputs and cultivation protection (e.g. anti-hail and shading nets, anti-frost systems). Each tracker can be equipped with a valve control system that allows an external source to control spray irrigation. The pumping and the daily biaxial movement would allow the water to disperse evenly.

These examples show that the transition to energy-smart food practices is already under way. Currently however, the pace of change is slow. For these practices to have a large-scale impact, significant scaling up is required.

Policies and institutions for energy-smart food and CSA

The promotion and scaling-up of energy-smart food practices requires innovative supportive policies and institutions. CSA policies and institutions that promote low-carbon farming practices are relevant to energy-smart food production, as many of these practices promote energy efficiency and renewable energy. Particular attention should be paid to ensuring participatory gender-sensitive decision-making processes on issues related to modern energy services. For bioenergy, it is especially important to consider the security of land tenure for local farmers. Some examples of policies specifically related to energy efficiency and renewable energy are summarised in Table 5.5.

Table 5.5
Examples of policy instruments to promote energy efficiency and renewable energy

Energy efficiency	Renewable energy
The introduction of freight truck fuel economy standards and payload limits Minimum energy performance standards (MEPS) for machinery is used in food systems Energy performance labels on appliances Vehicle speed restrictions Packaging recycling regulations Higher charges for landfill disposal of organic wastes Capacity building, research, education and communication	Promotion of renewable energy markets Financial incentives, such as tax exemption, feed-in tariffs and tradable certificate-based renewable energy obligations Standards, permits and building codes Alternatives to landfill with an energy component (e.g. incineration with energy recovery methane capture from landfill) Capacity building, research, education and communication

Source: FAO, 2011a

Energy-smart food interventions that lead to reduced CO_2 emissions (renewable energy or energy efficiency interventions) can make use of many of the climate change financial mechanisms discussed in Module 14 on financial instruments and investments. In addition, there are financing sources especially targeted for renewable energy use, energy efficiency and increased energy access. These include: innovative business models like energy service companies (ESCOs)[6]; financial instruments, such as feed-in-tariffs; tradable certificates; integrated municipal arrangements; and public-private funding schemes.

Thailand is a country that has enacted several policies that are favourable to renewable energy. Regulations were adopted in 2002 to simplify the grid connection requirements for small electricity generators up to 1 megawatt (MW) (World Bank, 2011). This and other policies led to the development of integrated sugarcane and rice biorefineries that produce food, ethanol, heat and electricity. In addition, organic residues were returned to the soil, increasing soil fertility. By 2008, 73 biomass projects using a variety of residues, including bagasse and rice husks, had been developed with an installed capacity of 1 689 MW (IPCC, 2011).

Implementing such policies requires innovative institutional mechanisms. Again, it should be noted that agricultural institutions that promote low-carbon agriculture also contribute to the production of energy-smart food. The division of labour and financial instruments are other elements that must be taken into account by institutional mechanisms that work to promote concern about integrated food-energy systems (FAO, 2011a). Examples in this are listed below.

- In parts of the United Kingdom where farmers are producing wheat, a bioelectricity plant buys the straw through a subsidiary company that collects the farmers' straw. Seventy percent of the fuel needed to run the bioelectricity plant comes from the straw feedstock, the rest from another feedstock and natural gas. In this system, farmers produce wheat and leave energy matters to more competent players (Bogdanski *et al.*, 2010).
- At the district model biogas farm in China, farmers cultivate crops and are not responsible for raising pigs and producing the biogas themselves. Instead, the farmers contribute money to the district pig farm for purchasing the pigs. The district farm is responsible for raising the pigs and generating the energy. The farmers get in return yearly dividends from any sales of pigs, cheap biogas and cheap liquid fertilizer from the district farm.
- In Bangladesh, two innovative business schemes are tapping into the private sector's needs for biofertilizer to drive the development of household biomass production for energy (ISD, 2010). One scheme seeks to create a steady supply of bioenergy through a cattle-leasing programme. Programme participants, who

[6] An energy service company is a commercial business providing a broad range of comprehensive energy solutions including designs and implementation of energy savings projects, energy conservation, power generation and energy supply, energy infrastructure outsourcing and risk management.

are mainly women, receive funding to purchase a cow and a calf from an organic tea farm. The women then repay the loan through the sale of milk and dung. In the second scheme, still in its pilot phase, households receive loans from the organic tea farm to pay for setting up a biogas system. The households repay the loan by selling dung and/or the slurry to the tea farm. Once the biogas installation has been completely paid for, the households have the option to continue selling the slurry and dung to the farm.

- 'Fee for service'[7] schemes, such as ESCO, leasing or concession arrangements schemes are other options for financing energy-smart food.

The need for cross-sectoral coordination in bioenergy development is illustrated by the example from Sierra Leone presented in Box 5.6.

Box 5.6
Bioenergy addressed through a cross-ministerial platform in Sierra Leone

Sierra Leone, a post-conflict resource-rich country, is classified as a low-income food-deficit country. Seventy percent of the population lives below the poverty line and 35 percent are undernourished. Agriculture is a key sector of the economy. The country depends heavily on imported fossil fuels, fuelwood and charcoal for household energy, and the population has minimal access to electricity. Currently, modern bioenergy is not produced in Sierra Leone, but a number of investors are moving into the country. Bioenergy development in such a fragile environment can involve major risks, but may represent an opportunity to attract much needed investment in agriculture. Agriculture-led growth through bioenergy investments could reduce poverty, stimulate the economy and increase access to energy. However, the process for achieving this needs to be clearly understood and carefully managed. The inclusion of smallholder farmers, social protection, and sustainable resource management are key elements in the process.

The Ministry of Energy and Water Resources (MEWR) formally requested the technical support of FAO to assess the potential for sustainable bioenergy development in the country using the Bioenergy and Food Security (BEFS) approach. A first step was the establishment of an interministerial working group, the Bioenergy and Food Security Working Group (BEFS WG). Its first activity was to identify the country's main concerns and challenges for bioenergy development as well as the country's immediate needs and longer-term requirements. One of these immediate needs is to have information that would allow Sierra Leone to screen and direct investors coming to the country. The working group is currently developing a set of guidelines for sustainable bioenergy investment. As land grabbing is becoming a major concern in Sierra Leone, the guidelines will address the issue of community inclusion and conflict management. In the longer term, there is the need to identify the country's potential for sustainable bioenergy development, cover data and information gaps, and address long-term institutional requirements and training needs both at policy and technical levels.

A multi-partner programme for scaling up energy-smart food

Shifting to more energy-smart food systems is an important step towards reaching the broader CSA goals. Decision-makers need to adopt a long-term view to make the needed paradigm shift to food systems that are energy-smart and contribute to climate change mitigation and adaptation as well as food security. Although this shift will not be fully accomplished in the short term, there is no time for delay. The key question at hand is not, 'If or when we should we begin the transition to energy-smart food systems?', but rather 'How can we get started and make gradual but steady progress?' The shift towards energy-smart food systems will be gradual and can only be achieved through sustained efforts. Understanding and implementing energy-smart food systems is a complex multidisciplinary task that requires a multipartner programme. Towards this end, the Energy-Smart Food for People and Climate was launched in 2012. It aims to help countries promote energy-smart agrifood systems through the identification, planning and implementation of climate-smart measures that integrate energy, water and food security.

[7] Fee-for-service (FFS) is a payment model where services are unbundled and paid for separately.

5.4 Conclusions

This module has introduced the concept of energy-smart food system and its important role in transitioning to climate-smart agriculture. One of its main conclusions is that the dependence of agrifood systems on fossil fuels represents a major threat to food security and contributes significantly to climate change. The challenge of reducing this dependency can be met by up-scaling of energy-smart food systems which improve energy efficiency, increase the use and production of renewable energy, and broaden access to modern energy services in agrifood systems. The case studies of the module indicated how different technological solutions and integrated systems in distinct contexts can be both energy- and climate-smart. They presented e.g. low-cost machinery, biofuels, integrated food-energy systems, modern technology and new type of cross-sectoral collaboration needed for energy-smart food systems. It was emphasized, however, that in addition to synergies between energy-smart food and CSA objectives there are also possible tradeoffs which need to be recognized. The module ended by stating that the shift to the new approach requires long-term vision and commitment as well as multidisciplinary efforts, but there is no time for delay.

Notes

This module was written by Olivier Dubois (FAO), Alessandro Flammini (FAO), Anne Bogdanski (FAO) and Jonathan Reeves (FAO).

Acronyms

APCAEM	Asian and Pacific Centre for Agricultural Engineering and Machinery
BEFS	Bioenergy and Food Security Approach
BEFS WG	Bioenergy and Food Security Working Group in Sierra Leone
CA	Conservation agriculture
CO_2	Carbon dioxide
CSA	Climate-smart agriculture
ESCAP	Economic and Social Commission for Asia and the Pacific
ESCO	Energy Service Company
ESMAP	Energy Sector Management Assistance Program
FFS	Fee-for-service
GDP	Gross Domestic Product
GHG	Greenhouse gas
GJ	Gigajoule
GtC	Gigatonne of carbon
HEAT	Hands-on Energy Adaptation toolkit
ICT	Information and communication technologies
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISD	Institute for Sustainable Development
Kg	Kilogram
kj	Kilojoule
kWh	Kilowatt hour
LPG	Liquefied petroleum gas
MDG	Millennium Development Goal
MEPS	Minimum energy performance standards
MEWR	Ministry of Energy and Water Resources in Sierra Leone
MJ	Megajoule
MW	Megawatt
N_2O	Nitrous oxide
RA	Conventional (regular) agriculture
REM	Revolution Energy Maker
UK DEFRA	United Kingdom's Department for Environment, Food and Rural Affairs
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US EPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture

References

Asian and Pacific Centre for Agricultural Engineering and Machinery (APCAEM) & Economic and Social Commission for Asia and the Pacific (ESCAP). 2010. *Agricultural mechanization at a glance – selected country studies in Asia on agricultural machinery development.* (available at http://www.unapcaem.org/publication/AM_2010_6C.pdf)

Biggs, S. & Justice, S. 2011. *Rural development and energy policy: lessons for agricultural mechanization in South Asia.* Occasional paper No. 19. New Delhi, India, Observer Research Foundation. (available at www.observerindia.com/cms/export/orfonline/modules/occasionalpaper/attachments/occ_rural_1296292421217.pdf)

Bogdanski, A. 2012. *Integrated food–energy systems for climate-smart agriculture.* Agriculture & Food Security, 1: 9. (available at http://www.agricultureandfoodsecurity.com/content/1/1/9/abstract)

Bogdanski, A., Dubois, O., Jamieson, C. & Krell R. 2010. *Making integrated food-energy systems work for people and climate*. Rome, FAO. (available at http://www.fao.org/docrep/013/i2044e/i2044e.pdf)

Bogdanski, A. & Roth, C. 2012. *Integrated food-energy systems: growing fuel wood on farm in Malawi*. Nature & Faune, 26 (2):57–62. (available at http://www.fao.org/docrep/016/ap343e/ap343e.pdf)

Cassman, K. G., Dobermann, A. & Waters, D.T. 2002. *Agroecosystems, nitrogen use efficiency, and nitrogen management.* Ambio, 31: 131—140.

Chum, H., Faaij, A., Moreira, J., Berndes, G., Dhamija, P., Dong, H., Gabrielle, B., Goss Eng, A., Lucht, W., Mapako, M., Masera Cerutti, O., McIntyre, T., Minowa, T. & Pingoud K. 2011. *Bioenergy*. IPCC special report on renewable energy sources and climate change mitigation.

Doets, C.E.M., Best, G. & Friedrich, T. 2000. *Energy and conservation agriculture.* Internal FAO paper, Rome.

Energy Sector Management Assistance Program (ESMAP). 2011. *Climate impacts on energy systems: key issues for energy sector adaptation.* World Bank. (available at https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/E-Book_Climate%20Impacts%20on%20Energy%20Systems_BOOK_resized.pdf)

ESMAP. 2013. *Hands-on Energy Adaptation Toolkit (HEAT).* (available at http://esmap.org/esmap/node/312)

FAO. 2009. *Small scale bioenergy initiatives – brief description and preliminary lessons on livelihood impacts from case studies in Asia, Latin America and Africa.* 149 pp. Environment and Natural Resources Management working paper No. 31. Policy Innovation Systems for Clean Energy Security (PISCES), Practical Action, and FAO. Rome, FAO. (available at http://www.fao.org/docrep/011/aj991e/aj991e00.htm)

FAO. 2010. *What woodfuels can do to mitigate climate change.* FAO Forestry Paper No. 162. (available at http://www.fao.org/docrep/013/i1756e/i1756e00.htm)

FAO. 2011a. *"Energy-smart " food for people and climate.* Issue paper. (available at http://www.fao.org/docrep/014/i2454e/i2454e00.pdf)

FAO. 2011b. *The case for "energy-smart" food systems.* Policy Brief. (available at http://www.fao.org/docrep/014/i2456e/i2456e00.pdf)

FAO. 2013. *FAO support to decision-making for sustainable bioenergy.* Bioenergy. (available at http://www.fao.org/bioenergy/28392-0a61de8f511d0a4d08b2137bc929214a7.pdf)

FAOSTAT. 2012. *FAO statistical yearbook.* (available at http://faostat.fao.org)

Geoghegan, T., Anderson, S., & Dixon, B. 2008. *Opportunities to achieve poverty reduction and climate change benefits through low-carbon energy access programmes.* The Ashden Awards for sustainable energy, GVEP International & IIED. (available at *http://www.ashdenawards.org/files/reports/DFID_report.pdf*)

Gustavsson J., Cederberg C., Sonesson U., van Otterdijk R. & Meybeck, A. 2011. *Global Food Losses and Food Waste*, FAO.

International Energy Agency (IEA). 2011a. *World energy outlook 2011.* Paris.

Intergovernmental Panel on Climate Change (IPCC). 2011. *Special report on renewable energy and climate change mitigation.* Chapter 11. Policy, financing and implementation. Working Group III, Intergovernmental Panel on Climate Change. (available at http://srren.ipcc-wg3.de/report/IPCC_SRREN_Ch11)

Islam, M. & Shirazul, D. 2009. *Farm mechanisation for sustainable agriculture in Bangladesh: problems and prospects*. (available at www.unapcaem.org/Activities%20Files/A09105thTC/PPT/bd-doc.pdf)

Institute for Sustainable Development (ISD). 2010. *Increasing access to homestead biogas in Tentulia: pilot project.* (available at http://www.snvworld.org/en/Documents/Inreasing_access_to_homestead_biogas_in_Tentulia_Bangladesh_2010.pdf)

Preston, R. 2010. *The Tosoly farm, Santander, Colombia.* Unpublished paper.

Soil Conservation Council of Canada (SCCA). 2012. *Producers are finding the reduced tillage zone.* (available at http://www.soilcc.ca/ggmp_region/nb-02.php)

Smil, V. 2008. *Energy in nature and society- general energetic of complex systems, 512 pp.* Cambridge, Massachusetts, MIT Press.

Steele, P. E. 2011. *Agro-mechanization and the information services provided by FAOSTAT.* Unpublished internal report. Rome, FAO.

United Kingdom's Department for Environment, Food and Rural Affairs (DEFRA). 2003. *Waste implementation programme: fact sheets, November 2003.* (available at http://archive.defra.gov.uk/environment/waste/residual/newtech/documents/factsheet1103.pdf)

UK DEFRA. 2010. *Food statistics pocketbook 2010.*

UK DEFRA. 2011. *Food statistics yearbook 2011.*

United Nations Development Programme (UNDP). 2009. *The energy access situation in developing countries: a review focusing on the least developed countries and sub-Saharan Africa.* UNDP & WHO. (available at http://content.undp.org/go/newsroom/publications/environment-energy/www-ee-library/sustainable-energy/undp-who-report-on-energy-access-in-developing-countries-review-of-ldcs---ssas.en)

United States Department of Agriculture (USDA). 2010. *Energy use in the U.S.* food system.

United States Environmental Protection Agency (US EPA). 2009. *Opportunities to reduce greenhouse gas emissions through materials and land management practices.* (available at http://www.epa.gov/oswer/docs/ghg_land_and_materials_management.pdf)

World Bank. 2011. *One goal, two paths: achieving universal access to modern energy in East Asia and the Pacific.* Washington D.C., the World Bank.

Additional Resources

FAO. 2000. *The energy and agriculture nexus, environment and natural resources.* NRC working paper No. 4.

FAO. 2008. *The state of food and agriculture— biofuels: prospects, risks and opportunities.* (available at ftp://ftp.fao.org/docrep/fao/011/i0100e/i0100e.pdf)

FAO. 2012. *Energy-smart food at FAO: an overview.* Rome. (available at http://www.fao.org/docrep/015/an913e/an913e00.htm)

Giampietro, M. 2002. *Energy use in agriculture.* Encyclopedia of Life Sciences, 15 pp. MacMillan Publishers. Nature Publishing Group. (available at www.els.net)

IEA. 2011b. *Technology roadmap – biofuels for transport.* (available at http://www.ieabioenergy.com/LibItem.aspx?id=6826)

Love Food Hate Waste. 2013. *Save time and Money.* (available at http://england.lovefoodhatewaste.com/content/save-time-money-0)

OECD & FAO. 2011. *OECD-FAO agricultural outlook 2011-2020.* (available at http://www.agri-outlook.org/pages/0,2987,en_36774715_36775671_1_1_1_1_1,00.html)

REN 21. 2011. *Renewables 2011 – global status report.*

United Nations (UN). 2010. *Energy for a sustainable future - The Secretary General's advisory group on energy and climate change (AGECC).Summary report and recommendations.* New York, USA, UN.

UN. 2011. *A vision statement by Ban Ki-moon, Secretary-General of the United Nations.* New York, USA, UN. (available at http://www.sustainableenergyforall.org/resources)

MODULE 6:

CONSERVATION AND SUSTAINABLE USE OF GENETIC RESOURCES FOR FOOD AND AGRICULTURE

Overview

This module describes the nature of genetic resources for food and agriculture and outlines why these resources are essential for climate-smart agriculture. After a brief description of the expected impacts of climate change on genetic resources for food and agriculture, the module highlights their role in climate change adaptation and mitigation.

Examples from around the world are used to demonstrate how the conservation and use of the rich genetic diversity of plants and animals both between and within species used for food and agriculture can benefit present and future generations.

Key messages

- Genetic resources for food and agriculture are the basis for sustainable agriculture and food security. They are essential elements for increasing the efficiency and resilience of food systems.
- Genetic resources are the raw materials that farmers, breeders and researchers rely upon to improve the quality and the amount of food produced, and to respond to new conditions, including changes in climate.
- The conservation and sustainable use of genetic resources provide important options for adapting agricultural production to the impacts of climate change. Consequently, any loss of genetic diversity is a threat to the well-being of present and future generations.
- A proper understanding of genetic resources (e.g. inventory, characterization, and monitoring) is a prerequisite for coping with climate change. A conservation strategy that uses a combination of ex situ and in situ techniques is most likely to safeguard the genetic diversity required to meet the needs of present and future generations.
- Ensuring that the appropriate genetic resources with the relevant traits for climate change adaptation and mitigation are available and accessible is crucial. In most countries, a significant part of the genetic diversity used in food and agriculture originates from other countries. Countries, both developed and developing are thus interdependent, when it comes to getting access to these genetic resources to safeguard their food security.

Contents

List of Boxes

6.1 Genetic resources for food and agriculture

Agriculture, including livestock keeping, forestry, aquaculture and fisheries, depends on the three components of biodiversity: the diversity of species, the diversity within each species and the diversity of ecosystems. The diversity of genetic resources for food and agriculture (i.e. plants, animals, aquatic resources, forests, micro-organisms and invertebrates) plays an essential role in meeting basic human food and nutritional needs and maintaining essential ecosystem services, such as pest and disease regulation. Genetic diversity gives rise to the diverse characteristics that enable different plants and animals to fulfill different roles in the environment. Their genetic make-up also influences how they will respond to environmental challenges, such as extreme temperatures, drought, flooding and pests and diseases; it also regulates the length of the growing season and production cycle and the sensitivity of organisms to inputs, such as fertilizer, water and feed. Genetic resistance to pests, diseases and drought found within crop and animal genepools, have been key priority of conservation and breeding programmes to improve crops varieties and animal breeds.

High diversity of genetic resources may appear redundant at one point in time, it however may become important when the environment changes. Such redundancy will allow for the continued functioning of the ecosystem and the provisioning of ecosystem services because different genotypes perform slightly different roles and occupy different environmental niches (Lin, 2011). This is why the diversity of genetic resources for food and agriculture is essential for maintaining and enhancing the efficiency and the resilience of agro-ecosystems and food systems.

Centuries of selection and domestication by farmers and breeders, combined with natural selection, have led to the development of thousands of varieties of crops. For generations, this rich diversity has allowed people to obtain food and sustain their livelihoods in difficult terrain and under extreme climatic conditions. It has helped agricultural communities to cope with unexpected changes. Likewise, rural communities have developed livestock breeds that can support livelihoods in some of the most inhospitable areas on Earth, from Arctic tundras and high mountains to hot dry deserts, where crop production is often difficult or impossible (see also Module 8 on livestock).

However, genetic diversity is being lost at an alarming rate. Among the main threats to biodiversity are climate change, loss of natural habitats and environmental degradation. Changes in consumer demand and the use of only a few species, varieties and breeds also contribute to genetic erosion. For example, it is estimated that currently only 30 crops provide over 90 percent of human food energy needs, and just five of them (rice, wheat, maize, millet and sorghum) provide about 60 percent of the energy intake of the world's population (FAO, 2010c). While the number of plant species that supply most of the world's energy and protein is relatively small, the diversity within these species is often immense. For example, there are an estimated 100 000 distinct varieties of the rice species Oryza sativa. Farming communities in the Andes cultivate more than 175 locally named potato varieties (FAO, 2009). In addition there are 50 000 to 60 000 species of crop wild relatives which are potential gene donors for crop improvement. It is this diversity within species that allows for the cultivation of crops across many different regions and under many different environmental conditions (see also Module 7 on crop production systems).


©FAO/PJ Mahler

Of the approximately 8 300 recorded livestock breeds, 22 percent are at risk of extinction, and 8 percent have already become extinct (FAO, 2012a). Food production from livestock is also heavily concentrated in a small group of species. While more than 30 mammalian and bird species have been domesticated, three species (cattle, chickens and pigs) account for about 88 percent of the world's annual meat production from livestock, two species (cattle and buffaloes) for about 96 percent of milk production and just one species (chickens) for about 92 percent of egg production (figures for 2011 as recorded in FAO's statistical database FAOSTAT).

The world's aquatic ecosystems contain over 175 000 species of fish, molluscs, crustaceans and aquatic plants (FAO, forthcoming). The widespread domestication and selection in aquatic species has only recently begun, but rapid progress is being made. FAO estimates that over 350 species of fish and aquatic invertebrates and plants are farmed around the world. However, only ten species (comprised of shellfish, crustaceans, plants and fin fish) account for half of the total aquaculture production (FAO, 2013a). The processes of domestication and selection have created significant inter- and intra-specific diversity (see also Module 10 on fisheries and aquaculture).

Forests are home to over 80 percent of terrestrial biodiversity. Genetic diversity provides the fundamental basis for evolution of forest tree species, enabling them to adapt to changing and adverse conditions (see also Module 9 on forestry). There are over 80 000 tree species, but less than one percent of these have been studied in any depth for their present and future potential. As a result of pressure on forest lands and the effects of unsustainable use of forest resources, the great potential of forest genetic resources, including their potential for coping with climate change, is at risk of being lost forever, before it can be identified, let alone utilized (FAO, 2013c).

Micro-organisms (e.g. bacteria and fungi) and invertebrates (e.g. insects, arachnids and earthworms) are the most numerous groups of species on Earth. They contribute to the delivery of essential ecosystem services, including regulating services, such as disease and pest control; and supporting services, such as the decomposition of organic matter and nitrogen fixation, which contribute to maintaining healthy soils. Micro-organisms and invertebrates are also essential in many food and agro-industrial processes, including fermentation (e.g. for yoghurt and cheese) and bioremediation, (e.g. the use of micro-organism metabolism to remove pollutants or other contaminants). Pollination services by animals, especially insects, affect 35 percent of the world's crop production and increase the outputs of 87 of the world's leading food crops (FAO, 2013b).

The exchange of genetic material among farmers, local communities and breeders has been common practice in the food and agriculture sector. Production systems and technologies, including their associated genetic diversity, have frequently been transferred to other countries and regions. As a result, a significant part of the genetic diversity used in food and agriculture today is of exotic origin, and few countries are self-sufficient in terms of their genetic resources for food and agriculture (Palacios, 1998). Most countries need to access genetic resources from elsewhere for their agricultural production and food security. Consequently, these countries should be regarded as interdependent when it comes to genetic resources. In the future, it can be expected that the challenges posed by climate change will increase the trend towards greater international exchange of genetic resources for food and agriculture (Schloen *et al.*, 2011).

6.2 Genetic resources for food and agriculture: a prerequisite for climate-smart agriculture

Climate change and genetic resources for food and agriculture have a two-way relationship. On the one hand, climate change severely threatens genetic resources. On the other hand, there is a growing recognition that conserving and using genetic diversity is essential for coping with climate change.

Climate change puts stress on and poses many risks to genetic resources for food and agriculture. In general, climate change is expected to change species distribution, population sizes, community composition, the timing of biological events and the behaviour of many species. Climate change will also affect ecosystem dynamics in various ways. Potential consequences include asynchrony between crop flowering and the presence of pollinators, and increasingly favourable conditions for invasive alien species, pests and parasites. As ecosystems change, the distribution and abundance of disease vectors are likely to be affected, which will have consequences for the epidemiology of many crop and livestock diseases (Pilling and Hoffmann, 2011; Jarvis *et al.*, 2009).

Climate change threatens the crop and animal genetic resources that might be used in adapting production systems to future conditions. On the one hand, extreme weather events (e.g. heat waves, droughts and floods), which are predicted to increase in frequency because of climate change, can pose an immediate threat to the survival of breeds and varieties that are only raised in specific and very limited areas. On the other hand, as conditions change, varieties and breeds may be abandoned by farmers and livestock keepers, and may be lost forever if steps are not taken to ensure their conservation.

Climate change scenarios also indicate that genetic resources for food and agriculture will need to move geographically, even from one country to another. The knowledge needed for the most appropriate use of those genetic resources, whether scientific, traditional or indigenous, will also need to be shared and made available to new users. The transfer of resources and knowledge will not simply be a natural and spontaneous process. It will need to be implemented and supported by effective international cooperation.

Natural forests are unlikely to be able to migrate quickly enough to "follow" the climates to which they are adapted. At least in the short term, natural forests will have to rely on "plasticity", the peculiar ability of trees to change their characteristics in response to changes in the environment without changing their genetic structure. In the future, some assisted migration is likely to be necessary. For example, trees can be grown in plantations, either as seeds or seedlings, and transported to sites where the future climate is expected to match their requirements. Although assisted migration of tree species and populations within species is recognized as a potentially important response to climate change, the approach has not yet been widely used. The example presented in Box 6.1 is an exception (Loo *et al.*, 2011) (see also Module 9 on forestry).

Box 6.1
Changes in seed transfer guidelines in response to climate change: an example from Canada

During the 1980s, the Canadian province of British Columbia adopted the concept of seed zones. Provenance trials were established for commercially important tree species, and the province's forest land was classified on the basis of geography, climate and vegetation. The boundaries of seed zones were identified by relating the adaptive characteristics of the tree populations to the ecological classification of the land.

Increasing concern about the effects of climate change led to a new approach in which the potential effects of climate change were assessed using an ecosystem-based climate envelope model. The results predicted that tree species whose northern range limit lies in British Columbia could gain suitable new habitat at a rate of at least 100 kilometers per decade.

On the basis of this and similar work, seed transfer policies in the province were re-examined and British Columbia now claims to be the first jurisdiction to have modified seed transfer standards specifically in response to climate change. The modest modification allows seeds of most species in most areas to be moved 100 to 200 meters upwards in elevation. The new policy is an implicit recognition of the need for assisted migration to ensure that tree plantations in the province will be adapted to future climatic changes.

Sources: Ying and Yanchuk, 2006; Hamann and Wang, 2006; Wang *et al.*, 2006; British Columbia Ministry of Forests, Lands and Natural Resource Operations, 2008

However, in some cases, moving existing genetic resources for food and agriculture and knowledge will not be enough. There will be a constant need to improve the level of characterization, selection, reproduction and deployment in the field of the suitable genetic resources adapted to the new climate. These activities will need targeted and forward-looking investments. Generating new knowledge in this area will increasingly be essential to cope with climate change in the future.

Genetic resources for food and agriculture will continue to represent key resources for building the resilience of agro-ecosystems and providing suitable varieties and breeding stocks with which to adapt production to changing conditions, in particular, changing climatic conditions. Crops, animals and other genetic resources that the world relies on to ensure food security and nutrition will need to adapt to the impacts of climate change. The conservation and sustainable use of a wide range of genetic diversity are fundamental in developing resilience to shocks, shortening production cycles and generating higher yields, ideally with better quality and higher nutritional content. Breeding activities need to continue addressing a variety of factors to ensure that genetic resources for food and agriculture are able to adapt to new production conditions.

The traits that may be important for climate change adaptation include:

- capacity to tolerate high temperatures and droughts;
- fire resistance and tolerance, especially for trees;
- resistance or tolerance to diseases and parasites;
- capacity to utilize scarce and poor quality feed and soil;
- tolerance to lower water quality, especially for aquatic organisms (e.g. lack of available oxygen, acidification, increased or reduced salinity, increased turbidity and siltation, increased levels of pollutants);
- in livestock, capacity to range over harsh terrain in search of feed and water;
- phenotypic plasticity; and
- fecundity and fertility rates.

The nutrient contents of different varieties and breeds can vary considerably and can play a significant role in food security and nutrition. Nutritional value should be considered in breeding activities. Commonly consumed species and varieties are not necessarily the ones with the richest nutrient contents. For example, potato is a predominant staple in some countries. There are over 5 000 varieties of potatoes, and nutrient contents vary significantly among these varieties. Iron content of different varieties of potatoes ranges from 0.14 to 10.4 milligrams per 100 grams edible portion. This wide variation in iron content can lead to significant differences in the iron nutritional status of consumers (Burlingame *et al.*, 2009).

The use of the appropriate genetic resources for food and agriculture will help farmers, pastoralists, fisher folk, fish farmers and forest managers to reduce their vulnerability to risks associated with climate change (e.g. harvest losses due to pests, diseases or droughts) and improve their livelihoods.

Aquatic ecosystems and their biota account for the largest carbon and nitrogen fluxes on the planet and serve as its largest carbon sinks (Pullin and White, 2011). In addition, the role that natural forests and tree planting can play in mitigating climate change through carbon sequestration has been widely recognized. However, the significance of genetic variation within species is less well appreciated. Trees can only provide mitigation services if they are well adapted to their surroundings and have the potential to adapt to future changes. Moreover, in the case of smallholder agro-forestry systems, trees will only become established if they provide clear livelihood benefits. Current payment mechanisms to reward farmers for sequestrating carbon by growing trees are generally inefficient and provide only limited rewards. The main reason farmers plant trees will continue to be the desire to obtain the products and services directly provided by the trees. The genetic attributes that enable the trees to provide these products and services are crucial (Loo *et al.*, 2011).

Micro-organisms play an important role in the sequestration of carbon in soil organic matter. They also release carbon in the form of carbon dioxide (CO_2) when soil organic matter decomposes. Given the enormous amount of carbon stored in the world's soils, micro-organisms are extremely significant to climate change mitigation (see also Module 4 on soils). Their contribution to carbon sequestration can be promoted by practices such as amending soil with organic fertilizers, the proper management of crop residues, no-tillage agriculture, maintaining cover crops on the soil surface, avoiding flood irrigation and carefully managing the use of fertilizers (Beed *et al.*, 2011).

The report of the Intergovernmental Panel on Climate Change (IPCC) indicates that agriculture contributes about 47 percent and 58 percent of total anthropogenic emissions of methane (CH_4) and nitrous oxide (N_2O), respectively. However, there is a range of uncertainty in the estimates. The main sources of non-CO_2 emissions from agriculture are CH_4 from enteric fermentation (38 percent) and N_2O emissions from soils (32 percent) (IPCC, 2007). Globally, cattle are the major source for enteric CH_4 emissions. Dietary manipulation and improved feeding systems can reduce CH_4 emissions and nitrogenous emissions and contribute to climate change mitigation. A better understanding of the micro-organisms involved in the digestive processes in the rumen will provide a basis for interventions that improve the efficiency of digestion and reduce the amount of pollutants produced by ruminant livestock (McSweeney and Mackie, 2012) (see also Module 8 on livestock).

Using and conserving genetic resources for food and agriculture

In agricultural systems, breeds and varieties of livestock and crops that are abandoned by farmers or pastoralists (i.e. are no longer used for production) often face the risk of extinction. The abandonment of particular genetic resources can be caused by increasing availability and popularity of alternative varieties or breeds (usually those developed through intensive breeding programmes), changes in consumer demand and changing agricultural practices and production systems.

When the survival of breeds or varieties is threatened because they are falling out of use, efforts should be made, where feasible, to promote alternative uses for them. In this regard, there are opportunities, particularly in developed countries, to develop niche markets for specialized products (see Box 6.2) and to use grazing animals in the management of landscapes and wildlife habitats.

Box 6.2
Marketing to promote locally adapted breeds and improve livelihoods

Throughout the world and over centuries, small-scale livestock keepers and pastoralists have developed animal breeds that are well-suited to local conditions. Hardy and disease-resistant, many of these breeds can survive on little water and scant vegetation. They can continue producing meat and milk in areas where modern, imported breeds cannot survive without expensive housing, feed and veterinary care. Traditional breeds allow people in inhospitable areas to earn a living and maintain valuable traits for future breeding efforts. However, these breeds are often in danger of disappearing, pushed out by modern production techniques and more competitive exotic breeds. Finding niche markets for these products is one way of ensuring the survival of these breeds and enabling the people who keep them to earn more.

FAO has compiled eight cases from Africa, Asia and Latin America where outside interventions have attempted to develop markets for specialty products from locally adapted breeds. The products include wool, cashmere, meat, hides, milk and dairy products, from dromedaries, Bactrian camels, sheep and goats. The countries included in the case studies are Argentina, India, Kyrgyzstan, Mauritania, Mongolia, Somalia and South Africa. Some of the initiatives targeted urban markets within the country; others were aimed at export markets.

Source: FAO, 2010a

The use of genetically diverse varieties and breeds should be promoted as it improves the resilience of agro-ecosystems, preserves future breeding options and helps to reduce genetic erosion. Broadening the accessible genetic resource base enables more effective management of genetic resources for food and agriculture. For example, a wide range of accessible plant genetic diversity allows farmers to change crops, varieties and farming systems to meet changing climate conditions (Asfaw and Lipper, 2011).

A number of traditional production systems increase the diversity of genetic resources and employ specific techniques for ensuring their optimal use. These systems can influence the agro-ecosystem in such a way that it becomes more able to cope with some of the expected secondary effects of climate change. Rice-fish agricultural systems, which co-evolved with wet rice cultivation in China about 2 000 years ago, are an example (see Box 6.3). These systems are sustainable and can provide a valuable source of protein, especially for subsistence farmers practising rainfed agriculture.

Box 6.3
Rice-fish agriculture systems in China

The rice-fish cultural system is practised in a mountainous area of the southern Zhejiang province in China, in Longxian Village in Qingtian County. In this system, rice fields are irrigated using gravity-fed methods that draw water from streams. Fish swim though the streams and live in the paddies.

The system creates an ecological symbiosis. Fish provide nutrition and fertilizer to rice, regulate micro-climatic conditions and eat larvae and weeds in the flooded fields. Their presence reduces the cost of labour needed for fertilization and pest control. The extension of the shallow water surface in rice fields and the disturbances caused by the activities of the fish help maintain high levels of oxygen in the water, which is essential for fish growth.

Because little or no chemical fertilizers and pesticides are used in the paddy fields, the system also supports the conservation of agricultural biodiversity, including: traditional rice varieties; native breeds of carps (red, black, white); and other wild aquatic species, such as frogs, toads, newts, salamanders, snails, rice field eels and loaches.

By enabling communities to sustain themselves, the rice-fish agriculture systems create favourable eco-environmental conditions that help conserve other crop species cultivated in home gardens (e.g. lotus roots, beans, taro, eggplant, Chinese plums, mulberry and forest tree species of ethno-botanical and medicinal uses).

All the services provided by the rich biodiversity of the rice-fish agricultural system strengthen the resilience of the whole wetland ecosystem. The system can help farmers adapt to changing climate conditions and contribute to the development of climate-smart agriculture. The application of integrated rice-fish farming is now being validated through field activities in Mali and in Burkina Faso, where there is considerable potential for the integration of irrigation and aquaculture (reviewed in Halwart and Dam, 2006).

Source: GIAHS, 2013a

Farmers and herders interact with the ecosystems in which they live. Similarly, domesticated crops and animals also interact with species in the wild. Nomadic and semi-nomadic pastoral systems foster particularly valuable interactions between domestic and wild species.

Box 6.4
Sustainable practices of nomadic pastoralists

In the Islamic Republic of Iran, the highly diverse vegetation of the rangelands has evolved together with the livestock and land management systems of pastoralists. Wildlife has also evolved side by side with nomadism. Nomadic pastoralists describe how throughout time livestock have grazed side by side with wild ungulates.

They speak of "the brotherhood of livestock and wildlife." The Qashqai nomadic pastoralists have sophisticated scouting and early warning systems that enable them to predict droughts, take preventive measures and adopt coping strategies.

Over time, the Qashqai have developed irreplaceable techniques of habitat management and rangeland rehabilitation for maintaining the diversity of bio-ecological systems. Most Qashqais know the names and properties of every botanical species on the rangelands. They can provide comprehensive descriptions of their value for medicine, food, feed and manufacturing, and their place in the ecosystem.

Under the indigenous management systems of the Qashqai, the cutting of living trees, other than in extreme need and with sustainable use in mind, is prohibited and considered a sin. Sustainable use of non-timber products (e.g. gums, medicinal and veterinary plants, vegetable dyes, mushrooms and other edible herbs and fruits) are relied on for subsistence and only occasionally sold at markets.

The Qashqai's sustainable hunting practices have preserved wildlife for centuries. Adaptive methods for capturing and storing water in drylands and maintaining springs and water holes for their livestock have also provided water for wildlife.

Source: GIAHS, 2013c

Mobile systems usually provide pastoralists with the flexibility needed to adapt to changing climatic conditions and erratic and unpredictable availability of resources. Livestock trampling, browsing and seed dispersal, and the deposition of manure on grazing lands and along migration routes, help to maintain rangeland productivity and biodiversity and make the grassland more resilient to changes. The removal or drastic reduction of grazing often results not only in lower long-term productivity, but also changes the landscape, which becomes dominated by shrubs.

In situ conservation

The Convention on Biological Diversity defines *in situ* conservation as the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species on-farm, in the surroundings where they have developed their distinctive properties. This definition encompasses two distinct concepts, namely *in situ* conservation sensu strict (in the strict sense), and on-farm conservation. While *in situ* conservation primarily deals with wild species in natural habitats and ecosystems, on-farm conservation deals with domesticated species in traditional farming systems. However both concepts are generally referred to as *in situ* conservation. By managing organisms in their natural state or within their normal range, *in situ* conservation maintains both the population and the evolutionary processes that enable the population to adapt. *In situ* conservation of wild relatives is most commonly carried out by protecting the sites where important populations of the target species are present and designating these sites as genetic reserves.

Forest tree species are typically long-lived, highly genetically diverse organisms that have developed natural mechanisms (e.g. with huge capacity of dispersal of pollen and of seeds over wide areas) to maintain high levels of intraspecific variation. These mechanisms, combined with native environments that change considerably over time and across wide areas, have contributed to the evolution of forest tree species into some of the most genetically variable organisms on Earth. For forest species, the term circa situm (also "circa situ") has been used to refer to conservation within altered agricultural landscapes (e.g. agroforestry systems, home gardens) outside the species' natural habitat but within its native geographical range (FAO, 2013c).

Genetic resources for food and agriculture play an integral part in agricultural and food production systems. The maintenance and evolution of these genetic resources strongly depend on continued human intervention and, in many cases, on traditional knowledge passed from generation to generation over centuries. Box 6.5 provides an example of how an ancient technique has allowed the conservation and sustainable use of genetic resources essential for food and nutrition security.

Box 6.5
Temperature regulation and soil fertility in the southern Peruvian Andes


©/GIAHS

In the southern Peruvian Andes, over 4 000 metres above sea level, farmers cultivate several varieties of potatoes and other native crops, such as quinoa. They use "raised fields" locally known as waru-waru: a platform of soil surrounded by ditches filled with water. During the day, these water-filled trenches are warmed by sunlight. When temperatures drop at night, the water gives off the heat that protects the crops from frost. The system also helps maintain soil fertility. In the canals, silt, sediment, algae, and plant and animal residues decay into a nutrient-rich muck which can be dug out seasonally and added to the raised beds. This productive and inexpensive technique requires no modern tools or fertilizers. However, it is highly specialized and requires specific expertise and traditional knowledge that has been developed over centuries.

Source: GIAHS, 2013d

Capture fisheries are the only remaining major source of food that is based on wild resources. The sustainable management of these wild resources requires *in situ* conservation. Because they are common property, unmanaged open-access fisheries tend to be overexploited, which has the potential to drive local species into extinction. The private sector, national governments, regional fishery management bodies and scientific institutions are all involved in conserving these resources in their natural environments, so that fisheries can continue to provide the services that communities and economies depend on. Maintaining the health of wild aquatic resources, their gene-pool and the ecosystems that support them will allow fisheries systems and fishers to adapt to new climatic conditions (see also Module 10 on fisheries). Box 6.6 provides an example of a subregional programme for improving fish for aquaculture and protecting native gene pools.

Box 6.6
Tilapia Volta Project in West Africa

The Tilapia Volta Project brings together national fisheries institutions and national environmental institutions from six West African countries (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Mali and Togo). The project protects native gene pools of tilapia by characterizing wild genetic resources, which can also serve as a measure for adapting to climate change, and establishing a conservation plan that includes the identification of conservation zones. At the same time, the project is developing an improved aquaculture strain of Nile tilapia (the cichlid species Oreochromis niloticus), which is one of the two principal species used in West African fish culture and is native to the Volta River Basin. The improved strain will have better production characteristics (e.g. improved growth rates).

Source: FAO, 2010b

When managed in an integrated way, entire agro-ecosystems, including useful species (such as cultivated crops, forages and agroforestry species) and their wild and weedy relatives, can be highly productive and resilient systems (see more on landscapes in Module 2). For example, the Kuttanad Wetland, the only farming system in India in which rice is cultivated below sea level (see Box 6.7), contributes to the conservation of biodiversity and ecosystem services and supports the livelihoods of local communities.

Box 6.7
Kuttanad below-sea-level farming system

In India, local people have transformed the swamps located below sea level, which form the Kuttanad Wetland, into cultivable, fishable and habitable lands. They have done this through the natural reclamation of flood deposits, sediments, sand, silts and the buried remains of timber of huge trees and natural litters. The Kuttanad agro-ecosystem can be categorized into three ecosystems: rice fields (Karapadam); wetlands (Kayal); and buried lands (Kari). The local communities have intelligently and prudently managed these three ecosystems through a farm system that supports a wide variety of plants (e.g. Oryza sativa, Cocos nucifera, Areca catechu, Mangifera indica, Artocarpus hirsuitus, Vigna unguiculata, Sesamun orientale, Musa paradisiaca, and some tuber crops), endemic fish, clams, mangroves and associated species. The rice fields are popularly known as Puncha Vayals, which traditionally favoured only rice cropping, now have turned into diversified cropping and rotational systems with inland and estuarine fish cultivation. The Kuttanad below-sea-level farming system has allowed the development of specific genetic resources that can grow in saline soils and then be conserved on-farm. The sustainable use of these resources and the knowledge that has been generated to manage them represent a local response to community needs that can help famers cope with the impact of climate change.

Source: GIAHS, 2013b

Ex situ conservation

Ex situ conservation is the maintenance of genetic material outside of the natural environment where the species have evolved. This type of conservation maintains the genetic integrity of the material at the time of collecting and is a static form of conservation. Gene banks, botanical gardens and zoos are typical examples of *ex situ* conservation facilities.

When it is not cost-effective or not possible to conserve genetic resources *in situ* or on-farm, the best option is to collect these resources and conserve them in gene banks, where their diversity can be easily made accessible and available. When properly characterised and evaluated, genetic resources from *ex situ* collections can reveal valuable genetic characters (adaptive traits) for adapting agriculture to changing climatic conditions and help farmers cope with potential losses (Snook *et al.*, 2011). The Seeds for Needs project in Ethiopia has demonstrated the value of *ex situ* collections for climate change adaptation (see Box 6.8).

Around 7.4 million samples of crop diversity are stored in 1 750 gene banks around the world (FAO, 2010c). Nevertheless, there is a risk that material conserved in gene banks might get lost. One attempt to provide insurance against the loss of seeds in gene banks, as well as a refuge in which seeds can be safeguarded in the event of large-scale crises, is the Svalbard Global Seed Vault. The seed vault conserves a wide variety of plant seeds in a dry and cold underground cavern. These seeds are duplicate samples, or "spare" copies, of seeds held in gene banks worldwide.

Box 6.8
Seeds for Needs project in Ethiopia

The Seeds for Needs project in Ethiopia uses ex-situ collections to help farmers, mainly women, cope with climate change. The project created climate profiles of all the accessions maintained at the Ethiopian National Genebank's Institute of Biodiversity and Conservation. The accessions most likely to be adapted to future growing conditions in areas with similar environmental profiles were identified using the collecting, characterisation and evaluation data from germplasm collections and Geographic Information System technology. These varieties were then tested by selected farmers who cultivated them based on their own experience, indigenous knowledge and adaptation strategies. After the testing process, the best performing and most adaptable varieties were distributed to farming communities for multiplication with the support of local community gene banks and agribusinesses.

Source: Bioversity International, 2013

For fish species, techniques and technologies for the maintenance of genetic material are in the early stages of development. The common carp (*Cyprinus carpio*) is one of the oldest cultured and most widely domesticated fish in the world. It has been cultured in China for more than 2 500 years (Zhu *et al.,* 2005). The species is very adaptable both in the wild and in aquaculture (Bakos and Gorda, 2001). In Hungary, the genetic improvement of common carp started in 1962 at the Research Institute for Fisheries, Aquaculture and Irrigation (Bakos, 1964). The Institute presently has a live gene bank that includes 15 Hungarian and 15 foreign carp strains (Bakos *et al.*, 2006). Intense research on cross-breeding has led to the development of three top productive hybrids for different conditions in fish farms and natural waters (Bakos and Gorda, 1995).

In aquaculture, the domestication of species and the development of breeds suited for aquaculture are of high importance because they allow for a more efficient utilization of resources. In farm crops and in livestock, the process of selecting valuable traits has been going on for centuries. In the aquaculture sector, however, this process is in its infancy, and selective breeding programmes remain highly dependent on inputs from wild genetic resources.

In the case of animal genetic resources, *ex situ* conservation usually involves *in vitro* cryoconservation of gametes or embryos in a gene bank. Cryoconservation can be supported by *ex situ – in vivo* conservation. This involves the conservation of a limited number of live animals in a small breeding herd or a zoo. Under these conditions, animals are kept outside their original production environment and their ability to adapt to changing conditions is impaired. *Ex situ* conservation is a cost-intensive process. In most developing countries, it cannot be undertaken without international support (FAO, 2007).

Integrating *in situ* and *ex situ* conservation

For specific genetic resources, some conservation systems may be more effective than others. However, a complementary conservation strategy that uses a combination of *ex situ* and *in situ* techniques is most likely to safeguard genetic diversity. In this conservation strategy, the establishment of on-farm conservation programmes and protected areas is complemented by genebanks and other *ex situ* conservation systems.

Over the last decade, a number of initiatives at national and international levels have succeeded in promoting on-farm management in farmers' fields. They have also identified specific sites and priority activities suited for the *in situ* conservation of crop wild relatives where these wild resources are at risk. One of the operational systems that support such initiatives is the Benefit Sharing Fund of the International Treaty on Plant Genetic Resources for Food and Agriculture, which was established as a direct international response to the challenges of climate change and food security. The Treaty's Multilateral System ensures access to the wide range of plant genetic diversity needed to respond to the ecological and socio-economic challenges faced by agriculture. In Peru for example, farming communities have established a potato park, where potato genetic diversity is protected *in situ* by local indigenous people. These communities have benefited from seed exchange and the *ex situ* conservation of many varieties that had disappeared from farmers' fields (see Box 6.9).

Box 6.9
Potato park in Peru

Peru's potato park, a unique 12 000 hectare reserve high in the Andes, near Cusco, was established to conserve the region's potato biodiversity, a task that has become increasingly difficult as warming climates have altered the growing patterns of some of the area's local varieties. The reserve is home to six indigenous Quechua communities whose 8 000 residents own the land and control access to local resources, but manage their communal lands jointly for their collective benefit. The communal activities are spearheaded by an organization known as the "guardian of native potatoes", the Papa Arariwa Collective.


©FAO/Sandro Cespoli

In the potato park, which is located within a microcenter of origin for potatoes, a typical family farm grows 20 to 80 varieties. Most of these varieties are grown for local consumption or regional barter. As the climate becomes warmer, local potato farmers have begun experimenting with different varieties at higher altitudes where temperatures are lower. The farmers are using many varieties that had disappeared from their fields but that had been conserved in the gene bank of the International Potato Center. The Benefit-sharing Fund of the International Treaty on Plant Genetic Resources for Food and Agriculture is working with the local farmers to repatriate varieties from the genebank into their fields. More than 1 345 varieties can be found in the Potato Park: 779 were collected locally; 410 were repatriated from the International Potato Center; and 157 were received through seed exchanges. The fact that these varieties were disease-free helped increase yields. The popularity of the older potato varieties increased thanks to marketing efforts and the increased attention these varieties received. The conservation of these potato varieties through in situ utilization will provide invaluable support to local communities in adapting to climate change.

Source: Farmers' Rights, 2013

Many plant and animal species found in wild ecosystems are valuable for food and agriculture, or play an important cultural role in local societies. They can provide a safety net when food is scarce. Moreover, they are increasingly being marketed locally and internationally, which provides an important contribution to local household incomes. Integrating *in situ* and *ex situ* conservation techniques is an effective strategy for the conservation of wild relatives and species harvested from the wild. While *in situ* conservation is generally the strategy of choice for these species, this should be backed up by *ex situ* programmes, which can greatly facilitate their use.

6.3 Concluding remarks

The genetic diversity of living species is a precious and irreplaceable resource that humankind needs to continue valuing, conserving and using. Genetic resources for food and agriculture safeguard agricultural production and provide options for coping with climate change (e.g. seeds with higher yields, better quality, earlier maturity, better adaptation and higher resistance to diseases, insects, and environmental stress). Domesticated species, breeds and varieties and their wild relatives will be the main source of genetic resources for adaptation to climate change. *In situ* and *ex situ* conservation and sustainable use of genetic resources for food and agriculture and their wild relatives will be critical for the development of climate-smart agriculture. With the interdependence of countries increasing, the transfer of genetic resources and the knowledge related to their use needs to be supported through effective cooperation between countries. The fair and equitable sharing of benefits arising from the use of genetic resources also needs to be properly addressed.

Notes

This module was written by Damiano Luchetti, Ehsan Dulloo, Anna Asfaw and Linda Collette (FAO) with contributions by Devin Bartley, Cassandra De Young, Mary Jane Dela Cruz, Matthias Halwart, Kathrin Hett, Irene Hoffmann, Mario Marino, Albert Nikiema, Dafydd Pilling, Beate Scherf, Doris Soto, Kim-Anh Tempelman and Álvaro Toledo (FAO) in coordination with the Secretariat of the Commission on Genetic Resources for Food and Agriculture and FAO's inter-departmental working group on biodiversity.

Acronyms

CO_2	carbon dioxide
CH_4	methane
GIAHS	Globally Important Agricultural Heritage Systems
IPCC	Intergovernmental Panel on Climate Change
N_2O	nitrous oxide

References

Asfaw, S. & Lipper, L. 2011. *Economics of PGRFA management for adaptation to climate change: a review of selected literature.* FAO Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 60.

Bakos, J. 1964. *Comparative testing of common carp strains at Fish Culture Research Institute, Szarvas (in Hungarian), Halászat.*

Bakos, J. & Gorda, S. 1995. *Genetic improvement of common carp strains using intraspecific hybridization.* Aquaculture, 129: 183–186.

Bakos, J. & *Gorda, S.* 2001. Genetic resources of common carp at the Fish Culture Research Institute. Szarvas, Hungary. FAO Fisheries Technical Paper. No. 417. Rome, FAO. 106p.

Bakos J., Varadi, L., Gorda, S. & Jeney, Z. 2006. *Lessons from the breeding program on common carp in Hungary.* In R.W. Ponzoni, B.O. Acosta, A.G. Ponniah, eds. Development of aquatic animal genetic improvement and dissemination programs: current status and action plans, pp. 27–33. WorldFish Center Conferences Proceedings. (available at http://www.worldfishcenter.org/resource_centre/Development%20of%20Aquatic_1.pdf)

Beed, F., Benedetti, A., Cardinali, G., Chakraborty, S., Dubois, T., Garrett, K. & Halewood, M. 2011. *Climate change and micro-organism genetic resources for food and agriculture: state of knowledge, risks and opportunities.* Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 57.

Bioversity International. 2013. *Seeds for needs project.* (available at http://www.bioversityinternational.org/research/sustainable_agriculture/seeds_for_needs.html)

British Columbia Ministry of Forests, Lands and Natural Resource Operations. 2008. *Amendments to the standards: climate based upward elevation changes.* (available at http://www.for.gov.bc.ca/code/cfstandards/amendmentNov08.htm)

Burlingame, B., Mouillé, B. & Charrondière, R. 2009. *Nutrients, bioactive non-nutrients and anti-nutrients in potatoes.* Journal of Food Composition and Analysis, 22(6): 494–502.

FAO. 2007. *The state of the world's animal genetic resources for food and agriculture, B.* Rischkowsky & D. Pilling, eds. FAO Commission on Genetic Resources for Food and Agriculture. Rome.

FAO. 2009. *Plant genetic resources: use them or lose them.* FAO Commission on Genetic Resources for Food and Agriculture Factsheet. Rome.

FAO. 2010a. *Adding value to livestock diversity: marketing to promote local breeds and improve livelihoods.* League for Pastoral Peoples and Endogenous Livestock Development, Life Network, International Union for Conservation of Nature & FAO. Rome.

FAO. 2010b. *Practical regional concerns involving the development and distribution of improved aquaculture seed.* Committee for Inland Fisheries and Aquaculture of Africa.

FAO. 2010c. *Second report on the state of the world's plant genetic resources for food and agriculture.* FAO Commission on Genetic Resources for Food and Agriculture. Rome.

FAO. 2012a. *Status and trends of animal genetic resources: 2012.* Intergovernmental Technical Working Group on Animal Genetic Resources for Food and Agriculture. FAO Commission on Genetic Resources for Food and Agriculture. Rome.

FAO. 2013a. *FishStat plus.* (available at http://www.fao.org/fishery/statistics/software/fishstat/en)

FAO. 2013b. *Pollinators.* (available at http://www.fao.org/biodiversity/components/pollinators/en/)

FAO. 2013c. *The state of the world's forest genetic resources.* FAO Commission on Genetic Resources for Food and Agriculture. Rome.

FAO. Forthcoming. *Improving the information base for aquatic genetic resources for the state of the world's aquatic genetic resources.* FAO Expert Workshop, 1-4 March, 2011. Madrid.

Farmers' Rights. 2013. *Best practices: the Peruvian potato park.* (avaialble at http://www.farmersrights.org/bestpractices/success_benefit-sharing_7.html)

Globally Important Agricultural Heritage Systems (GIAHS). 2013a. *Favourable eco-environmental conditions through rice-fish culture in China.* (available at http://www.giahs.org/giahs-sites/south-east-asia/rice-fish-culture-china/en/)

GHIAS. 2013b. *Kuttanad below sea-level farming system.* (available at http://www.giahs.org/sites/south-east-asia/kuttanad-below-sea-level-farming-system-india/en)

GIAHS. 2013c. *Qashqai nomadic pastoralism, Iran.* (available at http://www.giahs.org/sites/middle-east-and-central-asia/qashqai-nomadic-pastoralism-iran/detailed-information/en/)

GHIAS. 2013d. *Temperature regulation and soil fertility in southern Peruvian Andes.* (available at http://www.giahs.org/sites/central-and-south-america/andean-agriculture-peru/en/)

Halwart, M. & Dam, A.A.V. 2006. *Integrated irrigation and aquaculture in West Africa: concepts, practices and potential.* Rome, FAO. 181 pp.

Hamann, A. & Wang, T. 2006. *Potential effects of climate change on ecosystem and tree species distribution in British Columbia.* Ecology, 87(11): 2773–2786.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate change 2007: mitigation of climate change.* Contribution of Working Group III to the Fourth Assessment Report of the IPCC.

Jarvis, A., Upadhyaya, H., Gowda, C.L.L., Aggarwal, P.K., Fujisaka, S. & Anderson, B. 2009. *Climate change and its effect on conservation and use of plant genetic resources for food and agriculture and associated biodiversity for food security.* FAO Thematic Background Study.

Lin, B.B. 2011. *Resilience in agriculture through crop diversification: adaptive management for environmental change.* Bioscience, 61: 183–193. American Institute of Biological Sciences.

Loo, J., Fady, B., Dawson, I., B. Vinceti & G. Baldinelli. 2011. *Climate change and forest genetic resources: state of knowledge, risks and opportunities.* FAO Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 56. Rome.

McSweeney, C., & Mackie, R. 2012. *Micro-organisms and ruminant digestion: state of knowledge, trends and future prospects.* FAO Commission on Genetic Resources for Food and Agriculture. CGRFA Background Study Paper No. 61. Rome.

Palacios, X.F. 1998. *Contribution to the estimation of countries' interdependence in the area of plant genetic resources.* FAO Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 7 rev 1. Rome.

Pilling, D. & Hoffmann, I. 2011. *Climate change and animal genetic resources for food and agriculture: state of knowledge, risks and opportunities.* FAO Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 53. Rome.

Pullin, R. & White, P. 2011. *Climate change and aquatic genetic resources for food and agriculture: state of knowledge, risks and opportunities.* FAO Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 55. Rome.

Schloen, M., Louafi, S. & Dedeurwaerdere, T. 2011. *Access and benefit-sharing for genetic resources for food and agriculture: current use and exchange practices, commonalities, differences and user community needs.* Report from a Multi-Stakeholder Expert Dialogue. FAO Commission on Genetic Resources for Food and Agriculture Background Study Paper No. 59. Rome.

Snook, L., Dulloo, M. E., Jarvis, A., Scheldeman, X. & Kneller, M. 2011. *Crop germplasm diversity: the role of gene bank collections in facilitating adaptation to climate change.* Chapter 25. In S.S Yadav, R. Redden, J.L. Hatfield, H. Lotze-Campen and A. Hall, eds. Crop Adaptation to Climate Change. John Wiley & Sons, Inc.

Wang, T., Hamann, A., Yanchuk, A., O'Neill, G. A. & Aitken, S.N. 2006. *Use of response functions in selecting lodgepole pine populations for future climates.* Global Change Biology, 12(12): 2404–2416.

Ying, C.C. & Yanchuk, A.D. 2006. *The development of British Columbia's tree seed transfer guidelines: purpose, concept, methodology, and implementation.* Forest Ecology and Management, 227: 1–13.

Zhu, J., Wang, Gong, Y. & Chen, J. 2005. In D.J. Penman, M.V. Gupta & M.M. Dey, eds. *Carp genetic resources for aquaculture in Asia*. WorldFish Center Technical Report No. 65. 152 p.

MODULE 7:

CLIMATE-SMART CROP PRODUCTION SYSTEM

Overview

Climate-smart crop production contributes to food security, by addressing different aspects of current and projected climate change impacts through adaptation and mitigation actions. While agriculture contributes significantly to climate change, it also provides opportunities for adapting to, and mitigating, climate change effects. The first part of this module outlines the impacts of climate change on crop production. The second part describes the sustainable crop production intensification (SCPI) paradigm and illustrates how sustainable agriculture is inherently "climate-smart." In describing the underlying principles of SCPI, the module draws heavily on the FAO publication *Save and Grow*. *Save and Grow* — a rich source of information, case studies and technical references — was produced following an Expert Consultation held in 2010: it is a guide and toolkit of sustainable technologies and practices, but also explores the policies and institutional arrangements for the large-scale implementation of SCPI. The module also describes options for land managers and farmers to adapt, and contribute to the mitigation of climate change. Text boxes provide examples of sustainable crop production practices, techniques and approaches for climate change adaption and mitigation.

Key messages

- Unpredictable and erratic climatic patterns resulting from climate change will affect crop production. This will have an impact on farmer livelihoods and food availability. Climate-smart crop production provides management options to farmers to both adapt to, and mitigate, climate change.
- Climate-smart agriculture (CSA) is sustainable agricultural production "seen from the lens" of climate change. Sustainable crop production looks at reducing reliance on non-renewable external inputs, and capitalizing on/enhancing natural biological processes to improve production in a more environmentally-friendly way and avoiding degradation of production relevant natural resources.
- To cope with the challenges of climate change, crop production must adapt (e.g. crop varietal selection, plant breeding, cropping patterns and ecosystem management approaches) and become resilient to changes (frequency and intensity).
- Crop production can contribute to mitigating climate change by reducing greenhouse gas (GHG) emissions - for example by reducing the use of/judiciously using inorganic fertilizers, avoiding soil compaction or flooding to reduce methane emissions (e.g. in paddy rice systems) and sequestering carbon (e.g. planting perennial crops and grass species).
- Farmers are the primary custodians of knowledge about their environment, agro-ecosystems, crops and cropping patterns, and local climatic patterns. Adapting cropping practices and approaches will be related to local farmers' knowledge, requirements and priorities. Sustainable crop production provides farmers with options for farming sustainably, taking into account the local ecosystem.
- Integrated approaches — such as crop-livestock systems, rice-fish systems and agroforestry — diversify food sources and consequently strengthen the resilience of farmers' livelihoods. They also provide opportunities for mitigating climate change.
- CSA needs to be strongly supported by sub-national and local policies. Agricultural ecosystems are site specific, with their own environmental, social and economic specificities.

Contents

List of Figures

List of Tables

List of Boxes

7.1 Introduction

Crop production, which is vital to global food security, is being affected by climate change all over the world. However, the impact is being felt more severely in the more impoverished communities. It has been predicted that over the next decades, billions of people, especially those living in developing countries, will face shortages of water and food and greater risks to health and life because of climate change. With fewer social, technological and financial resources for adapting to changing conditions, developing countries are the most vulnerable to the impacts of climate change (UNFCCC, 2007).

Although some crops in some regions of the world may benefit, the overall impacts of climate change on agriculture are expected to be negative (IFPRI, 2009). For example, climate variability and the frequency of extreme climatic events, such as droughts and flooding, will affect precipitation. Higher temperatures may affect yields in a negative way and favour the growth of weeds and the proliferation of crop pests. In many areas, rising sea levels also will hamper crop production. Furthermore, crop failures and long-term declines in productions will occur. The impact of climate change will hit developing countries the hardest, and it is in these countries where food security will be most threatened.

7.2 Climate change impacts

The successes and failures of crops have always been subject to prevailing environmental factors, and the mechanisms for managing the stresses created by these factors continue to be the subject of extensive studies in a variety of disciplines. Crop production is increasingly vulnerable to risks associated with new and evolving climatic changes. These are variations in environmental conditions that pose significant challenges to farmers, over and beyond those that are experienced 'normally.' The planet is facing more extreme weather events, such as heavy precipitation, higher coastal waters, geographic shifts in storm and drought patterns, and warmer temperatures (IPCC, 2012).

Climate change is expected to cause substantial crop reductions in southern Africa (up to 30 percent by 2030 for maize production) and South Asia (up to 10 percent for staples, such as rice, and more than 10 percent for millet and maize) (Lobell *et al.*, 2008). In mid- to high-latitudes, depending on the crop, productivity may increase slightly with increases in local mean temperatures of up to 1–3 degrees Celsius. At lower latitudes, crop productivity will decrease even with a relatively minor change in temperature (IPCC, 2007). Localized extreme events and sudden pest and disease outbreaks are already causing greater unpredictability in production from season to season and year to year, and require rapid and adaptable management responses (FAO-PAR, 2011).

By 2050, it is predicted that the global population will be over 9 billion people, increasing the demand for food and other agricultural products. At the same time, the world faces challenges such as land and water scarcity, increased urbanization, and climate change and volatility. Agricultural production remains the main source of income for most rural communities (about 86 percent of rural people - 2.5 billion), who depend on agriculture for their livelihood (World Bank, 2008). Improving adaptation of the agricultural sector to the adverse effects of climate change will be imperative for protecting and improving the livelihoods of the poor and ensuring food security (FAO, 2012a). In practical terms, climate change adaptation requires more than simply maintaining the current levels of performance of the agricultural sector; it requires developing a set of robust and yet flexible responses that will improve the sector's performance even under the changing conditions brought about by climate change engenders.

Measures must be devised for reducing the negative impacts of agriculture on the ecosystem. Agriculture accounts for 13.5 percent of GHG emissions, or about 1.8 gigatonnes of carbon equivalent per year (Gt C eqv./year) (6.6 Gt carbon dioxide [CO_2] eqv./year), mainly in the form of methane (CH_4) and, more pertinent to crop production, nitrous oxide (N_2O) from fertilized soils, enteric fermentation, biomass burning, flooded rice production (paddy) and manure and fertilizer production (IPCC, 2007).

In addition, overall land use and land use change accounts for about 31 percent of the total human-induced GHG emissions into the atmosphere (Scherr and Sthapit, 2009).

The overall efficiency of the agricultural sector– its resilience, adaptive capacity and its potential for contributing to the mitigation of the effects of climate change and variations– can be enhanced by improving these constituent components. Indeed, by improving the efficiency of agricultural production, emissions can be reduced and sequestration capacity enhanced. Conversely, climate change will have a significant impact on crop production (Table 7.1), but alternative adaptation approaches and practices can address this by helping to reduce the net GHG emissions while maintaining or improving yields (FAO, 2011; Pretty *et al.*, 2011).

Table 7.1
Examples of projected climate change impacts on crop production

Event	Potential impact
Cold periods becoming warmer and shorter; over most land areas, days and nights becoming hotter (*virtually certain*)	Increased yields in colder environments; decreased yields in warmer environments; increased outbreaks of new insect pests and pathogens; potential impacts on crop production
Heavy precipitation events increasing in frequency over most areas (*very likely*)	Damage to crops; soil erosion; inability to cultivate land owing to waterlogging of soils
Drought-affected area increases (*likely*)	Land degradation and soil erosion; lower yields from crop damage and failure; loss of arable land
Intense tropical cyclone activity increases (*likely*)	Damage to crops
Extremely high sea levels increase in incidence (excludes tsunamis) (*likely*)	Salinization of irrigation water, estuaries and freshwater systems; loss of arable land

Source: adapted from IPCC, 2007, in FAO, 2008a

7.3 Sustainable crop production intensification

Crop production has been evolving since the domestication of crop species 10 000 years ago. Varietal selection, the use of wild plants and wild relatives of plants, irrigation techniques, planting methods, cropping patterns and fertilization are some of the practices that have been, and are being, used to improve crop production. In relatively recent times, crop production has increased significantly, providing more food for a growing global population. The best known and documented example of this is the Green Revolution, which swept through much of the developing world during the 1960s. The Green Revolution was characterized by the planting of high-yielding crop varieties, with the associated chemical package and irrigation. As a result, farmers increased cereal food production from 800 million tonnes to over 2.2 billion tonnes between 1961 and 2000. While an estimated one billion people were saved from famine, this has come with a high price tag in the long term. In many countries, decades of intensive cropping have degraded fertile land, depleted groundwater, triggered an upsurge in pests, eroded biodiversity and polluted the air, water and soil. Intensive crop production is no longer sustainable, and a new paradigm should emerge – and this is what *Save and Grow* – i.e. sustainable crop production intensification – is about (FAO, 2011). It means a productive agriculture that conserves and enhances natural resources through an ecosystem approach that capitalizes on natural biological inputs and processes. It reduces the negative impacts on the environment and enhances natural capital and the flow of ecosystem services. SCPI also contributes to increasing systems' resilience – a critical factor, especially in light of climate change.

SCPI can be achieved through good farming practices that are based on improving efficiencies and managing biological processes. It is based on agricultural production systems and management practices that include:

- maintaining healthy soil to enhance soil-related ecosystem services and crop nutrition;
- cultivating a wider range of species and varieties in associations, rotations and sequences;
- using quality seeds and planting materials of well adapted, high-yielding varieties;
- adopting the integrated management of pests, diseases and weeds; and
- managing water efficiently.

SCPI, and the crop production practices and approaches that it entails, is inherently climate smart. The sustainability of crop production systems presupposes that the risks and vulnerabilities arising from climate change are also addressed.

CSA aims at achieving the same food security objectives as sustainable agriculture, but through the lens of climate change.

It is important to understand that crop production, from land preparation through planting to the delivery of produce to the farm gate, constitutes an integral part of a farming system, which in turn is a part of the broader agro-ecosystem and landscape. The actual crop is but one element of an agro-ecosystem. Other elements include soil, biodiversity and ecosystem services— but crops can also be integrated within other production systems, such as agroforestry, integrated crop-livestock and rice-fish systems.

Box 7.1
Integrated crop-livestock systems

In conventional farming systems, there is a clear distinction between arable crops and pastureland. Under SCPI, this distinction is no longer applicable, since annual crops may be rotated with pasture without the destructive intervention of soil tillage (FAO, 2011). Practical innovations have harnessed synergies between crop, livestock and agroforestry production to improve the economic and ecological sustainability of agricultural systems and at the same time provide a flow of valued ecosystem services. Through increased biological diversity, efficient nutrient recycling, improved soil health and forest conservation, integrated systems increase environmental resilience and contribute to climate change adaptation and mitigation. They also enhance livelihood diversification and efficiency by optimizing production inputs, including labour. In this way, integrated systems also increase producers' resilience to economic stresses (FAO, 2011).

Integrated crop-livestock systems imply a diverse range of integrated ecological, biophysical and socio-economic conditions (FAO, 2010a). They aim to increase profits and sustain production levels while minimizing the negative effects of intensification and preserving natural resources (IFAD, 2009). They also have environmental, social and economic benefits. These systems, which enhance the natural biological processes above and below the ground, represent a synergistic combination that: (a) reduces erosion; (b) increases crop yields, soil biological activity and nutrient recycling; (c) intensifies land use, improving profits; and (d) can therefore help reduce poverty and malnutrition and strengthen environmental sustainability (IFAD, 2009).

There are numerous examples of how crop-livestock systems are being implemented. In the Southern Caucasus region, grain and livestock production have been integrated into a system of mixed farming in which cereals and pulses are grown in flatter, better-watered lowland soils and sheep and goats graze and browse on rougher upland terrain (whether locally or by means of seasonal transhumance). This has proven to be effective, both ecologically and nutritionally, in sustaining the growing number of sedentary villages (FAO, 2010b). Also, in Azerbaijan, near Xudat, farmers have adapted to the great diversity of land forms, climate and soils by developing a mosaic of crops and livestock systems. To protect wild biodiversity, soil and water resources, they alternate annual and perennial crops, and avoid cultivating crops in fragile environments (FAO, 2010b).

A priori, crop production is aimed at providing food security, contributing to sustainable diets, supplying raw materials for industries and generally, improving and sustaining livelihoods. The linkages between crop production to wider overarching agricultural production systems and its value in socio-economic contexts are part of the *Save and Grow* paradigm. These relationships and other elements of the production system are largely covered in other modules (see for example Module 1 on general principles of climate-smart agriculture, Module 3 on water management, Module 4 on soil management, Module 5 on energy systems, Module 6 on genetic resources and Module 8 on livestock and crop-livestock systems).

As climate changes, the resilience and adaptive capacity of agricultural production systems and agricultural landscapes will become more important (see Module 2 on climate-smart landscapes and production systems). To become more resilient and better able to adapt to changing conditions, crop production systems will need to rely more on ecological processes that produce positive feedbacks on sustainability and production and ensure improved provision of all ecosystem services (FAO-PAR, 2011). Progress in this area could be made by adopting existing agricultural practices that have already been proven to have multiple benefits for food security and environmental health. However, there are barriers to adoption of these practices that need to be addressed through enabling means (e.g. investments, capacity building, financing, information, research, incentives and supportive policies).

7.4 Underlying principles: management of natural biological processes

Sustainable crop production and climate change adaptation and mitigation in agriculture are not distinct from each other. The management of agro-ecosystems for producing food, fodder and fuel and the management of agro-ecosystems to adapt to and mitigate climate change have the same underlying principles and can work together to achieve the same goal: ensuring that everyone has enough safe, nutritious food now and in the future. Both crop production and climate change adaptation and mitigation require a resilient ecosystem, which can be attained through approaches and practices that are based on the sustainable management of biodiversity and ecosystem services.

Climate-smart crop production is a sustainable crop production system, both of which address climate change. Sustainable agricultural systems provide opportunities for climate change adaptation and mitigation by contributing to the delivery and maintenance of a range of public goods, such as clean water, carbon sequestration, flood protection, groundwater recharge and landscape amenity value. By definition, sustainable agricultural systems are less vulnerable to shocks and stresses. In terms of technologies, productive and sustainable agricultural systems make the best of crop varieties and livestock breeds and their agro-ecological and agronomic management (Beddington *et al.,* 2012).

The negative effects of climate change on productivity are already being felt by the agriculture sector. For example, in India, rice production decreased by 23 percent during 2001–2002 (FAOSTAT, 2012) because of drought. In Indonesia, flooding caused about 1 344 million tonnes of losses in rice production (Redfern *et al.,* 2012). In Mississippi in the United States of America, flooding before the harvest season caused an estimated loss of up to US$ 8 billion in 2008 (USGCRP, 2009). To secure future food production, crop production will need to adapt to and mitigate climate change. To contrast the effects of climate change, there is a need for a better understanding of the biological processes (below and above ground) involved in farm management practices. In this regard, ecosystem management must incorporate measures for building resilience and mitigating risk in agriculture. These elements are becoming increasingly critical under changing climatic conditions.

Box 7.2
System of Rice Intensification in Afghanistan

The System of Rice Intensification (SRI) is a set of farming practices developed to increase the productivity of land, water and other resources (see Annex A.4.1 in Module 4 on soils). SRI is based on the principle of developing healthy, large and deep-root systems that can better resist drought, waterlogging and rainfall variability, all of which are potential impacts of climate change. It has proved particularly beneficial to some areas worldwide as it requires only intermittent water application to create wet and dry soil conditions, instead of continuous flood irrigation. The average increase in income from SRI in eight countries (Bangladesh, Cambodia, China, India, Indonesia, Nepal, Sri Lanka and Viet Nam) has been shown to be around 68 percent with yield increases of 17 to 105 percent and decreases in water requirements between 24 and 50 percent (Africare *et al.*, 2010).

Considering the better growth and performance of rice plants and subsequent increase in yields and productivity of the rice field with SRI elsewhere, in 2011 Afghanistan introduced SRI as an important practice of sustainable rice intensification to the farmers in Farmer Field Schools (FFS). With SRI, yields of up to 7 tonnes per hectare were achieved (PIPM, 2012) – double the farmers' average yields in the area – using 50 percent less water than used in conventional rice cultivation practices in Afghanistan. It has also reduced the use of chemical fertilizers, and there has been no insect or disease infestation at all in SRI fields. The use of SRI is now being extended throughout a number of provinces in Afghanistan as one way to mitigate the effects of unreliable rainfall.

Biodiversity is necessary to sustain key functions of the ecosystem (its structure and process) and provide essential ecosystem services. It is an important regulator of agro-ecosystem functions, not only in the strictly biological sense of its impact on production, but also in satisfying a variety of needs of the farmer and society at large. In particular, biodiversity increases resilience of agro-ecosystems and is, as such, a means for reducing risk and adapting to climate change. Agro-ecosystem managers, including farmers, can build upon, enhance and manage the essential ecosystem services provided by biodiversity as a part of their efforts towards sustainable agricultural production.

The conservation and enhancement of biodiversity in cropping systems both above and below ground (e.g. soil biodiversity – see Box 7.3), and the management of ecosystem services underpin sustainable farming practices. The composition and diversity of planned biodiversity (e.g. selected crops) influences the nature of the associated diversity (plant, animal, microbial) and consequently the delivery of ecosystem services. An ecosystem approach is also a means to integrate planned biodiversity that is maintained with the associated diversity (e.g. wild pollinators – see Box 7.4). For example, greater on-farm diversity of plants, greater soil coverage and more perennial cultivation may build resilience throughout the agro-ecosystem (e.g. resistance to noxious species).

Box 7.3
Biological nitrogen fixation

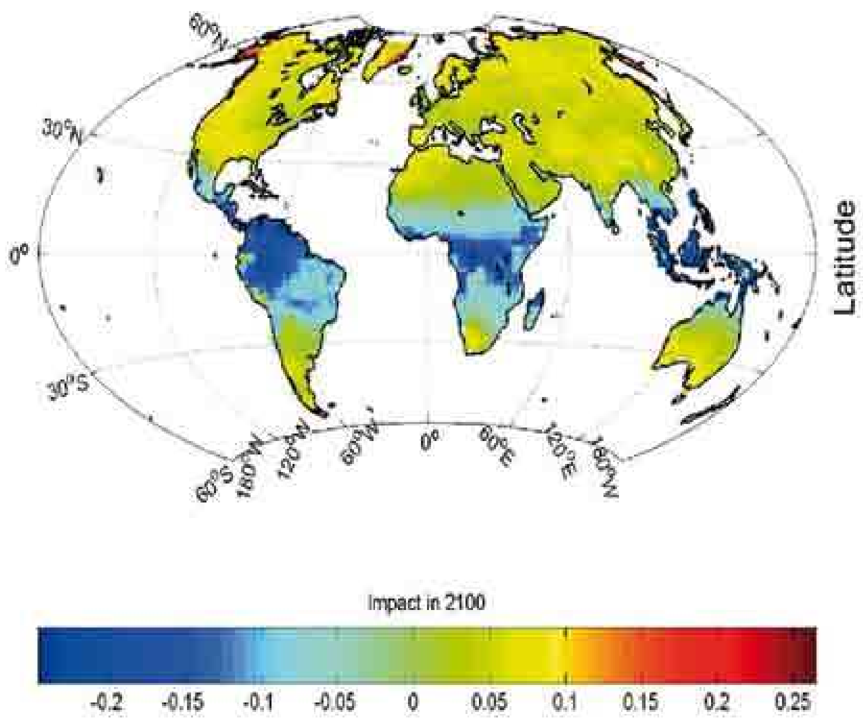
In agricultural systems, some types of microbes can carry out biological nitrogen fixation (BNF) as free-living organisms: heterotrophic and autotrophic bacteria and cyanobacteria. Other micro-organisms can only fix nitrogen through a symbiotic relationship with plants, mainly legume species. In agricultural areas, about 80 percent of BNF is achieved by the symbiotic association between legumes and the nodule bacteria, *rhizobia*. Farmers have some scope to influence BNF, through legume selection, the proportion of legume and grass seed in forage mixtures, inoculation with bacteria such as *rhizobia*, crop nutrition (especially nitrogen and phosphorous), weed, disease and pest controls, planting time, cropping sequence and intensity, and defoliation frequency of forage swards. However, some factors, including unfavourable temperatures and droughts, that affect BNF cannot be controlled. Also some legume species are better at fixing nitrogen than others. In perennial temperate forage legumes, red clover and lucerne can typically fix 200–400 kg of nitrogen per hectare (whole plant fixation, above and below ground).

Source: FAO, 2009a

Box 7.4
Managing ecosystem services: the case of pollination

Over 75 percent of the leading global food crops are dependent on pollination services provided by animals. Pollinators, especially bees, affect 35 percent of the world's crop production. The global economic value of pollination services is estimated to be US$ 214 billion per year (Gallai *et al.*, 2009). However, pollinators can be sensitive to rising temperatures, and crop growth may equally be affected by high temperatures and drought. These changes can potentially cause dysfunctions in plant-pollinator interactions (Kjøhl *et al.*, 2011).

Figure 7.1
Predicted impact of warming on thermal performance of insects in 2100



On the basis of patterns in warming tolerance, climate change is predicted to be most deleterious for insects in tropical zones

Source: Deutsch *et al.*, 2008

In the tropics, most pollinators already live close to their optimal range of temperature tolerance. Increases in temperature, therefore, could have greater negative impacts in tropics, and thus the developing world.

Although more targeted data sampling is needed to better understand the impacts of climate change on pollinators, pollination-friendly management practices contribute building resilience in ecosystems (at the landscape level).

In multiple agro-ecosystems and ecologies, pollinator-friendly management practices have been identified that serve to enhance yields, quality, diversity and resilience of crops and cropping systems. Examples include:

- preserving wild habitat;
- managing cropping systems, flower-rich field margins, buffer zones and permanent hedgerows to ensure habitat and forage;
- cultivating shade trees;
- managing for bee nest sites through such means as leaving standing dead trees and fallen branches undisturbed;
- reducing application of pesticides and associated risks; and
- establishing landscape configurations that favour pollination services.

Pollination management practices can also be undertaken to explicitly build safeguards in response to climate change. Examples of how farming communities may best adapt to climate change impacts on pollinators include giving consideration to the seasonal availability of resources needed by pollinators and ensuring connectivity of natural habitats in farming areas (allowing easier pollinator dispersal for range shifts in response to changing climates).

Source: FAO, 2009a

Agricultural intensification also requires fertile and healthy soils. Nutrient deficiencies and soil-borne pests and diseases are major limiting factors for crop production, especially on degraded soils in large areas of Africa and Southeast Asia. For example, the parasitic weed, *Striga* (Box 7.5), causes less damage when found in healthy soils. Even the damage caused by pests not found in the soil, such as maize stem borers, is reduced in healthy soils.

Box 7.5
Climate change may influence Striga distribution and invasive potential

Striga, considered to be one of the biggest obstacles to food production in Africa, includes about 40 species, of which 11 species are parasites on agricultural crops (FAO, 2003). It is a parasitic weed that enters the roots of other plants and removes their essential nutrients and reduces their growth. The weed is one of the major constraints to the production of cereals and legumes in sub-Saharan Africa. On average, Striga infests as much as 40 million hectares of farmland in sub-Saharan Africa. It can cause yield losses of up to 100 percent (IAASTD, 2009) and an average reduction in productivity of 12 to 25 percent. In Africa, it affects the livelihoods of about 300 million people (FAO, 2003).

The monoculture of cereals, in which farmers use continuous cropping and follow poor agronomic practices such as the lack of crop rotation, promotes the formation of Striga. This is particularly true in agro-ecosystems where high human population densities put strong pressures on arable land. Striga has been known to have devastating effects on many food crops, specifically maize (Zea mays), sorghum (Sorghum bicolor) and sugar cane (Saccharum officinarum) (Eplee, 1992) and represents a real threat to cereal production and food security of affected countries.

To deal with striga, people hand-weed the land, but in extreme cases where there is heavy infestation, the only option is to abandon the farm land. However, abandonment only increases the parasite pressure in contaminated fields, as the seed can remain dormant and viable in the soil for at least 5 to 10 years (Parker and Riches, 1993). Farmers use a variety of pest control methods (organic manure, crop rotation, fallow), but the results can often be unsatisfactory. A rational combination of pest control methods (cultural, biological and low risk pesticides) prevents spread of pests, provides better protection for the crops and improves yields. In particular, the introduction of legumes (e.g. mucuna) into the crop rotation as cover and catch crop tends to suppress the incidence of Striga. Projects have been implemented in Benin, Burkina-Faso, the Niger, Mali and Senegal to compare different management methods to alleviate the problem (FAO, 2008b).

Stiga thrives in temperatures of 30 to 35 degrees Celsius under semi-arid conditions. Climate change that leads to increased temperatures or affects rainfall patterns may influence the geographic distribution and invasive potential of Striga (Cotter *et al.*, 2012).

In addition, the maintenance and enhancement of soil health contributes to food security in "more direct ways." A large portion of global crop production is taken up by maize, rice, wheat and other crops, such as oil crops. For human nutrition, however, a healthy diet is based on the variety of crops. These provide a range of essential nutrients, vitamins and minerals, and fruits and vegetables of high nutritional value. In addition, crop variety not only provides food, fuel and fibre goods, but also environmental services. For example, pulses are an important part of local food crops in developing countries and are a key source of protein in the diets of the world's poorest countries. In farming systems, pulses represent an input-saving and resource-conserving technology because they fix nitrogen in the soil and thereby reduce the need for chemical fertilizer. The cultivation of pulses also reduces soil pathogens (FAO, 2012b).

Conservation agriculture is an example of an approach that manages natural biological processes for resource-saving agricultural crop production. It aims at achieving competitive agricultural yields while helping to reduce degradation of natural resources. Undisturbed soil with a sufficient supply of organic matter provides a good habitat for soil fauna. Avoiding mechanical soil tillage increases the populations of earthworms, millipedes, mites and other animals living in the soil. This microfauna takes over the task of tillage and builds soil porosity and structure. It incorporates organic matter from the soil surface; the excrements provide stable soil aggregates and the vertical macro-pores created by worms serve as drainage channels for excess water. This makes the land less susceptible to flooding and erosion, since it improves the infiltration of water into the ground. The organic matter incorporated by soil microfauna into the soil improves soil structure and water storage capacity, which in turn helps plants to survive longer during drought spells. Both are important strategies for farming adaptations to changing climate effects and contribute to mitigation efforts. By managing biological processes, conservation agriculture can contribute to climate change adaptation and mitigation by reducing GHG emissions and sequestering carbon (FAO, 2012c).

Box 7.6
Conservation agriculture with ripper-furrower system in Namibia

Farmers in the north of Namibia are using conservation agriculture practices to grow drought-tolerant crops, including millet, sorghum and maize. The farming system uses a tractor-drawn ripper-furrower to rip the hard pan to a depth of 60 centimetres and to form furrows for in-field rainfall harvesting. The harvested water is concentrated in the root zone of crops, which are planted in the rip lines together with a mixture of fertilizer and manure. Tractors are used in the first year to establish the system. From the second year onwards, farmers plant crops directly into the rip lines using an animal-drawn direct seeder.

Crop residues are consumed mainly by livestock, but the increased biomass produced by the system also provides some residues for soil cover. Farmers are encouraged to practice crop rotation with legumes. These techniques lengthen the growing season and improve soil structure, fertility and moisture retention. Average maize yields have increased from 300 kilograms per hectare to more than 1.5 tonnes.

Source: FAO, 2011

Increased levels of organic matter in soil also help mitigate climate change by storing carbon from atmospheric CO_2 in soil organic matter. The formation of stable organic matter through the process of humification is mediated by soil micro-organisms. Another element of biological tillage is the introduction of crops, including trees and shrubs, with deep penetrating tap-roots. Some 'pioneer' crops, such as lupine, jack-beans (*canavalia*) or radish, can break subsoil compactions if, for example, they are planted in the crop rotation or intercropped as green manure cover crops (FAO, 2009a).

7.5 Climate-smart approaches and practices

To achieve SCPI, all aspects of sustainability (social, economic, political and environmental) must be taken into consideration in conjunction with the overall context. Global, regional and national instruments, treaties, conventions, codes and policies are an essential component in the enhancement and sustainable use of natural resources. Policies at, or that impact, the sub-national and local levels— as well as institutional capacity— are also important for addressing local social, economic and agro-ecological conditions (see Module 12 on institutions and Module 13 on policies). Improving market linkages, reducing post-harvest losses (see Module 11 on post-harvest practices) and conserving agricultural biodiversity will also contribute to ensuring that improved farming practices deliver the anticipated benefits.

At the field level, there are a wide range of agricultural practices and approaches that are currently available that can contribute to increased production while still focusing on environmental sustainability. It needs to be emphasized that outlining these is not a blueprint of actions that can be undertaken in all agro-ecosystems. What this module does is present options of management practices and approaches that— considering the ecological, social, policy and economic dimensions of a specific location— can contribute to climate-smart crop production. These practices and approaches for crop production can provide adaptation measures and/or mitigation benefits.

Adaptation

Environmental stresses have always had an impact on crop production, and farmers have always looked for ways to manage these stresses. Climate change adaptation requires more than simply maintaining the current level of performance from the agricultural sector, it requires developing a set of responses that allow the sector to improve performance under the changing conditions brought about by climate change. Because agricultural production remains the main source of income for most rural communities, adaptation of the agricultural sector to the adverse effects of climate change will be imperative for protecting and improving the livelihoods of the poor and ensuring food security (FAO, 2012a). Some ways of local adaptation to stress is through plant breeding, pest management strategies, and seed delivery systems, to name a few.

Examples of changes in climatic conditions that influence crop systems include: rain quantity and distribution, and consequently water availability; extreme events, such as floods and droughts; higher temperatures; and shifting seasons. The rate of climate change may exceed the rate of adaptation for natural systems, including crops, and this creates high concern for food availability (Allara *et al.*, 2012). In essence, what this means is that crops that were usually planted in one area may no longer be able to grow there. In addition, the ecosystem services that ensure crop growth (e.g. pollination, soil biodiversity) may also be affected. For these reasons, it is necessary to address crop production at the farming systems level. With appropriate technical, institutional, socio-economic and policy infrastructure in place, there is a huge potential for crop management practices and approaches to adapt to, and contribute to, the mitigation of climate change.

Box 7.7
Agricultural approaches and practices that contribute to climate change adaptation

Different approaches and practices for sustainable crop production can contribute to climate change adaptation. They provide options for location-specific contexts and should be adapted with local farmers/farming communities.

Examples include:

- ecosystem-based approaches;
- conservation agriculture;
- integrated nutrient and soil management;
- mulch cropping;
- cover cropping;
- alterations in cropping patterns and rotations;
- crop diversification;
- using high quality seeds and planting materials of adapted varieties;
- integrated pest management;
- integrated weed management;
- grasslands management;
- water and irrigation management;
- landscape-level pollination management;
- organic agriculture; and
- land fragmentation (riparian areas, forest land within the agricultural landscape).

Sources: FAO-PAR, 2011; FAO, 2008a; Lin, 2011; FAO, 2009b; FAO, 2012a

While some of these measures can be implemented readily at the level of individual farms or households, others need broader infrastructural and political support and have much longer timeframes. An example is with the conservation and management of grasslands, which has an enormous potential to sequester carbon, provide food and feed (e.g. honey, grazing livestock, wild cereals, hunting, medicinal plants) and energy (e.g. solar, charcoal, hydropower, wind-power).

Mitigation

Agriculture is a significant source of GHG emissions, but at the same time, it offers tremendous potential for mitigating climate change. Agricultural production accounts for over a third of global GHG emissions mainly in the form of CH_4 and N_2O from fertilized soils, enteric fermentation, biomass burning, paddy rice production, as well as manure and fertilizer production. In addition, contributors to the release of CO_2 into the atmosphere are land-use changes and soil degradation. Through practices that capitalize on natural biological processes, crop production can provide an opportunity to mitigate climate change in two ways: by storing carbon and by reducing GHG emissions.

Box 7.8
Agricultural approaches and practices that contribute to climate change mitigation

There are many different approaches and practices for sustainable crop production that can contribute to climate change mitigation. As with climate change adaptation, these approaches and practices can provide options for location-specific contexts and should be adapted with local farmers/farming communities.

Examples include:

- conservation agriculture;
- soil compaction management;
- improved farming systems with several crop rotations;
- crop diversification;
- promotion of legumes in crop rotations;
- growing cover crops;
- mulch cropping;
- restoration of cultivated peaty soils and degraded lands;
- soil management practices that reduce fertilizer use (e.g. urea deep placement);
- integrated nutrient management;
- growing nutrient-use efficient crop varieties;
- integrated crop and livestock systems;
- dedicated energy crops to replace fossil fuel use;
- emission control and reduction (combustion engines, animal waste);
- improved rice cultivation techniques;
- water management/conservation, irrigation, water table management; and
- agroforestry.

Sources: FAO, 2004; FAO, 2008a; FAO, 2009b; FAO, 2012a; FAO, 2012c

7.6 Conclusions

Crop production contributes to climate change, but it also presents opportunities for adapting to and mitigating climate change. The principles underlying SCPI are in line with the practices and approaches available for climate change adaptation and mitigation. Climate-smart agriculture is agriculture that moves away from unstable systems and systems that depend mainly on external inputs, towards systems that can be more efficient and resilient by relying on natural auto-control mechanisms. This is mainly reflected in systems being managed through an ecosystem approach at the landscape level, as well as in integrated systems. Practices and approaches can be used by land managers/farmers, but climate change adaptation and mitigation options cannot be implemented from a "purely technical" standpoint alone— they also rely on the social support of the population involved. It is crucial that land managers/farmers be supported by being given options and opportunities, sustained by institutions and policy. Strong policies as well as tools and institutions at country level are essential to counteract the effects of climate change in agricultural production systems and the livelihood of the rural population, particularly in developing countries. There is the need for strong government commitment to develop and/or adapt agricultural policies to take into consideration climate change, its potential impact and ways to overcome or minimize its effects. In addition, local expertise offers an immense repository of knowledge— not only about biophysical aspects of agricultural production, but also of the needs of communities and farmers. Climate-smart systems are able to respond and adapt to changing climates, particularly to the increased variability, and can, in targeted instances, contribute to mitigating a further change in the climate. By the very nature of such systems, they need to be efficient, which at the same time makes them sustainable and productive. Conversely, a production system, which is productive and sustainable at the same time, can only be so if it is climate-smart. Therefore production systems as reflected in the *Save and Grow* approach, are at the same time inherently climate-smart.

Notes

This module was written by Nadine Azzu (FAO) and Suzanne Redfern (FAO) with contributions from Theodor Friedrich (FAO), Gualbert Gbehounou (FAO), Amir Kassam (FAO), Chikelu Mba (FAO) and Cornelis VanDuijvendijk (FAO).

Acronyms

BNF	biological nitrogen fixation
C	carbon
CH_4	methane
CO_2	carbon dioxide
CO_2 eqv.	carbon dioxide equivalent
CSA	climate-smart agriculture
FFS	Farmer Field Schools
GHG	greenhouse gas
Gt	gigatonne
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
N2O	nitrous oxide
PAR	Platform for Agrobiodiversity Research
PIPM	Promoting Integrated Pest Management Project
SCPI	Sustainable Crop Production Intensification
UNFCCC	United Nations Framework Convention on Climate Change
USGCRP	United States Global Change Research Program

References

Africare, Oxfam America & WWF-ICRISAT Project. 2010. *More rice for people, more water for the planet.* Hyderabad, India, WWF-ICRISAT Project. (available at http://www.sri-india.net/documents/More_Water_For_The_Planet.pdf)

Allara, A., Kugbei, S., Dusunceli, F. & Gbehounou, G. 2012. *Coping with changes in cropping systems: plant pests and seeds*. FAO-OECD Workshop on Building Resilience for Adaptation to Climate Change in the Agriculture Sector. Rome. (available at http://typo3.fao.org/fileadmin/templates/agphome/documents/faooecd/PestSeeds.pdf)

Beddington, J., Asaduzzaman, M., Clark, M., Fernandez, A., Guillou, M., Jahn, M., Erda, L., Mamo, T., Van Bo, N., Nobre, C.A., Scholes ,R., Sharma, R. & Wakhungu, J. 2012. *Achieving food security in the face of climate change.* Final report from the Commission on Sustainable Agriculture and Climate Change. Copenhagen, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). (available at www.ccafs.cgiar.org/commission)

Cotter, M., Renzoandre de la Pena-Lavander, R. & Sauerborn, J. 2012. *Understanding the present distribution of the parasitic weed Striga hermonthica and predicting its potential future geographic distribution in the light of climate change.* Braunschweig, Germany, 25th German Conference on Weed Biology and Weed Control. Stuttgart, Germany, Universitat Hohenheim.

Deutsch, C.A., Tewksbury J.J., Huey R.B., Sheldon K.S., Ghalambor, C.K., Haak D.C. & Martin P.R. 2008. *Impacts of climate warming on terrestrial ecotherms across latitude.* Proc. Natl. Acad. Sci. USA, 105: 6668–6672.

Eplee, R.E. 1992. *Witchweed (Striga asiatica): an overview of management strategies in the USA.* Crop Protection, 11(1): 3–7.

European Commission. 2011. *Climate change.* (available at http://ec.europa.eu/dgs/jrc/index.cfm?id=2290)

FAO. 2003. *Weed management for developing countries, R.* Labrada, ed. Rome (available at http://www.fao.org/docrep/006/y5031e/y5031e0j.htm)

FAO. 2004. *Carbon sequestration in dryland soils.* (available at http://www.fao.org/fileadmin/templates/nr/images/resources/pdf_documents/wsrr102.pdf)

FAO. 2008a. *Climate change adaptation and mitigation in the food and agriculture sector.* High-level conference on food security – the challenges of climate change and bioenergy. (available at ftp://ftp.fao.org/docrep/fao/meeting/013/ai782e.pdf)

FAO. 2008b. *Progress on farmer training in parasitic weed management, R.* Labrada, ed. Rome.

FAO. 2009a. *Increasing crop production sustainably, the perspective of biological processes.* Rome.

FAO. 2009b. *Climate change and biodiversity for food and agriculture: taking systemic and second order effects into account, by M.* Flitner & J. Herbeck. Commission on Genetic Resources for Food and Agriculture. (available at ftp://ftp.fao.org/docrep/fao/meeting/017/ak223e.pdf)

FAO. 2010a. *An international consultation on integrated crop-livestock systems for development, the way forward for sustainable production intensification.* Integrated Crop Management. Vol. 13. Rome.

FAO. 2010b. *Gardens of biodiversity – conservation of genetic resources and their use in traditional food production systems by small farmers of the Southern Caucasus.* Rome.

FAO. 2011. *Save and grow: a policymaker's guide to the sustainable intensification of smallholder crop production.* Rome.

FAO. 2012a. *Economics of plant genetic resource management for adaptation to climate change.* A review of selected literature, by S. Asfaw & L. Lipper. (available at http://www.fao.org/docrep/015/an649e/an649e00.pdf)

FAO. 2012b. *FAO statistical yearbook, 2012: world food and agriculture.* (available at http://www.fao.org/docrep/015/i2490e/i2490e00.htm)

FAO. 2012c. *Soil organic carbon accumulation and greenhouse gas emission reductions from conservation agriculture: a literature review.* (available at http://www.fao.org/fileadmin/user_upload/agp/icm16.pdf)

FAO. 2012d. *What is conservation agriculture?* (available at http://www.fao.org/ag/ca/1a.html)

FAO-PAR (Platform for Agrobiodiversity). 2011. *Biodiversity for food and agriculture: contributing to food security and sustainability in a changing world.* Rome. (available at http://agrobiodiversityplatform.org/files/2011/04/PAR-FAO-book_lr.pdf)

FAOSTAT. 2012. *FAO statistical yearbook.* (available at http://www.fao.org/docrep/015/i2490e/i2490e00.htm)

Gallai, N., Salles, *J.M.,* Settle, J. & Vaissiere, B.E. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. Ecol. Econom., 68: 810–821.

International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD). 2009. *Agriculture at a crossroads.* Subglobal report, Vol. 5. B.D. McIntyre, H.R. Herren, J. Wakhungu & R.T. Watson, eds. Washington D.C., IAASTD. (available at http://www.agassessment.org/reports/subglobal/agriculture_at_a_crossroads_volume%20v_sub-saharan%20africa_subglobal_report.pdf)

International Fund for Agricultural Development (IFAD). 2009. *Integrated crop-livestock farming systems.* Livestock thematic papers, tools for project design. (available at http://www.ifad.org/lrkm/factsheet/integratedcrop.pdf)

International Food Policy Research Institute (IFPRI). 2009. *Climate change: impact on agriculture and costs of adaptation.* (available at http://www.ifpri.org/publication/climate-change-impact-agriculture-and-costs-adaptation)

Intergovernmental Panel on Climate Change (IPCC) . 2007. *Technical Summary.* In Climate change 2007: mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge, UK, and New York, USA, Cambridge University Press.

IPCC. 2012. *Summary for policy makers.* In C.B. Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G-K. Plattner, S.K. Allen, M. Tignor & P.M. Midgley, eds. Managing the risks of extreme events and disasters to advance climate change adaptation, pp. 1–19. A special report of Working Groups I and II of the IPCC. Cambridge, UK, Cambridge University Press.

Kjøhl, M., Nielsen, A. & Stenseth, N.C. 2011. *Potential effects of climate change on crop pollination.* Rome, FAO.

Lin, B.B. 2011. *Resilience in agriculture through crop diversification: adaptive management for environmental change.* BioScience, 61(3): 183—193.(available at http://www.aibs.org/bioscience-press-releases/resources/Lin.pdf)

Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P. & Naylor, R.L. 2008. *Prioritizing climate change adaptation needs for food security in 2030.* Science, 319 (5863): 607–610.

Parker, C. & Riches, C.R. 1993. *Parasitic weeds of the world: biology and control*, 332 pp. Wallington, UK, CAB International.

PIPM (Promoting Integrated Pest Management) Project. 2012. *FFS for building the capacity of farmers for healthy crops, more yields and more incomes.* Bulletin No.2. Kabul, Ministry of Agriculture, Irrigation and Live-stock, Government of Norway and FAO.

Pretty, J., Toulmin, C. & Williams, S. 2011. *Sustainable intensification in African agriculture*. International Jour-nal of Agricultural Sustainability, 9(1): 5–24.

Redfern, S.K., Azzu, N. & Binamira, J.S. 2012. *Rice in Southeast Asia: facing risks and vulnerabilities to respond to climate change.* In Building resilience for adaptation to climate change in the agriculture sector. Proceed-ings of a Joint FAO-OECD Workshop. Rome, FAO.

Scherr, S.J. & Sthapit, S. 2009. *Farming and land use to cool the planet*. Module 3. State of the world: into a warming world. Washington D.C., The Worldwatch Institute.

The World Bank. 2008. *Agriculture and poverty.* Agriculture for Development Policy Brief. (available at sit-eresources.worldbank.org/SOUTHASIAEXT/Resources/223546-1171488994713/3455847-1192738003272/Brief_AgPovRedctn_web.pdf)

United Nations Framework Convention on Climate Change (UNFCCC). 2007. *Climate change: impacts, vulner-abilities and adaptation in developing countries.* (available at http://unfccc.int/resource/docs/publications/im-pacts.pdf)

United States Global Change Research Program (USGCRP). 2009. *Global climate change impacts in the United States* . Karl, T.R., J.M. Melillo, and T.C. Peterson, eds. United States Global Change Research Program. New York, USA, Cambridge University Press.

MODULE 8: CLIMATE-SMART LIVESTOCK

Overview

This module assesses the role of livestock in climate-smart agriculture (CSA). Adopting a farming system perspective, it highlights the main climate-smart strategies for the sector. The first section describes trends in the livestock sector and the contribution it makes to food security. The second section assesses the impact of climate change on livestock and identifies adaptation and mitigation needs. It also presents an overview of emissions caused by livestock. The module outlines the principles of climate-smart livestock, focusing on increased efficiency of resource use and building resilience. The last section gives insights into main strategies for achieving climate-smart livestock and covers land-based, mixed and landless systems.

Key messages

- Livestock can make a large contribution to climate-smart food supply systems.
- Mitigation options are available along the entire supply chain. They are mostly targeted to feed production, enteric fermentation and manure management.
- Livestock's role in adaptation practices relates primarily to the management of organic matter and nutrients, and the diversification of incomes.
- Several CSA practices are readily available for implementation. These practices include grassland restoration and management (e.g. sylvopastoral systems), manure management (e.g. recycling and biodigestion) and crop-livestock integration.
- Barriers to adoption are most often related to a lack of information, limited access to technology and insufficient capital. Overcoming these barriers requires specific policy interventions, including extension work and financing mechanisms, such schemes for improving access to credit and payment for environmental services.
- A CSA approach that considers the entire food supply chain is particularly relevant to the livestock sector, given the sector's strong interrelationship with crop production.

Contents

List of Figures

List of Tables

List of Boxes

List of Case Studies

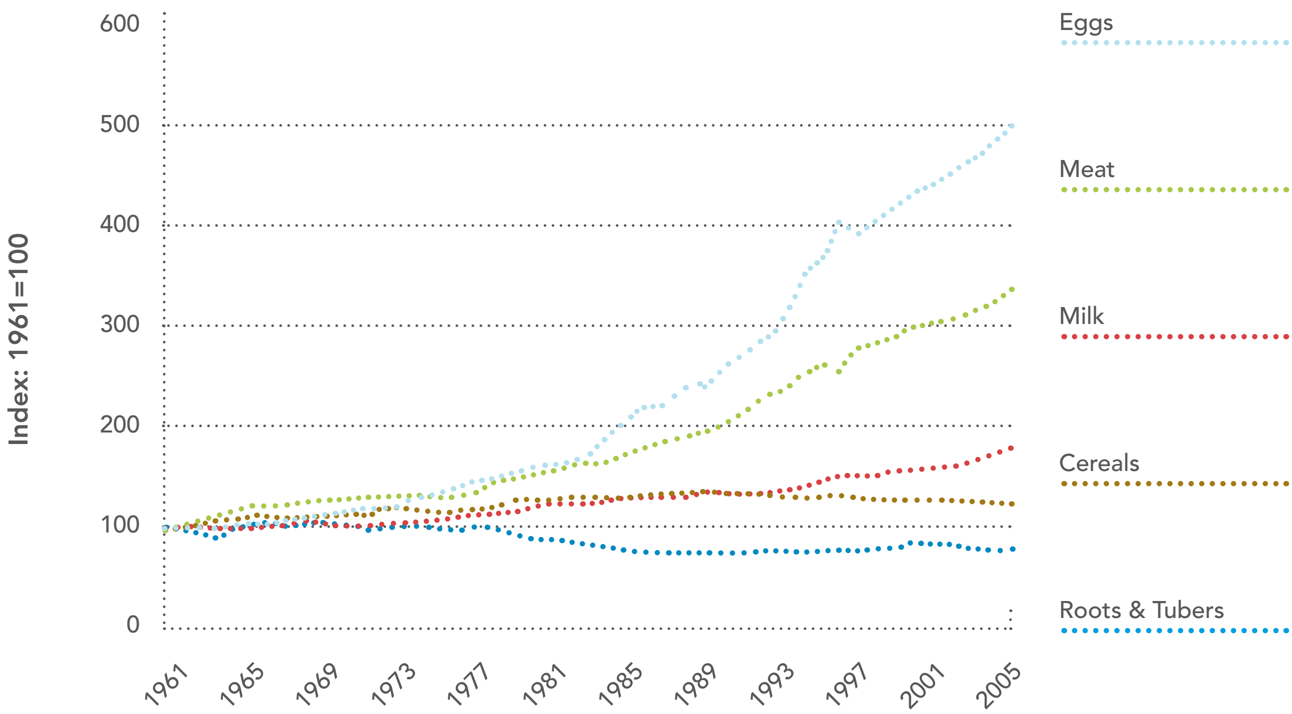
8.1 Introduction

Climate change is having substantial effects on ecosystems and the natural resources upon which the livestock sector depends. Climate change will affect the sector directly, through increased temperature, changes in the amount of rainfall and shifts in precipitation patterns. Indirect impacts will be experienced through modifications in ecosystems, changes in the yields, quality and type of feed crops, possible increases in animal diseases and increased competition for resources. At the same time, livestock food chains are major contributors to greenhouse gas (GHG) emissions (FAO, 2006a).

Sector trends

Global production of meat, milk and eggs has rapidly expanded during the last decades in response to growing demand for livestock products. This increase in demand, which has been particularly strong in developing regions, has largely been driven by expanding populations and increasing incomes. For example, between 1960 and 2005 annual per capita consumption of meat more than tripled; consumption of milk almost doubled; and per capita consumption of eggs increased fivefold in the developing world (see Figure 8.1).

Figure 8.1
Per capita consumption of major food items in developing countries



Source: FAO, 2009a

The factors that have driven growth in livestock product demand in the developing world (rising incomes, population growth and urbanization) will continue to be influential over the coming decades, although the effects will be tempered (FAO, 2006b; FAO, 2009a). Projected declines in the rate of population growth, coupled with decelerating consumption in the two countries that have mostly driven the global upsurge in consumption (China and India), are major factors that will influence future aggregate demand. Excluding Brazil and China, per capita meat consumption in developing countries is expected to increase to 26 kilograms in 2030 and 32 kg in 2050. In terms of future consumption, it is projected that a marked gap will continue to exist between developed and developing countries. This gap indicates that there is scope for further growth in the livestock sector. Driven by demand, global production of meat is projected to more than double, from 229 million tonnes in 1999/2001 to 465 million tonnes in 2050. Milk production is expected to increase from 580 to 1 043 million tonnes (FAO, 2006b).

Contribution to food security

Livestock make a necessary and important contribution to global calorie and protein supplies. However, livestock need to be managed carefully to maximize this contribution. While livestock products are not absolutely essential to human diets, they are valued and they will continue to be consumed in increasing amounts. Meat, milk and eggs in appropriate amounts are valuable sources of complete and easily digestible protein and essential micronutrients. Overconsumption causes health problems.

Livestock can increase the world's edible protein balance by transforming inedible protein found in forage into forms that people can digest. On the other hand, livestock can also reduce the global edible protein balance by consuming large amounts edible protein found in cereal grains and soybeans and converting it into small amounts of animal protein. The choice of production systems and good management practices are important for optimizing the protein output from livestock. Livestock production and marketing can help stabilize the food supplies and provide individuals and communities with a buffer against economic shocks and natural disasters. However, the food supply from livestock can be destabilized, particularly by disease outbreaks.

Access to food derived from livestock is affected by income and social customs. Access to livestock as a source of income, and hence food, is also unequal. Gender dynamics play a part in this inequality, particularly in pastoralist and small-scale farming communities, where female-headed households tend to have fewer resources and consequently own fewer and smaller livestock, and within families where the larger and more commercial livestock operations are often controlled by men. These problems are not unique to livestock, but they are prevalent among both producers and consumers of livestock products and they demand attention.

8.2 Adaptation and mitigation needs

The impact of climate change on livestock

Climate change poses serious threats to livestock production. However, these impacts are difficult to quantify due to the sector's uncertain and complex interactions between agriculture, climate, the surrounding environment and the economy. Increased temperatures, shifts in rainfall distribution and increased frequency of extreme weather events are expected to adversely affect livestock production and productivity around the world. These adverse impacts can be the direct result of increased heat stress and reduced water availability. Indirect impacts can result from the reduced quality and availability of feed and fodder, the emergence of livestock disease and greater competition for resources with other sectors (Thornton, 2010; Thornton and Gerber, 2010; FAO, 2009b).

The effects of climate change on livestock are likely to be widespread. The most serious impacts are anticipated in grazing systems because of their dependence on climatic conditions and the natural resource base, and their limited adaptation opportunities (Aydinalp and Cresser, 2008). Impacts are expected to be most severe in arid and semi-arid grazing systems at low latitudes, where higher temperatures and lower rainfall are expected to reduce yields on rangelands and increase land degradation (Hoffmann and Vogel, 2008).

The direct impacts of climate change are likely to be more limited in non-grazing systems mostly because the housing of animals in buildings allows for greater control of production conditions (Thornton and Gerber, 2010; FAO, 2009b). In non-grazing systems, indirect impacts from lower crop yields, feed scarcity and higher energy prices will be more significant. Climate change could lead to additional indirect impacts from the increased emergence of livestock diseases, as higher temperatures and changed rainfall patterns can alter the abundance, distribution and transmission of animal pathogens (Baylis and Githeko, 2006). However, the net impacts of climate change are unclear when considered in combination with other important environmental and socio-economic factors that also affect disease prevalence, such as changes in land use, host abundance, international trade, migration and public health policy (Randolph, 2008; Kurukulasuriya and Rosenthal, 2003).

Table 8.1
Direct and indirect impacts of climate change on livestock production systems

	Grazing system	Non-grazing system
Direct impacts	• increased frequency of extreme weather events • increased frequency and magnitude of droughts and floods • productivity losses (physiological stress) due to temperature increase • change in water availability (may increase or decrease, according to region)	• change in water availability (may increase or decrease, according to region) • increased frequency of extreme weather events (impact less acute than for extensive system)
Indirect impacts	Agro-ecological changes and ecosystem shifts leading to: • alteration in fodder quality and quantity • change in host-pathogen interaction resulting in an increased incidence of emerging diseases • disease epidemics	• increased resource prices (e.g. feed, water and energy) • disease epidemics • increased cost of animal housing (e.g. cooling systems)

Overview of emissions

The livestock sector is a major contributor to climate change, generating significant emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Livestock contribute to climate change by emitting GHGs either directly (e.g. from enteric fermentation and manure management) or indirectly (e.g. from feed-production activities, conversion of forest into pasture). Based on a Life Cycle Assessment (LCA), it is estimated that the sector emits about 7.1 gigatonnes of CO_2 equivalent (CO_2 eqv.), about 18 percent of the total anthropogenic GHG emissions (FAO, 2006a).

Along the animal food chain, the major sources of emissions are (FAO, 2006a):

- Land use and land-use change: 2.5 gigatonnes of CO_2 eqv. (36 percent of the sector's emissions); including forest and other natural vegetation replaced by pasture and feed crops in the neotropics (CO_2) and carbon release from soils, such as pasture and arable land dedicated to feed production (CO_2).
- Feed production (except carbon released from soil): 0.4 gigatonnes CO_2 eqv. (6 percent of the sector's emissions), including fossil fuels used in manufacturing chemical fertilizer for feed crops (CO2) and chemical fertilizer application on feed crops and leguminous feed crop (N_2O, and ammonia [NH_3]).
- Animal production: 1.9 gigatonnes CO_2 eqv. (27 percent of the sector's emissions), including enteric fermentation from ruminants (CH_4) and on-farm fossil fuel use (CO_2).
- Manure management: 2.2 gigatonnes CO_2 eqv. (31 percent of the sector's emissions), mainly through manure storage, application and deposition (CH_4, N_2O, NH_3).
- Processing and international transport: 0.03 gigatonnes CO_2 eqv. (less than 0.1 percent of the sector's emissions).

There are striking differences in global emission intensities among commodities. For example, on a global scale, the emission intensity of meat and milk, measured by output weight, corresponds on average to 46.2 kg CO_2 eqv. per kg of carcass weight (CW), 6.1 kg CO_2 eqv./kg CW and 5.4 kg CO_2 eqv./kg CW for beef, pork and chicken meat[1], respectively, and 2.8 kg CO_2 eqv./kg of milk (FAO, 2013a and b, forthcoming). There is significant variability in emissions across the different regions. For example, the FAO LCA of GHG emissions from the global dairy sector, found emissions per unit of milk products varied greatly among different regions. Emissions from Europe and North America range between 1.6 and 1.9 kg CO_2 eqv. per kg fat and protein corrected milk (FPCM) at the farm gate. The highest emissions are estimated for sub-Saharan Africa with an average of 9.0 kg CO_2 eqv./kg FPCM at the farm gate. GHG emissions for Latin America and the Caribbean, Near East and North Africa and South Asia, range between 3 and 5 kg CO_2 eqv./kg FPCM at the farm gate. The global average is estimated at 2.8 kg CO_2 eqv. (FAO, 2013a). Results from the same study of the global dairy sector also found

[1] Emission intensity estimates for beef, chicken meat and pork are based on FAO's recent work on the LCA of GHG emissions from the livestock sector (FAO 2013a and b, forthcoming).

GHG emissions to be inversely related to productivity. At very low levels of milk production (200 kg per cow per year) emissions were found to be 12 kg CO_2 eqv./kg FPCM compared to 1.1 kg CO_2 eqv./kg FPCM for high production levels (about 8 000 kg of milk). This reflects the strong relationship between livestock intensification and GHG emissions on a global scale (Gerber *et al.*, 2011).

Climate-smart livestock

Overall principles

Resource use efficiency

Given the current and projected scarcity of resources and the anticipated increase in demand for livestock products, there is considerable agreement that increasing efficiency in resource use is a key component to improving the sector's environmental sustainability. More efficient use of natural resources is a crucial strategy for decoupling growth in the livestock sector from adverse environmental impacts. Efficiency in the use of natural resources is measured by the ratio between the use of natural resources as input to the production activities and the output from production (e.g. kg of phosphorus used per unit of meat produced, or hectares of land mobilized per unit of milk produced). The concept can be extended to the amount of emissions generated by unit of output (e.g. GHG emissions per unit of eggs produced). Examples of opportunities that fall within this strategy are higher yields per hectare, higher water productivity, higher feed efficiency, improved management of manure and fertilizers and reduced losses along the food chain (Westhoek *et al.*, 2011).

Improving the feed-to-food conversion efficiency in animal production systems is a fundamental strategy for improving the environmental sustainability of the sector. A large volume of food is wasted even before it reaches the consumer. A recent FAO (2011) study suggests that about one-third of food produced is wasted. Reduction of waste along the animal food chain can substantially contribute to reducing the demand for resources, such as land, water, energy, as well as other inputs, such as nutrients.

The current prices of inputs, such as land, water and feed, used in livestock production often do not reflect true scarcities. Consequently, there is the overutilization of resources by the sector and inefficiencies in production processes. Any future policies to protect the environment will have to introduce adequate market pricing for natural resources. Ensuring effective management rules and liability, under private or communal ownership of the resources, is a further necessary policy element for improving the use of resources.

Building resilience: buffering and risk management at farm and system level

Traditionally, livestock producers have been able to adapt to various environmental and climatic changes. Now however, expanding populations, urbanization, economic growth, increased consumption of animal-based foods and greater commercialisation have made traditional coping mechanisms less effective (Sidahmed, 2008). As a result, the identification of coping and risk management strategies has become very important.

Particularly in pastoral and agro-pastoral systems, livestock are key assets held by poor people and fulfil multiple economic, social, and risk management functions. Livestock is also a crucial coping mechanism in variable environments. As this variability increases, livestock will become more valuable. For many poor people, the loss of livestock assets means a collapse into chronic poverty and has long-term effects on their livelihoods.

A wide array of adaptation options is available (see, for instance, Kurukulasuriya and Rosenthal, 2003; IPCC, 2007). Possible adaptive responses include: technological options (e.g. more drought-tolerant crops); behavioural modifications (e.g. changes in dietary choices); managerial choices (e.g. different farm management practices); and policy alternatives (e.g. planning regulations and infrastructural development). Some options may be appropriate for the short-term, others for the long-term (or both). In the short-term, adaptation to climate change is often framed within the context of risk management (see Module 15 on disaster risk reduction). Washington *et al.* (2006) outline an approach for addressing the challenges of climate change that depends on a close engagement with climate variability. Helping decision makers understand and deal with current levels of climate variability can provide one entry point to the problems posed by increasing variability in the future and the options that may be needed to build resilience. However, there are still problems to be addressed concerning the uncertainty of climate projections and projected impacts and how this uncertainty can be appropriately treated when determining response options (Wilby *et al.*, 2009).

Longer-term approaches to adaptation are often described in terms of 'climate-proofing development'. These approaches can involve system changes (e.g. a change in the set of commodities produced or the shift from extensive to mixed systems) or the adoption of new technology that is currently unavailable. There may be long lag times between the identification of a problem and the development of readily available and appropriate technology. Research carried out today needs to be appropriate to the environment 20-30 years from now. This has implications for how research is targeted as well as for the design, testing and implementation of the research. One approach may involve searching for homologues of projected future climate conditions in areas where similar conditions exist now and where breeding and selection can be carried out (Burke *et al.*, 2009).

Main strategies

This section summarizes the main CSA strategies for dominant livestock production systems: land-based systems, mixed systems and landless systems.

Land-based systems

While there are several climate-smart options available for land-based grazing systems, their applicability to low-input systems with infrequent human intervention tends to be quite limited. The main mitigation options for land-based grazing systems are reductions in enteric CH_4 emissions and CO_2 removals through soil carbon sequestration. Manure management mitigation options are much more limited in land-based systems.

The climate-smart options discussed below fall into three categories: those with clear mitigation and adaptation synergies; 'mitigation only' options; and 'adaptation only' options. Options for which there are risks of tradeoffs between mitigation, food security and adaptation have also been identified. Climate-smart options deemed suitable for land-based systems, along with their capacities to satisfy multiple climate-smart objectives, are listed in Table 8.2.

Table 8.2
Summary of CSA practices and technologies for land-based systems

Practices and technologies	Impact on food security	Effectiveness: adaptation	Effectiveness: mitigation	Main constraints to adoption
Grazing management	+/-	+	++	technical: especially in extensive systems
Pasture management	+		++	technical and economic in extensive systems
Animal breeding	+	++	++	technical, economic, institutional: especially in developing countries
Animal and herd management	+	++	+	technical, institutional: especially in developing countries
Animal disease and health	++	++	+	technical, institutional: especially in developing countries
Supplementary feeding	+	+	++	easy to implement, but costly
Vaccines against *rumen archaea*	++		+	not immediately available, may have low acceptability in some countries
Warning systems	++	+		technical, institutional: especially in developing countries
Weather-indexed insurance		+		technical, economic, institutional: especially in developing countries
Agroforestry practices	++	++	++	technical and economic

Mitigation/adaptation potential: + = low; ++ = medium

Grazing management

Grazing can be optimized by balancing and adapting grazing pressures on land. This optimization can increase grassland productivity and deliver mitigation and adaptation benefits. However, the net influence of optimal grazing is variable and highly dependent on baseline grazing practices, plant species, soils and climatic conditions (Smith *et al.*, 2008).

Perhaps the most clear-cut mitigation benefits arise from soil carbon sequestration that results when grazing pressure is reduced as a means of stopping land degradation or rehabilitating degraded lands (Conant and Paustian, 2002). In these cases, enteric emission intensities can also be lowered, because with less grazing pressure animals have a wider choice of forage, and tend to select more nutritious forage, which is associated with more rapid rates of live weight gain (LWG) (Rolfe, 2010). By restoring degraded grassland, these measures can also enhance soil health and water retention, which increases the resilience of the grazing system to climate variability. However, if grazing pressure is reduced by simply reducing the number of animals, then total output per hectare may be lower, except in areas where baseline stocking rates are excessively high (Rolfe, 2010).

One of the main strategies for increasing the efficiency of grazing management is through rotational grazing, which can be adjusted to the frequency and timing of the livestock's grazing needs and better matches these needs with the availability of pasture resources. Rotational grazing allows for the maintenance of forages at a relatively earlier growth stage. This enhances the quality and digestibility of the forage, improves the productivity of the system and reduces CH_4 emissions per unit of LWG (Eagle *et al.*, 2012). Rotational grazing is more suited to managed pasture systems, where investment costs for fencing and watering points, additional labour and more intensive management are more likely to be recouped.

In colder climates, where animals are housed during cold periods, there are also opportunities for controlling the timing of grazing. For example, early grazing of summer pastures is a major cause of grassland degradation in Northern China (see Case Study 8.1 for further information). Delaying grazing until the grass sprouts have reached a more advanced stage of maturity is an important sustainable grazing practice.

Finally, increasing livestock mobility, a traditional strategy of nomadic and transhumant herders in many parts of Africa for matching animal production needs with changing rangeland resources, can significantly enhance the resilience of these livestock systems to climate change. Land tenure reforms to deal with the encroachment of cultivated lands and other land uses that impede livestock mobility will be needed (Morton, 2007).

Pasture management and nutrition

Pasture management measures involve the sowing of improved varieties of pasture, typically the replacement of native grasses with higher yielding and more digestible forages, including perennial fodders, pastures and legumes (Bentley *et al.*, 2008). For example, in tropical grazing systems of Latin America, substantial improvements in soil carbon storage and farm productivity, as well as reductions in enteric emission intensities, are possible by replacing natural cerrado vegetation with deep-rooted pastures such as *Brachiaria* (Thornton and Herrero, 2010). However, there are far fewer opportunities for sowing improved pastures in arid and semi-arid grazing systems.

The intensification of pasture production though fertilization, cutting regimes and irrigation practices may also enhance productivity, soil carbon, pasture quality and animal performance. These approaches however, may not always reduce GHG emissions. Improved pasture quality through nitrogen fertilization may involve trade-offs between lower CH_4 emissions and higher N_2O emissions (Bannink *et al.*, 2010). Also, after accounting for energy-related emissions and N2O emissions associated with irrigation, the net GHG emissions of this practice may be negative on grazing lands (Eagle *et al.*, 2012). Grass quality can also be improved by chemical and/or mechanical treatments and ensiling.

With increasing variability in climatic conditions (e.g. increasing incidents of drought) due to climate change, there may be an increase in the frequency of periods where forage availability falls short of animal demands. In these situations, supplemental feeding can be an important adaptation strategy.

Animal breeding

Animal breeding to select more productive animals is another strategy to enhance productivity and thereby lower CH_4 emission intensities. Research has recently been done on the mitigation benefits of using residual feed intake as a selection tool for low CH_4 emitting animals, but so far findings have been inconclusive (Waghorn and Hegarty, 2011).

There is also evidence that cross-breeding programmes can deliver simultaneous adaptation, food security and mitigation benefits. For example, composite cattle breeds developed in recent decades in tropical grasslands of northern Australia have demonstrated greater heat tolerance, disease resistance, fitness and reproductive traits compared with pure shorthorn breeds that had previously dominated these harsh regions (Bentley *et al.*, 2008). In general, cross-breeding strategies that make use of locally adapted breeds, which are not only tolerant to heat and poor nutrition, but also to parasites and diseases (Hoffmann, 2008), may become more common with climate change.

Adaptation to climate change can also be fostered through the switching of livestock species. For example, the Samburu of northern Kenya, a traditionally cattle-keeping people, adopted camels as part of their livelihood strategy. This switch allowed them to overcome a decline in their cattle economy, which, from 1960 onwards, had been affected by drought, cattle raiding and animal disease (Sperling, 1987).

Animal and herd management, disease control and feeding strategies

As with all livestock production systems, there are a number of animal and herd management options for land-based systems that can enhance animal productivity, improve feed conversion efficiency and thereby reduce enteric emission intensities. Better nutrition, improved animal husbandry, the regular maintenance of animal health and the responsible use of antibiotics can improve reproduction rates, reduce mortality and reduce the slaughter age. All of these measures will therefore increase the amount of output produced for a given level of emissions. The impacts of these measures on adaptation are likely to be neutral.

In addition to enhanced animal health management to maintain and improve animal performance, the management of disease risks may also become increasingly important, as there may be an increase in the emergence of gastro-intestinal parasites due to climate change (Wall and Morgan, 2009). Breeding more disease-resilient animals is one approach to addressing this issue.

Vaccines

Because of their wide applicability, even for very low-input extensive systems with little human intervention, vaccines against methanogens (microorganisms that produce methane as a metabolic by-product in low-oxygen conditions) in the rumen are a potentially useful mitigation option for ruminants in land-based grazing systems. However, more research and development is needed before this option is ready for widespread adoption (Wright and Klieve, 2011).

Early warning systems and insurance

The use of weather information to assist rural communities in managing the risks associated with rainfall variability is a potentially effective (preventative) option for climate change adaptation. However, there are issues related to the effectiveness of climate forecasts for livestock management that still need to be addressed (Hellmuth *et al.,* 2007). Livestock insurance schemes that are weather-indexed (i.e. policy holders are paid in response to 'trigger events' such as abnormal rainfall or high local animal mortality rates) may also be effective where preventative measures fail (Skees and Enkh-Amgala, 2002). There may be limits however to what private insurance markets can do for large vulnerable populations facing covariate risks linked to climate change (UNDP, 2008). In situations where risks are unacceptably high for the private sector, recently developed public-private partnership approaches to index-based livestock insurance, in which the public sector underwrites a share of these risks, could play an important role. Indexed insurance schemes based on satellite imagery are being piloted in several areas of drought-prone northern Kenya (Barrett *et al.,* 2008; Mude, 2009).

Agroforestry practices

Agroforestry is an integrated approach to the production of trees and non-tree crops or animals on the same piece of land. Agroforestry is important both for climate change mitigation (carbon sequestration, improved feed and consequently reduced enteric methane) and for adaptation in that it improves the resilience of agricultural production to climate variability by using trees to intensify and diversify production and buffer farming systems against hazards. Shade trees reduce heat stress on animals and help increase productivity. Trees also improve the supply and quality of forage, which can help reduce overgrazing and curb land degradation (Thornton and Herrero, 2010).

Box 8.1 Silvopastoral systems in Central and South America

In a Global Environmental Facility (GEF) funded project, the Tropical Agricultural Research and Higher Education Centre (CATIE) worked with FAO, Nitlapan in Nicaragua and the Fundación Centre for Research on Sustainable Farming Systems (CIPAV) in Colombia and the World Bank to evaluate the impacts of payment for environmental services on the adoption of silvopastoral systems. From 2003 to 2006, cattle farmers from Colombia, Costa Rica and Nicaragua, received between US$ 2 000 and US$ 2 400 per farm (an amount that represents 10 to 15 percent of their net income) to implement the programme on silvopastoral systems. The programme led to a 60 percent reduction in degraded pastures in the three countries, and the area of land used for silvopastoral systems (e.g. improved pastures with high density trees, fodder banks and live fences) increased significantly. The environmental benefits associated with the project included a 71 percent increase in carbon sequestration (from 27.7 million tonnes of CO_{2}-eq in 2003 to 47.6 million tonnes CO_{2}-eq in 2006). Milk production increased by 10 percent, and farm income rose by 115 percent. Herbicide use dropped by 60 percent, and the practice of using fire to manage pasture is now less frequent.

Source: FAO, 2010a

Mixed systems

Because they serve multiple purposes, mixed livestock systems, if well managed, may be among the most promising means of adapting to climate change and mitigating the contribution of crop and livestock production to GHG emissions. There are a number of agronomic techniques and livestock management practices that have proven to be effective in delivering multiple benefits (food security, and improved climate change mitigation and adaptation). The options presented below deal with integrated mixed systems but focus on livestock-related interventions for CSA.

Integrated soil-crop-water management

Soil and water are intrinsically linked to crop and livestock production. For this reason, an integrated approach to soil and water management is vital for increasing efficiency in the use of resources, adapting to and mitigating climate change, and sustaining productivity. For example, by increasing the organic content of the soil through conservation tillage, the soil's water holding capacity increases, which makes yields more resilient and reduces erosion (Lal, 2009). Existing soil and water adaptation technologies include: minimum or zero tillage; erosion control; the use of crop residues to conserve soil moisture; and improved soil cover through cover crops. By increasing water infiltration, reducing evaporation and increasing storage of rainwater in soils, many crop management practices (e.g. mulching, green manures, conservation tillage and conservation agriculture) will help land users in areas projected to receive lower levels of precipitation adapt to climate change. Promoting the capture of carbon in the soil also mitigates climate change. Soil management practices that limit soil compaction, reduce tillage and retain crop residues lower the potential for N_2O loss, increase soil carbon and at the same time improve yields. In addition, managing pests, diseases or weeds using technologies such as the 'pull-and-push technology' can contribute to improving the availability of food and animal feed in crop-livestock systems (Lenné and Thomas, 2005).

Water use efficiency and management

In the coming decades, water management will be a critical component for adapting to climate change as well as socio-economic changes. Practices that increase the productivity of water use (defined as crop output per unit of water) may have significant climate change adaptation potential for all land production systems. A number of adaptation techniques and approaches that are specific to water management include: cultivation of crop varieties with increased resistance to extreme conditions; irrigation techniques that maximize water use; adoption of supplementary irrigation in rain-fed systems and water-efficient technologies to harvest water; and the modification of cropping calendars (timing or location) (FAO, 2011a). Descheemaeker *et al.* (2010) cite three broad strategies for improving livestock-water productivity in mixed crop-livestock systems: feed management (e.g. improving feed quality, increasing feed-water productivity, enhancing feed selection, strengthening grazing management); water management; and animal management (e.g. increasing animal productivity and health).

Sustainable soil management

Carbon sequestration in soils has the potential to mitigate climate change and bolster climate change adaptation (Pascal and Socolow, 2004). A climate-smart strategy involves creating a positive carbon budget in soils and ecosystems by using residues as mulch in combination with no-till farming and integrated nutrient management (i.e. the appropriate application of both synthetic and organic fertilizer). In addition, soil carbon sequestration delivers numerous ancillary benefits by improving soil quality and other ecosystem services. Restoration of degraded soils, through increases in soil organic carbon pools, improves production, which helps foster food security and improves nutrition. Increasing the pool of soil organic carbon is also important for improving efficiency in the use of nitrogen and potassium. Water quality also improves through a greater control of non-point source pollution (Lal, 2009).

Feed management

Herrero *et al.* (2008) estimate that crop residues can represent up to 50 percent of the diet of ruminants in mixed farming systems. While these feed resources provide an inexpensive feed source, they are usually of low digestibility and deficient in crude protein, minerals and vitamins. This low digestibility substantially limits productivity and increases CH_4 emissions. Increasing the digestibility of feed rations by improving the quality of crop residues, or supplementing diets with concentrates will reduce CH_4 emissions. Other existing feed management practices in mixed farming systems include the use of improved grass species and forage legumes. Animal productivity can be improved by using a multidimensional approach for improving the quality and thereby the utilization of food-feed crops. This can also lead to a reduction in animal numbers, lower feed requirements and reduced GHG emissions (Blümmel *et al.,* 2009).

Diversification to climate-resilient agricultural production systems

The diversification of sensitive production systems can enhance adaptation to the short- and medium-term impacts from climate change. Transitions within mixed farming systems are already occurring. In marginal areas of southern Africa, reductions in length of growing period and increased rainfall variability are leading to conversions from mixed crop–livestock systems to rangeland-based systems, as farmers find growing crops too risky in marginal environments (Thornton *et al.,* 2009). Changing the mix of farm products (e.g. proportion of crops to pastures) is an example of a farm-level adaptation option. Farmers may reassess the crops and varieties they grow, and shift from growing crops to raising livestock, which can serve as marketable insurance in times of drought. They may also introduce heat-tolerant breeds that are more resistant to drought. In a case study covering villages in three South African provinces, Thomas *et al.* (2007) found that during dry spells farmers tended to reduce their investment in crops or even stop planting altogether and focused instead on livestock production.

In most cases, these practices deliver multiple benefits. However, before long-term benefits can be reaped, there are some tradeoffs that need to be made in the short term with respect to emissions, productivity and food security. Consequently, despite the long-term benefits, poor subsistence farmers may not be willing or able to accept the short-term losses associated with some of these practices.

Table 8.3
Summary of CSA practices and technologies for mixed farming systems

	Management objective	Practices/technologies	Impact on food security	Effectiveness as an adaptation strategy	Effectiveness as an mitigation strategy	Main constraints to adoption
Crop and grazing land management	Improved crop varieties	conventional breeding (e.g. dual purpose crops, high yielding crops)	+++	+++	Uncertain	High investment costs; high prices of improved varieties, high input costs (e.g. fertilizer)
		Modern biotechnology and genetic engineering (e.g. genetically modified stress tolerant crops)	++	++	Uncertain	High investment costs, concerns with long-term potential impacts (e.g. loss of crop biodiversity, health concerns, limited enabling environment to support transfer of technology)
	Crop residue management	No-till/minimum tillage; cover cropping; mulching	+++	+++	++	Competing demands for crop residue biomass
	Nutrient management	Composting; appropriate fertilizer and manure use; precision farming	+++	++	++	Cost, limited access to technology and information
	Soil management	Crop rotations, fallowing (green manures), intercropping with leguminous plants, conservation tillage	+++	+++	++	Minimal gains over short term (e.g. short term decreases in production due to reduced cropping intensity)
	Grazing management	Adjust stocking densities to feed availability	+++	+++	+++	Risk aversion of farmers
		Rotational grazing	++	+++	+++	
Water management	Water use efficiency and management	Supplemental irrigation/water harvesting	++	++		Requires investment in infrastructure, extension, capacity building
		Irrigation techniques to maximize water use (amount, timing, technology)	++	++		
		Modification of cropping calendar	++	++		Lack of information on seasonal climatic forecast trends, scenarios
Livestock management	Improved feed management	Improving feed quality: diet supplementation; improved grass species; low cost fodder conservation technologies (e.g. baling, silage)	+++	+++	+++	High costs
	Altering integration within the system	Alteration of animal species and breeds; ratio of crop-livestock, crop-pasture	++	+++	++	Lack of information on seasonal climatic forecast trends, scenarios
	Livestock management	Improved breeds and species (e.g. heat-tolerant breeds)	++	++	++	Productivity trade-off: more heat-tolerant livestock breeds generally have lower levels of productivity
		Infrastructure adaptation measures (e.g. housing, shade)	++	+++	+	
	Manure management	Anaerobic digesters for biogas and fertilizer	+++	+++	+++	High investment costs
		Composting, improved manure handling and storage, (e.g. covering manure heaps) application techniques (e.g. rapid incorporation)	++	+	++	

Mitigation/adaptation potential: + = low; ++ = medium; and +++= high

Source: Adapted from FAO, 2009b; Smith *et al.*, 2008; World Bank, 2008

Landless systems

Climate-smart options are also available for intensive systems (Gill *et al.*, 2009; UNFCCC, 2008). These options mainly relate to manure management (pig, dairy, and feedlots) and enteric fermentation (dairy and feedlots). Because these systems are generally more standardised than mixed and grazing systems, there are fewer applicable options.

Table 8.4
Summary of CSA practices and technologies for landless systems

Practices/technologies	Impact on food security	Effectiveness as adaptation strategy	Effectiveness as mitigation strategy	Main constraints to adoption
Anaerobic digesters for biogas and fertilizer	+++	+++	+++	Investment costs
Composting, improved manure handling and storage (e.g. covering manure heaps), application techniques (e.g. rapid incorporation)	++	+	++	
Temperature control systems	++	+++	-	High investment and operating costs
Disease surveillance	++	+++	+	
Energy use efficiency		+	+++	Subsidized energy costs
Improved feeding practices (e.g. precision feeding)	+++	+	+++	High operating costs
Building resilience along supply chains	++	+++	-	Requires coordination along the chains

Mitigation/adaptation potential: + = low; ++ = medium; and +++= high

Improved waste management

Most methane emissions from manure derive from swine and beef cattle feedlots and dairies, where production is carried out on a large scale and manure is stored under anaerobic conditions. GHG mitigation options include the capture of CH_4 by covering manure storage facilities (biogas collectors). The captured CH_4 can be flared or used as a source of energy for electric generators, heating or lighting. Energy generated in this way can offset CO_2 emissions from burning fossil fuels.

Anaerobic digestion technology has been shown to be highly profitable in warm climates (Gerber *et al.*, 2008). Recent developments in energy policy have also enhanced its economic profitability in countries such as Germany and Denmark (AEBIOM, 2009). Manure application practices can also reduce N_2O emissions. Improved livestock diets, as well as feed additives, can substantially reduce CH_4 emissions from enteric fermentation and manure storage (FAO, 2006a). Energy-saving practices have also been demonstrated to be effective in reducing the dependence of intensive systems on fossil fuels.

Box 8.2
Spatial planning and recovery of nutrient and energy from animal manure - insights from Thailand

Experience from Thailand shows that improving the spatial distribution of livestock production is a cost-effective way of fostering better manure management practices. Policy makers need to pay increased attention to the spatial distribution of livestock production as it creates the right economic conditions for the recycling of manure as an input to other production activities. Of particular importance are policy instruments that ensure that animal densities are such that manure can be recycled within a reasonable distance from its production. This would reduce animal concentrations in areas, such as peri-urban neighbourhoods, with low nutrient absorption capacity.

Better distribution of livestock production increases farm profits and at the same time reduces emissions. However, relying solely on regional planning does not lead to acceptable levels of emission reductions, except in specific cases. Better distribution of livestock should be considered a basic, low-cost measure, which should be combined with the development and enforcement of regulations and communication activities.

The adoption of bio-digestion can increase farm profits by 10 to 20 percent and help reduce the environmental impact of livestock production.

A cost-efficient reduction of pollution from intensive waste production requires a combination of better spatial distribution of livestock production and pollution control measures.

Source: more information can be found at FAO, 2010b

Improved feed conversion

Carbon dioxide emissions associated with feed production, especially soybean, are significant (FAO, 2006a). Improved feed conversion ratios have already greatly reduced the amount of feed required per unit of animal product. However, there is significant variation between production units and countries. Further progress is expected to be made in this area through improvements in feed management and livestock breeding. Reducing the amount of feed required per unit of output (e.g. beef, milk) has the potential to both reduce GHG emissions and increase farm profits. Feed efficiency can be increased by developing breeds that grow faster, are more hardy, gain weight more quickly, or produce more milk. Feed efficiency can also be increased by improving herd health through better veterinary services, preventive health programmes and improved water quality.

Sourcing low-emission feed

Shifting to feed resources with a low-carbon footprint is another way to reduce emissions, especially for concentrated pig and poultry production systems. Examples of low-emission feeds include feed crops that have been produced through conservation agriculture practices or that have been grown in cropping areas that have not been recently extended into forested land or natural pastures. Crop by-products and co-products from the agrifood industry are also examples of low-emission feeds.

Improving energy use efficiency

Landless systems generally rely on greater amounts of fossil fuel energy than mixed and grazing systems (Gerber *et al.*, 2011: FAO, 2009b). Improving energy use efficiency is an effective way to reduce production costs and lower emissions. Dairy farms are seen as having great potential for energy use efficiency gains. Energy is used for the milking process, cooling and storing milk, heating water, lighting and ventilation. Cooling milk generally accounts for most of the electrical energy consumption on a dairy farm in developed countries. Cows are milked at temperatures around 35 to 37.5 degrees Celsius. To maintain high milk quality, which includes keeping bacteria counts low, the raw milk temperature needs to be lowered quickly to 3 to 4 degrees Celsius. Refrigeration systems are usually energy-intensive. Heat exchangers cooled by well water, variable-speed drives on the milk pump, refrigeration heat recovery units and scroll compressors are all energy conservation technologies that can reduce the energy consumed in the cooling system. These technologies can reduce GHG emissions, especially in countries where the energy sector is emission intensive.

Building resilience along supply chains

Landless livestock systems rely on purchased inputs. Climate change contributes to increased price volatility of these inputs, especially feed and energy, which increases the financial risks for stakeholders involved in the livestock supply chain. This is especially true where commodity stocks of inputs are kept at a minimum throughout the supply chain and buffering options against price hikes are limited. In addition, the changing disease patterns caused by climate change can quickly affect landless systems that heavily rely on transport in the supply chain. Resilience can be achieved either by allowing chains to overcome the crisis or by creating the conditions for quick recovery after the crisis. Although little experience has yet been developed in this area, greater coordination among the different stakeholders involved in the supply chain, insurance schemes, buffers and stocks may contribute to a greater resilience of supply chains that rely on landless livestock systems.

Conclusions

Livestock can make a large contribution to climate-smart food supply systems. The sector offers substantial potential for climate change mitigation and adaptation. Mitigation options are available along the entire supply chain and are mostly associated with feed production, enteric fermentation and manure management. Livestock's role in adaptation practices relates to organic matter and nutrient management (soil restoration) and income diversification. Livestock also makes a key contribution to food security, especially in marginal lands where it represents a unique source of energy, protein and micronutrients. The contribution of the livestock sector to food security could be strengthened, particularly in areas where current levels of consumption of livestock products are low.

This module has highlighted how some practices require making tradeoffs between adaptation, mitigation and food security. However, most practices offer opportunities to exploit synergies in these areas. Several CSA practices are readily available for implementation, such as sylvopastoral systems, grassland restoration and management, manure management (recycling and biodigestion) and crop-livestock integration. Barriers to adoptions are most often related to a lack of information, limited access to technology and insufficient capital. Overcoming these barriers requires specific policy interventions, including extension work and financing mechanisms, such schemes for improving access to credit and payment for environmental services (see Modules 13 on policies and 14 on financing).

Research efforts are also required to identify additional combinations of mitigation and adaptation practices that are adapted to specific production systems and environments (e.g. combined interventions addressing the management of feed, genetic resources and manure). The potential aggregated effects that changes in farming systems may have on food security and the use of natural resources at the regional level also need to be better understood.

This module has also highlighted that CSA approaches need to take into consideration production systems and supply chains. This is especially true in the case of livestock, given the strong interrelationships with crops (feed and manure management) and the wider environment. Addressing mitigation or adaptation issues requires paying attention to spillover and feedback effects along the chain.

Case Study 8.1
Range management for mitigation and adaptation, in the Three Rivers region of Northern China

Background

The restoration of degraded grasslands through sustainable grazing management (SGM) practices, including: reductions in grazing pressure on overstocked sites; the sowing of improved pastures; and better pasture management, can lock more carbon in soils and biomass, increase the water-holding capacity of the soil and enhance grassland biodiversity. More widespread adoption of SGM practices is currently hindered, in part, by the high costs individual producers face in accessing carbon markets.

The Three Rivers Sustainable Grazing Project is a pilot project in the Qinghai province of China that addresses these challenges. In the project, which covers a total of 22 615 hectares of lightly to severely degraded grazing land, yak- and sheep-herding households will select a combination of management options related to grazing intensity, grass cultivation and animal husbandry. The project's goal is to restore degraded grazing land, and thereby sequester soil carbon, and at the same time increase productivity, build resilience and improve livelihoods in smallholder herder communities. The average annual mitigation potential in the first 10 years of the project were an estimated 63 000 tonnes of CO_2 eqv. per year.

Key lessons, constraints and selection criteria

1. Technical mitigation and adaptation potential

The primary selection criteria for this project was its high carbon sequestration potential, which was linked to the prevalence of heavily degraded grazing land (38 percent of the project area), and the availability of simple and cost-effective restoration measures. For instance, the average annual sequestration potential per hectare over the entire project is estimated to be more than 3 tonnes of CO_2 eqv., compared with IPCC global estimates of 0.11 to 0.81 CO_2 eqv. for grasslands (Smith *et al.*, 2007). Also, by improving soil moisture and nutrient retention in soils, grassland restoration plays an important role in building resilience to climate change.

2. Productivity and economic returns

Assessments revealed that restoration of degraded grazing lands would also significantly enhance the productive potential of the project site. Economic returns to herders will be enhanced by including a package of complementary measures, such as the introduction of improved feeding, winter housing, post-farm processing and marketing activities. The project's capacity to deliver net economic returns is crucial, as it greatly increases the likelihood of voluntary herder enrolment, and improves the synergy between climate change mitigation and rural development objectives.

3. Carbon crediting methodology and applicability

The project activities are able to enhance the long-term productivity and profitability of the farming system. Nevertheless, during the first years of the project, carbon finance is critical to help cover the investment costs associated with grass planting, fencing and animal housing. A key constraint to accessing carbon market finance is the absence of carbon accounting methodology that is both affordable, but also sufficiently accurate for investors. To address this constraint, FAO has developed a grassland carbon accounting methodology that is currently being validated under the Verified Carbon Standard. Instead of relying solely on direct measurement, which is often prohibitively costly, this methodology uses carefully calibrated biogeochemical models in combination with the monitoring of management activities to estimate soil carbon pool changes. This important innovation significantly reduces the costs associated with measurement and verification and greatly facilitates access to carbon markets. While developed as part of the Three Rivers project, the grassland carbon accounting methodology will be applicable to sustainable grazing projects throughout the world.

4. Institutional constraints

In addition to the barriers related to biophysical and economic measurement and verification, institutional constraints also need to be considered. The project's work in this area takes into consideration institutions for monitoring and enforcement, as well as institutions for marketing livestock products, which is needed to make the SGM practices a profitable option for herders. A lack of enforcement of laws for the adoption of sustainable stocking levels is common throughout China's main grassland areas. It is important for the project to establish community-based monitoring mechanisms and build capacities to implement and monitor sustainable development in the longer-term.

Table 8.5
Summary of climate-smart indicator rankings

Indicators	Ranking (-5 to +5)
Food security	+2
Productivity	+2
Livelihoods	+3
Adaptation and resilience	+3
Climate change mitigation	+5
Water use and retention	+2
Biodiversity	+2

Source: Smith *et al.*, 2007

Case study 8.2
Developing climate-smart cattle ranch in the central region of Nicaragua

Since 2004, the Livestock and Environmental Management Programme at Tropical Agricultural Research and Higher Education Centre (CATIE) has been implementing participatory training processes in Central America with cattle producers using the farmer field school philosophy. This process has promoted the adoption of silvopastoral systems and good practices to improve income, food security, ecosystem services and adaptation to and mitigation of climate change. Seven dual-purpose farms (milked cows with calf at foot) were selected for each of the following groups: with silvopastoral system and traditional system. The first group was predominantly fed with improved pasture with trees, cut and carry fodder banks of forage grass (Pennisetum purpureum) and woody fodder (Gliricidia sepium and Cratylia argentea). Compared with traditional farming systems, the silvopastoral system farms had higher milk production per cow during the year. Farmers also earned more income and more carbon was stored in the soil (Table 8.6). The impacts of silvopastoral system innovations are clearly visible. However, sustainable participatory training processes (learning by doing) and incentive mechanisms (soft credits, certification and green markets in value chains) are required to encourage the uptake of these innovative practices. To meet the goals of CSA, farmers themselves must use their own assessments to develop design proposals that are based on silvopastoral system and good practices (e.g. efficient use and conservation of water, and manure management) and are suitable to the farm's biophysical and socioeconomic conditions. The farmers using silvopastoral system have the potential to contribute to reaching CSA objectives (Table 8.7) and would improve ecosystem health.

Table 8.6
Productive, economic and environmental performance of silvopastoral and traditional cattle farms in the Central region of Nicaragua

Indicator	Cattle ranch with silvopastoral practices	Traditional cattle ranch
Milk production (kg/cow/day)		
Rainy season	7.4	4.7
Dry season	4.4	2.9
Rank of income (US$/hectare/year)	346.3 - 519.6	227.7 – 327.8
Carbon sequestration (tonne/hectare)	11.0	5.3

Source: Chuncho, 2010

Table 8.7 Response farms with silvopastoral and traditional systems to the CSA approach functions

Variable	Cattle ranch with silvopastoral practices	Traditional cattle ranch
Food security	+3	+/-
Productivity	+4	+2
Livelihoods	+4	+2
Adaptation and resilience	+5	-1
Mitigation	+5	-1
Water use	+2	-1
Energy use	+3	-1
External inputs	+4	-2

Ranking -5 to +5

Source: Chuncho, 2010

Notes

This Module was written by Pierre Gerber (FAO) with contributions from Benjamin Henderson (FAO) and Carolyn Opio (FAO). Case study 8.2 was written by Muhammad Ibrahim (IICA-Belize), Cristóbal Villanueva (CATIE), Claudia Sepúlveda (CATIE), Diego Tobar (CATIE), Guillermo Chuncho (CATIE).

Acronyms

AEBIOM	European Biomass Association
CATIE	Tropical Agricultural Research and Higher Education Centre
CIPAV	Centre for Research on Sustainable Farming Systems
CO_2	carbon dioxide
CO_2 eqv.	carbon dioxide equivalent
CH_4	methane
CSA	climate-smart agriculture
CW	carcass weight
FPCM	fat and protein corrected milk
GEF	Global Environment Facility
GHG	greenhouse gas
IICA	Inter-American Institute for Cooperation on Agriculture
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
LCA	Life Cycle Assessment
LWG	live weight gain
NH_3	ammonia
N_20	nitrous oxide
SGM	sustainable grazing management
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change

References

European Biomass Association (AEBIOM). 2009. *European Biomass Association.* (available at http://www.aebiom.org/)

Aydinalp, C. & Cresser, M.S. 2008. *The effects of global climate change on agriculture*. American–Eurasian journal of agricultural and environmental science, 3: 672–676.

Bannink, A., Smits, M.C.J., Kebreab, E., Mills, J.A.N., Ellis, J.L , Klop, A., France, J. & Dijkstra, J. 2010. *Simulating the effects of grassland management and grass ensiling on methane emission from lactating cows.* Journal of agricultural science, 148:55-72.

Barrett,C.B., Carter, M.R., McPeak, J. & Mude A. 2008. *Altering poverty dynamics with index 608 insurance: Northern Kenya's HSNP+. BASIS brief 2008-08*. Madison, USA, University of Wisconsin. (available at www.basis.wisc.edu/live/amabrief08-08.pdf)

Baylis, M. & Githeko, A.K. 2006. *The effects of climate change on infectious diseases of animals.* Report for the Foresight Project on Detection of Infectious Diseases, Department of Trade and Industry, UK Government.

Bentley, D. & Hegarty, R. 2008. *Managing livestock enterprises in Australia's extensive rangelands for greenhouse gas and environmental outcomes: a pastoral company perspective*. Australian journal of experimental agriculture, 48: 60-64.

Blummel, M., Anandan, S. & Prasad, C.S. 2009. *Potential and limitations of byproduct based feeding system to mitigate green house gases for improved livestock productivity.* In Proceedings of 13th biennial conference of Animal Nutrition Society of India, pp. 68–74. Bangalore.

Burke, M.B., Lobell, D.B. & Guarino, L. 2009. *Shifts in African crop climates by 2050, and the implications for crop improvements and genetic resources conservation.* Global Environ.Change, 19: 317–325.

Chuncho, G. 2010. *Análisis de la percepción y medidas de adaptación al cambio climático que implementan en la época seca los productores de leche en Río Blanco y Paiwas, Nicaragua.* CATIE, Turrialba, CR. 170 p. (MSc. Thesis)

Conant, R.T. & Paustian, K. 2002. *Soil carbon sequestration in overgrazed grassland ecosystems.* Global Biogeochemical Cycles, 16: 1143.

Descheemaeker, K., Amede, T. & Haileslassie, A. 2010. *Improving water productivity in mixed crop-livestock farming systems of sub-Saharan Africa.* Agricultural water management, 97: 579–586.

Eagle, A.J., Olander, L.P., Henry, L.R., Haugen-Kozyra, K., Millar, N. & Robertson, G.P. 2012. *Greenhouse gas mitigation potential of agricultural land management in the United States: a synthesis of literature.* Report NI R 10-04, Third Edition. Durham, USA, Nicholas Institute for Environmental Policy Solutions, Duke University.

FAO. 2006a. *Livestock's long shadow: environmental issues and options.* Rome. (available at ftp://ftp.fao.org/docrep/fao/010/A0701E/A0701E00.pdf)

FAO. 2006b. *World agriculture: towards 2030/2050.* Rome.

FAO. 2009a. *Food security and agricultural mitigation in developing countries: options for capturing synergies.* Rome.

FAO. 2009b. *State of food and agriculture – livestock in the balance.* Rome.

FAO. 2010a. *Climate-smart agriculture: policies, practices and financing for food security, adaptation and mitigation.* Report prepared for The Hague Conference on Agriculture, Food Security, and Climate Change. Rome.

FAO. 2010b. *Livestock Waste Management in East Asia Project.* (available at http://www.fao.org/agriculture/lead/themes0/pollution/waste/en/ and http://www.fao.org/ag/againfo/home/en/news_archive/AGA_in_action/docs/LWMEA-Experience_Note.pdf)

FAO. 2011b. *World livestock 2011 – livestock in food security.* Rome.

FAO. 2011a. *Land and water options for climate change adaptation and mitigation in agriculture.* Thematic background paper for the state of the world's land and water resources for food and agriculture (SOLAW)— Managing systems at risk. Rome.

FAO. 2013a (forthcoming). *Greenhouse gas emissions from ruminant supply chains – a global life cycle assessment.* Rome.

FAO. 2013b (forthcoming)*. Greenhouse gas emissions from pig and chicken supply chains – a global life cycle assessment.* Rome.

Gerber, Pierre J.; Carsjens, Gerrit J.; Pak-uthai, Thanee and Robinson, Timothy P. 2008. *"Decision support for spatially targeted livestock policies: Diverse examples from Uganda and Thailand."* Agricultural Systems, 96 (1-3): 37-51.

Gerber, P., Vellinga, T., Opio, C., & Steinfeld, H. 2011. *Productivity gains and greenhouse gas intensity in dairy systems*. Livestock Science, 139: 100–108.

Gill, M.P., Smith, P. & Wilkinson, J.M. 2009. *Mitigating climate change: the role of domestic livestock.* Animal, 4 (3): 321—322.

Hellmuth, M.E., Moorhead, A., Thomson, M. & Williams, J. 2007. *Climate risk management in Africa: learning from practice.* Climate and Society, No.1. Palisades, NY, the International Research Institute for Climate and Society (IRI).

Herrero, M., Thornton, P.K., Kruska, R. & Reid, R.S. 2008. *Systems dynamics and the spatial distribution of methane emissions from African domestic ruminants to 2030*. Agriculture, Ecosystems and Environment, 126: 122—137.

Hoffman, M.T. & Vogel, C. 2008. *Climate change impacts on African rangelands*. Rangelands, 30: 12–17.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: impacts, adaptation and vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the IPCC, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds. Cambridge University Press, Cambridge, UK, 976 pp.

Kurukulasuriya, P. & Rosenthal, S. 2003. *Climate change and agriculture: a review of impacts and adaptations.* Climate Change Series Paper No. 91. Washington D.C., World Bank.

Lal, R. 2009. *Soil and water management options for adaptation to climate change.* Adapting agriculture to climate change, A. Eaglesham & R.W.F. Hardy, eds. NABC's twenty-first annual conference, Saskatoon.

Lenné, J. M. & Thomas, D. 2005. *Addressing poverty through crop-livestock integration: the contribution of past research to future challenges*. Integrating livestock-crop systems to meet the challenges of globalization, P. Rowlinson, C. Wachirapakorn, P. Pakdee, & M. Wanapat, eds. AHAT/BSAS International Conference, Khon Kaen, Thailand, pp. 13-26.

Morton, J.F. 2007. *The impact of climate change on smallholder and subsistence agriculture.* PNAS, 104: 19680–19685.

Mude, A. 2009. *Index-based livestock insurance for northern Kenya's arid and semi-arid lands: the Marsabit pilot.* Project document, ILRI, Nairobi, Kenya, 14 pp.

Pascal, S. & Socolow, R. 2004. *Stabilization wedges: solving the climate problem for the next 50 years with current technologies.* Science, 305: 968–972.

Randolph, S.E. 2008. *Dynamics of tick-borne disease systems: minor role of recent climate change.* Revue Scientifique et Technique. International Office of Epizootics, 27: 367–381.

Rolfe, J. 2010. *Economics of reducing grazing emissions from beef cattle in extensive grazing systems in Queensland.* The Rangeland Journal, 32: 197–204.

Sidahmed, A. 2008. *Livestock and climate change: coping and risk management strategies for a sustainable future.* Livestock and Global Climate Change conference proceeding, Tunisia.

Skees. J.R. & Enkh-Amgala, A. 2002. *Examining the feasibility of livestock insurance in Mongolia.* Policy Research Working Paper 2886, Washington D.C., World Bank.

Smith P., Martino D., Cai Z., Gwary D., Janzen H., Kumar P., McCarl B., Ogle S., O'Mara F., Rice C., Scholes B., Sirotenko O. 2007. *Agriculture*. In B. Metz, OR. Davidson, PR. Bosch, R. Dave and L.A. Meyer, eds. Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, United Kingdom and New York, USA.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach M. & Smith, J. 2008. *Greenhouse gas mitigation in agriculture.* Phil. Trans. R. Soc. B, 363: 789–813.

Sperling, L. 1987. *The adoption of camels by Samburu cattle herders.* Nomadic Peoples, 23: 1–18.

Thomas, D. S. G., Twyman, C., Osbahr, H. & Hewitson, B. 2007. *Adaptation to climate change and variability: farmer responses to intra-seasonal precipitation trends in South Africa.* Climatic Change, 83(3): 301–322.

Thornton, P.K., van de Steeg, J., Notenbaert, A. & Herrero, M. 2009. *The impacts of climate change on livestock and livestock systems in developing countries: a review of what we know and what we need to know.* Agricultural Systems, 101: 113-127.

Thornton, P.K. & Herrero, M. 2010. *Potential for reduced methane and carbon dioxide emissions from livestock and pasture management in the tropics.* New York, USA, PNAS.

Thornton, P.K. 2010. *Livestock production: recent trends, future prospects.* Philosophical Transactions of the Royal Society B, 365: 2853–2867.

Thornton, P.K. & Gerber, P. 2010. *Climate change and the growth of the livestock sector in developing countries.* Mitigation and Adaptation Strategies for Global Change, 15: 169–184.

United Nations Development Programme (UNDP). 2008. *Human Development Report 792 2007/2008: fighting climate change: human solidarity in a divided world.* New York, USA.

United Nations Framework Convention on Climate Change (UNFCC). 2008. *Challenges and opportunities for mitigation in the agricultural sector.* (available at *http://unfccc.int/resource/docs/2008/tp/08.pdf*)

Waghorn, G.C. & Hegarty, R.S. 2011. *Lowering ruminant methane emissions through improved feed conversion efficiency.* Animal Feed Science Technology, 166–167: 291–301.

Wall, R. & *Morgan, E.* 2009. Veterinary parasitology and climate change. Veterinary Parasitology, 163: 263.

Washington, R., Harrison, M., Conway, D., Black, E., Challinor, A., Grimes, D., Jones, R., Morse, A., Kay, G. & Todd, M. 2006. *African climate change - taking the shorter route.* Bulletin Of The American Meteorological Society, 87 (10): 1355–1366.

Westhoek, H., Rood, T., Van den Berg, M., Janse, J., Nijdam, D., Reudink, M. & Stehfest, E. 2011. *The protein puzzle: the consumption and production of meat, dairy and fish in the European Union.* The Hague, PBL Netherlands Environmental Assessment Agency. (available at http://www.pbl.nl/sites/default/files/cms/publicaties/Protein_Puzzle_web_1.pdf)

Wilby, R.L., Troni, J., Biot, Y., Tedd, L., Hewitson, B.C., Smith, D.G. & Sutton, R.T. 2009. *A review of climate risk information for adaptation and development planning.* International Journal of Climatology, 29: 1193–1215.

World Bank. 2008. *Climate change response strategies for agriculture: challenges and opportunities for the 21st century.* The International Bank for Reconstruction and Development and the World Bank.

Wright, A. D. G. & Klieve, A. V. 2011. *Does the complexity of the rumen microbial ecology preclude methane mitigation?* Animal Feed Science Technology, 166–167: 248–253.

Additional Resources

Bryan, E., Ringler, C., Okaba, B., Koo, J., Herrero, M. & Silvestri, S. 2011. *Agricultural land management: capturing synergies between climate change adaptation, greenhouse gas mitigation and agricultural productivity – Insights from Kenya.* Report to the World Bank. Report 3b of Adaptation of smallholder agriculture to climate change in Kenya project, 116 p.

Clements, R., Haggar, J., Quezada, A. & Torres, J. 2011. *Technologies for climate change adaptation – agriculture sector,* X. Zhu, ed. Risø Centre, Roskilde, UNEP.

FAO. 2012. *Crop residue based densified total mixed ration – a user-friendly approach to utilise food crop by-products for ruminant production, by T.K.* Walli, M.R. Garg & H.P.S. Makkar. FAO Animal Production and Health Paper No. 172. Rome. (available at http://www.fao.org/docrep/015/i2728e/i2728e00.pdf)

Gerber, P., Key, N., Portet, F. & Steinfeld, H. 2010. *Policy options in addressing livestock's contribution to climate change.* Animal, 4: 393–406.

Henderson, B., Gerber, P. & Opio, C. 2011. *Livestock and Climate Change, Challenges and Options.* CAB Reviews, 6(16).

Kaimowitz, D. & Angelsen, A. 2008. *Will livestock intensification help save Latin America's tropical forests?* Journal of Sustainable Forestry, 27: 1, 6–24.

Opio, C., Gerber,P. & Steinfeld, H. 2012. *Livestock and the environment: addressing the consequences of livestock sector growth.* Advances in Animal Biosciences, 2 (3): 601–607.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., Ogle, S., O'Mara, F., Rice, C., Scholes, B., Sirotenko, O., Howden, M., McAllister, T., Pan, G., Romanenkov, V., Schneider, U., Towprayoon, S., Wattenbach M. & Smith, J. 2006. *Policy and technological constraints to implementation of greenhouse gas mitigation options in agriculture.* Agriculture, Ecosystems and Environment, 118: 6–28.

Van Keulen, H. & Schiere, H. 2004. *Crop-livestock systems: old wine in new bottles?* New Directions for a Diverse Planet: Proceedings of the 4th International Crop Science Congress. Brisbane, Australia.

Vilela, L., Martha, Jr. G.B, Macedo, M.C.M., Marcho, R.L., Guimares, R., Pulrolnik, K. & Maciel, G.A. 2011. *Sistemas de integrao lavoura-pecuria na regio do Cerrado.* Pesquisa Agropecuria Brasileira, 46:1127–1138.

MODULE 9:
CLIMATE-SMART FORESTRY

Key messages

- Climate change and climate variability jeopardize the delivery of goods and ecosystem services from forests and trees that are essential to livelihoods and food security, to environmental sustainability, and to national development.
- Sustainable forest management (SFM) provides a fundamental foundation for climate change mitigation and adaptation and contributes to food security through various means. Climate-smart forestry will require more widespread application of SFM principles. Mainstreaming climate change into forest policy and practice will entail capturing synergies and managing tradeoffs with other forest management objectives.
- Because information on local level climate change impacts and vulnerabilities is generally lacking, strengthening local institutions and governance processes to improve capacities for sound forest-related decision-making under uncertainty and supporting "no regrets" adaptation actions are important strategies.
- Efforts to transition to climate-smart forestry will need to take place at all levels (individual/enterprise, community, national and regional) and time scales. Planning and implementation should involve all stakeholders, be tailored to the local circumstances, address equity issues and be gender sensitive.
- CSA in the forest sector will entail designing adaptation actions targeted at the most vulnerable communities and sectors of the population (e.g. women, elderly, indigenous people) and forest systems (e.g. dryland, mountain, coastal forests), focusing on the most efficient and cost-effective mitigation options and capitalizing on adaptation-mitigation synergies.
- Forest and tree ecosystem services are often largely overlooked and undervalued, but will become increasingly more important for human adaptation to climate change. Increased understanding of these services and means to maintain and enhance them and policies to support their delivery will be of heightened priority.
- Climate change responses, particularly mitigation policies, are leading to changes in markets for forest products and may drive substitution of forest products for more energy- or carbon-intensive products. Forest planning and management will have to be sensitive and adjust to such market changes.
- Clear definition of forest and tree tenure is important for the achievement of SFM and for adoption of climate change adaptation and mitigation measures. Clarity of ownership of forest carbon and rights to trade it will also be important to incentivize forest carbon projects.
- Forests and trees provide a range of forest products and ecosystem services. The benefits and costs of these will accrue differently to different stakeholders, as will the benefits' costs and benefits associated with mitigation and adaptation actions. The costs and benefits associated with mitigation and adaptation actions must be equitably shared to secure long-term commitment to their implementation.
- Forests are home to an estimated 60 million indigenous peoples who depend on them for their livelihoods and have a wealth of knowledge about the forest resources. When undertaking climate change mitigation and adaptation actions, it is essential to involve indigenous people in decisions on the management of the forests and to ensure that their rights are recognized and respected.

MODULE 10:

CLIMATE-SMART FISHERIES AND AQUACULTURE

Overview

This module looks at the climate-Smart Agriculture (CSA) concept from the perspective of the fisheries and aquaculture sector. Organized into six sections, the module provides an overview of the contributions made by the fisheries and aquaculture sector, the climate change impacts pathways that are affecting the sector and the vulnerabilities currently undermining resilience in aquatic systems. The ecosystem approach to fisheries and aquaculture (EAF/EAA) is presented as the underlying approach to developing climate-smart fisheries and aquaculture. Actions that support this approach are: sustainably increasing output productivity and efficiency within the sector; reducing the sector's vulnerability and increasing its resilience to change; and reducing and removing greenhouse gases (GHG) from within the sector. The module presents options for supporting these actions at different levels (national, regional, subsector, individual enterprise and community). The module concludes with an evaluation of the sector's progress towards CSA and the elements that support the successful transition to CSA. Boxes are used throughout the module to provide concrete examples of CSA actions and approaches.

Key messages

- Fisheries and aquaculture provide essential nutrition, support livelihoods and contribute to national development. However, the sector is facing significant challenges in maintaining its crucial contribution to these areas. Increasing global demand for fish and aquatic foods, ocean acidification and climate variability and change will only add to these challenges.
- Climate-smart fisheries and aquaculture will require: improving efficiency in the use of natural resources to produce fish and aquatic foods; maintaining the resilience aquatic systems and the communities that rely on them to allow the sector to continue contributing to sustainable development; and gaining an understanding of the ways to reduce effectively the vulnerability of those most likely to be negatively impacted by climate change.
- There is no lack of guidance for the sector. The Code of Conduct for Responsible Fisheries and the ecosystem approach to fisheries and aquaculture outline the principles and approaches that are central to ensuring the sustainability of the sector. However, the application of these principles and approaches is not keeping pace with the increasing need for their implementation.
- The general understanding of the implications of climate variability and change is improving. However, information on local-level impacts and vulnerabilities is lacking, which hampers adaptation planning. Improved capacities for decision-making under uncertainty are required.
- Examples of win-win tactics for attaining CSA objectives that are available to the sector include: the reduction of excess capacity and the implementation of fishing activities that are linked with improved fisheries management and healthy stocks; increased production efficiency through better integrated systems; improved feeding and reduced losses from disease in aquaculture; the reduction of post-harvest and production losses; and the further development of regional trade.
- The transition to CSA in fisheries and aquaculture will need to take place at all levels (individual,

business, community, national and regional) and time scales. All stakeholders from private and public sectors will need to be involved in the development of context-specific options to ensure the fisheries and aquaculture sector is climate-smart.

- To make the transition to CSA in fisheries and aquaculture, it will be necessary to ensure that the most vulnerable states, production systems, communities and stakeholders have the potential to develop and apply CSA approaches.
- Markets and trade may help buffer the impact of changes in production that affect food security, consumer prices and supply-demand gaps. However, the implications of climate change impacts and climate change policies on the entire supply and value chain need to be better understood. Appropriate policy measures need to be defined and implemented.

Contents

List of Figures

List of Tables

List of Boxes

List of Case Studies

10. 1 Introduction

This module addresses the following questions: What are the implications of climate change for the sector in relation to food security, nutrition and livelihoods? How can resilience be built and vulnerability be reduced within fisheries and aquaculture systems? What role does the sector need to do to reduce its greenhouse gas (GHG) emissions, provide alternative sources of energy and support aquatic systems' natural GHG sequestration and storage services?

The significance of fisheries and aquaculture

Fisheries and aquaculture support the incomes and livelihoods of 660-820 million people, about 10-12 percent of the world's population. The sector has an important role to play in gender equality, poverty and food security. With global fish supply over 150 million tonnes, more than 85 percent of this supply is used directly for food; supplying 15 percent of the world's protein and essential nutrition for around 4.3 billion consumers (FAO, 2012). The sector generates first sale values of over US$ 218 billion annually, and about 38 percent of production is traded internationally (FAO, 2012). Aquatic systems are also associated with rich biological diversity – with at least 27 000 species of fish, shellfish and aquatic plants, in a wide variety of ecosystems, so far identified (FAO, 2010a).

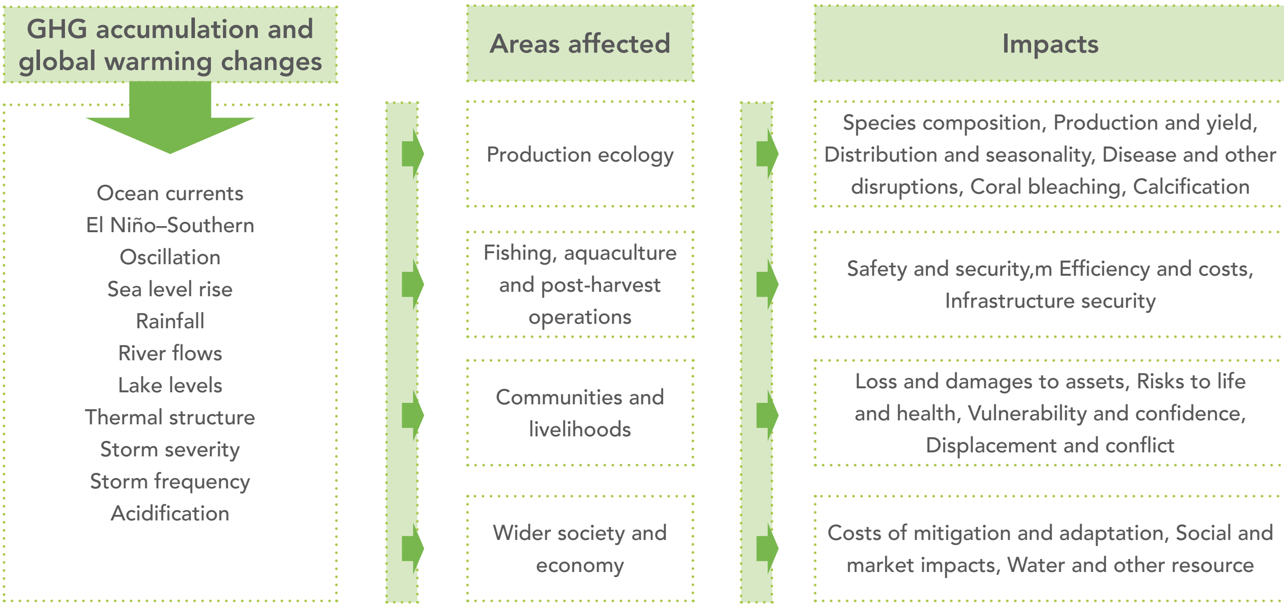
The global population is expected to increase to 9-10 billion by 2050. Expanding populations will create greater demand for aquatic foods, and the importance of fisheries resources and production systems will increase. However, there are significant concerns for the health of these resources with approximately 30 percent of assessed stocks estimated to be overexploited and global fish catches static or even declining (FAO, 2011). Consequently, aquaculture will have to satisfy much of the future demand for aquatic foods. To meet this demand, the aquaculture sector may need to increase production by 70-100 percent over current levels in the next two decades. However, aquaculture also faces increasing constraints as competition for land, water, energy and feed resources becomes more acute. These factors, combined with potential impacts of ocean acidification and climate change on ecosystems and on dependent communities, present significant challenges to the entire sector (Brander, 2007). The successful and continued delivery of benefits from fisheries and aquaculture will require the development of clearly targeted policies, sound management, technical changes and investments.

Climate change processes and impacts

The impacts of the accumulation of GHGs in the atmosphere and water relate to a number of physical phenomena including gradual changes in water temperature, acidification of water bodies, changes in ocean currents and rising sea levels. These physical changes affect ecological functions within aquatic systems and the frequency, intensity and location of extreme weather events (Cochrane *et al.*, 2009). A range of impacts on fisheries and aquaculture, both direct and indirect, can be expected. These are illustrated in Figure 10.1.

Ecosystem productivity is likely to be reduced in most tropical and subtropical oceans, seas and lakes. In high-latitude ecosystems, productivity is likely to increase (see Box 10.1). Physiological and behavioral processes of fish and the organisms they feed on will also be affected. The impacts, both positive and negative, will depend on the region and latitude. There is increasing evidence that global warming is already modifying the distribution of marine species. Warm-water species are being displaced towards the poles and experiencing changes in their size and the productivity of their habitats.

Figure 10.1
Example potential climate change impact pathways for fisheries and aquaculture

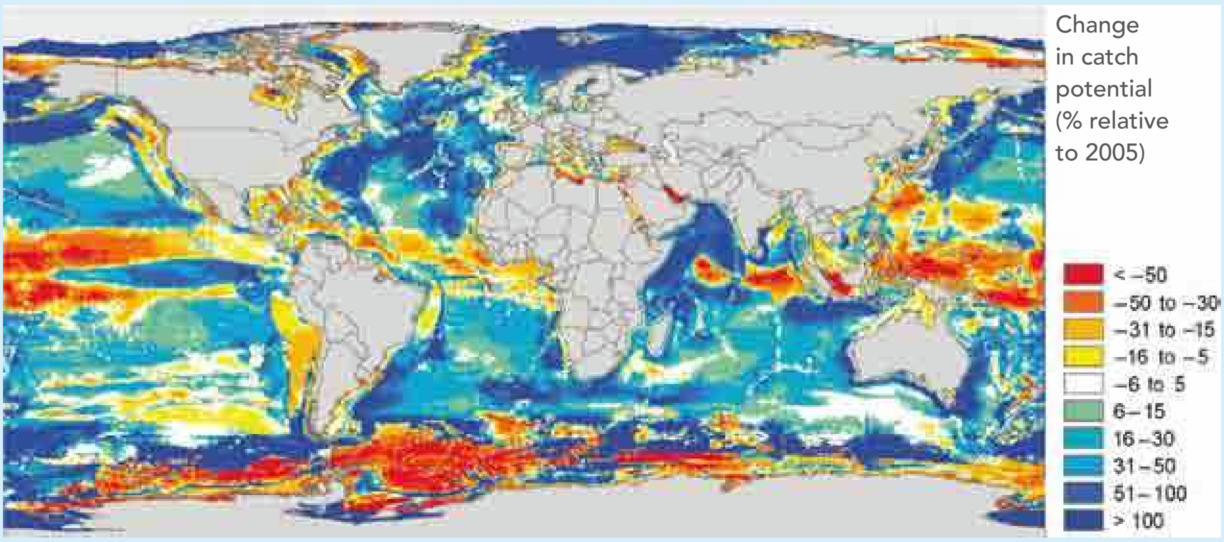


Source: developed from Badjeck *et al.*, 2010

Box 10.1
Predicted changes in fisheries catch potential between 2005-2055 under a higher GHG emissions scenario

Results of a modeling exercise on the latitudinal shift in catch under different GHG scenarios indicate that there could be drastic changes in the potential fisheries catch. Tropical countries could face up to a 40 percent drop in catch potential. High-latitude regions could enjoy as much as a 30 to 70 percent increase in catch potential.

How would the current top fishing countries fare under this scenario? The model predicted that, by 2055, exclusive economic zones (EEZ) average catch potentials in Nordic countries (such as Greenland [Denmark], Iceland and Norway) would increase by 18 to 45 percent; in the Alaskan (USA) and Russian Pacific EEZ by around 20 percent. In most EEZs around the world catch potentials would decline by various degrees, with Indonesia having the largest projected decline: over 20 percent across the 45 species currently targeted within its EEZ.



Source: Cheung *et al.*, 2009

Rising sea levels will displace brackish and fresh waters in delta zones and wipe out a range of productive agricultural practices. This will also destroy wetlands and have an impact on freshwater fisheries and aquaculture. On the other hand, higher sea levels may also create new environments and opportunities for the fisheries and aquaculture sector (e.g. for coastal aquaculture and mangrove development). Increased frequency and intensity of storms could directly endanger people and communities on coasts and damage housing, community facilities and infrastructure used for fisheries and aquaculture. Inland, the impacts on freshwater fisheries and aquaculture are also expected to be significant with increased variability in rainfall patterns as well as air and water temperatures affecting the productivity of rivers, lakes and floodplains. These impacts will also have a critical relationship with the use of freshwater resources for agriculture, industry, energy generation and urban water supplies (Ficke *et al*., 2007). For aquaculture, broader changes in hydrological conditions and seasonal changes in temperature, pH, salinity and ecosystem health are all expected to change productivity and increase risks. To address these changes, some production systems may need to be relocated. Impacts on post-harvest activities, on value addition and on the distribution of fish to local, national and global markets may also be significant, with potential changes in location and variability of supplies, and changes in access to other key inputs, such as energy and water for processing. All of these quantitative and spatial changes will occur at the same time as other global socio-economic pressures are exerted on natural resources. All of this will have wider impacts on food security, habitation and social stability.

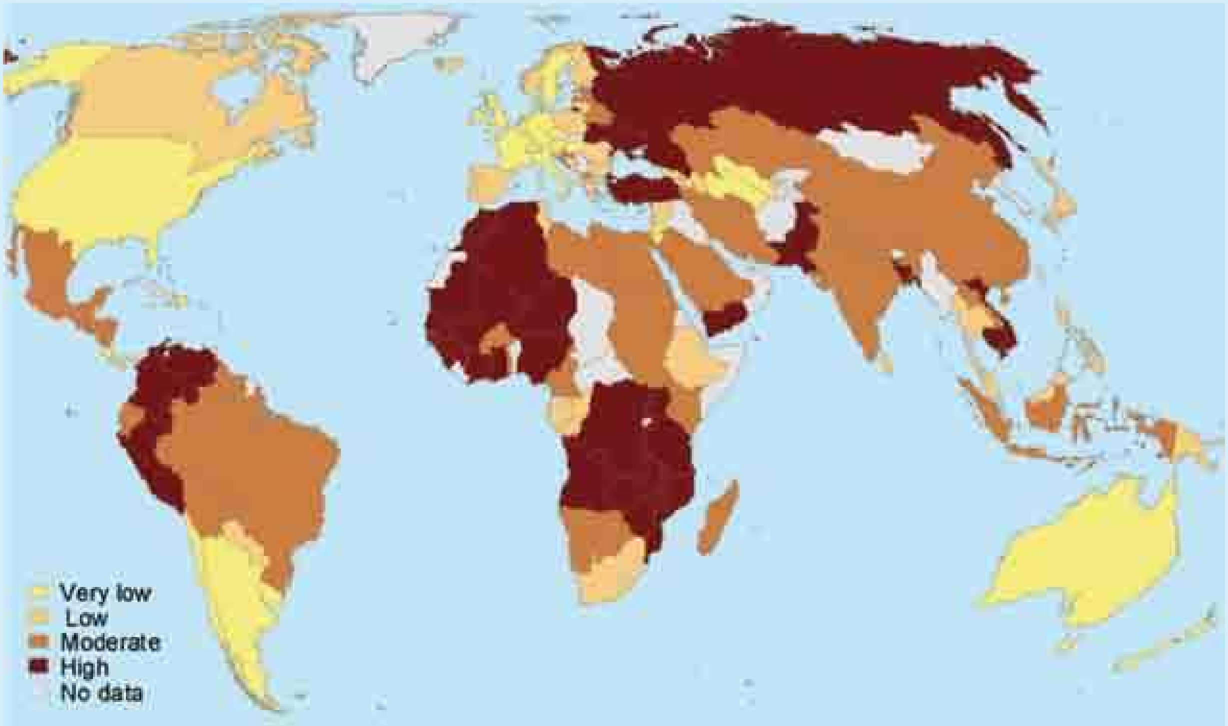
People, communities and vulnerability

According to the Intergovernmental Panel on Climate Change (IPCC), vulnerability to change is a function of the degree of exposure to climate change, the sensitivity of a system to such changes and the adaptive capacity of the system (IPCC, 2001; more on risks, vulnerabilities and resilience in Module 1). What vulnerability means to fisheries and aquaculture will depend on a variety of factors including: whose vulnerability is of concern; the scale at which adaptation planning is to take place; and the availability of data. Thus Allison *et al*., (2009) described the vulnerability of national economies through climate change potential impacts arising in their fisheries (see Box 10.3), while Bell *et al.,* (2011) focused on the vulnerability of species, food webs and ecosystems, and explored the issues related to tunas, their food web, coral reefs, mangroves, freshwater habitats and fisheries activities in the tropical Pacific islands. Cinner *et al*. (2012) built upon the IPCC model by imbedding the vulnerability of coral reef systems to climate change into measures of coral reef-dependent fishing communities' vulnerability in order to capture the links between the human and aquatic systems.

Fisheries- and aquaculture-dependent economies, as well as coastal and riparian communities, are likely to experience a range of effects of climate change. Impacts will include those that are associated with changes in the resource base, such as shifts away from traditional fishing grounds or changes in available fish species. There will also be direct risks to fishers, farmers and coastal communities due to sea level rise, stronger sea surges and changes in the frequency, distribution or intensity of tropical storms. Surrounding the changes in the aquatic food production system will also be a range of other impacts, such as increased risks of human diseases related to increased air and water temperatures. Climate change will also have an impact on food security, social services, social cohesion, and human displacement and migration. Many fishing and coastal communities already subsist in precarious and vulnerable conditions due to poverty and rural underdevelopment. The well-being of these communities is often undermined by poor access to capital, limited skills, the overexploitation of fish stocks, other natural resources and degraded ecosystems. As noted above, the vulnerability of fisheries, aquaculture and fishing communities depends not only on their exposure and sensitivity to change, but also on the uncertain ability of individuals or systems to anticipate these changes and adapt. The distribution of the bulk of the world's aquaculture production in the tropics, where population densities are high, makes the sector especially vulnerable (De Silva and Soto, 2009).

Box 10.2
Global mapping of national economies' vulnerability to climate change impacts through fisheries

Following the IPCC definition of vulnerability and using available data, national economies' relative vulnerability to climate change impacts through their fisheries was calculated for 132 countries. The analysis revealed that 16 African least developed countries (LDC) and three Asian LDC were among the highly vulnerable countries. Unfortunately, limited data precluded many small island developing states from being included in the analysis. However, given their high dependence on fisheries, low adaptive capacity and high exposure to extreme events, they are also likely to be among the more vulnerable countries.



While many African marine coastal fisheries are not likely to face huge physical impacts, the region's adaptive capacity to respond to climate change is relatively low and fish consumption high. As a result, economies there are highly vulnerable even to minor changes in climate and temperature. In the northern hemisphere, Russian and Ukrainian economies were ranked highly vulnerable due to a predicted high degree of warming impacting fisheries in this region and low adaptive capacities.

Sources: Allison *et al.*, 2009 and Daw *et al.*, 2009

10.2 Climate-smart approaches

Strategies for developing climate-smart approaches for fisheries and aquaculture are broadly similar to those for other sectors. As described elsewhere in this sourcebook, these strategies are connected with most, if not all, of the major cross-cutting themes of development and environment. As in other sectors, a number of issues need to be recognised and reconciled in order for the 'climate-smart' approach to become the default approach for development. Key considerations include the need to:

- respond to considerable increases in global demand for aquatic food in the face of climate change and other factors, and address specific issues of food access and livelihoods, across the entire supply, value and benefit chains;
- absorb effectively emerging technologies and adapt to market and socially driven changes within and around the sector;

- identify specific gaps in capacity, efficiency, and system resilience for the sector, and particularly those which are potentially likely to increase under climate stress, and identify generic or specific actions to address these gaps;
- address options for better policy and management integration within and across the sector, in terms of understanding the function and flows of goods and services from the aquatic systems as well as defining efficient use of these resources;
- connect effectively with related development objectives, such as hunger eradication, poverty alleviation, resource protection and rehabilitation, nutritional safety and health, personal and community empowerment, self-determination and vulnerability reduction; and
- develop approaches that are clearly recognizable and actionable by policy agents to work effectively with practitioners and beneficiaries at all levels and are based on clear evidence of functionality and effectiveness.
- In addressing these issues, there are many lessons to be learned from other sectors. However, fisheries and aquaculture have distinct characteristics, including:
- the significant level of social and economic dependence on wild fish stocks in small- and large-scale ecosystems, which are interacting with a wide range of activities that are driving climate change;
- the continued challenge of governance issues, particularly for fisheries resources, including the substantial levels of IUU (illegal, unreported and unregulated) fisheries, widespread fleet overcapacity in many fisheries, and potentially conflicted management environments;
- the transboundary nature of major resource systems, including areas beyond national jurisdiction (ABNJ), and the political complexity of resource management systems;
- specific issues of ecosystem complexity, with multiple-scale interactions of seascapes, watersheds and landscapes, uncertainties of change and impacts, and the difficulty of developing robust and practical models that are accessible to users;
- the high concentration of aquaculture around the tropics and in very populated areas;
- social issues related to the 'last-resort' or emergency uses of fisheries resources[1], as well as the widespread social marginalisation and poverty in fishing communities along many of the supply chains;
- the particularly rapid interactions of pollutants and pathogens in aquatic environments that are being acted upon by various drivers of acidification and climate change and the potential risks to productivity, stocks and human health;
- very limited development of risk and insurance markets for the sector, particularly for capture fisheries, and few mechanisms for community-based responses to less stable conditions; and
- data scarcity and difficulties in obtaining data in complex, highly heterogeneous, social, economic and ecological systems, and the challenge of creating a common understanding of important issues across these different systems and stakeholders.

In such a complex environment of human-ecosystem interactions, fully causal and quantitative relationships between climate variability, climate change and its impacts on fisheries and aquaculture cannot realistically be established. However, much can be done to reduce vulnerability using practical approaches, and there is considerable knowledge on how to build and maintain the resilience[2] of natural ecosystems and the human communities that inhabit them. In the fisheries and aquaculture sector, there is no lack of guidance in this area – the FAO Code of Conduct for Responsible Fisheries demonstrates the principles and standards applicable to the conservation, management and development of the world's fisheries, including aquaculture (FAO, 1995). These principles and standards cover issues such as the prevention of overfishing, the minimization of negative impacts to aquatic ecosystems and local communities, and the protection of human rights for a secure and

[1] In times of drought (emergency in agriculture), fisheries is used as an emergency food security source. Understanding the importance of this role will be necessary in cross-sectoral adaptation planning.

[2] Although the resilience concept is often limited to the ability of a system to 'bounce back' to its previous state when faced with a shock, it is often the case that simply returning to the status quo is not enough and efforts are needed to improve the ecological, social and economic well-being of the system before and after shocks. Building back better is a term that has been used in DRM to reflect the need not only to respond to emergencies but to put in place DRM that better prepares for the next potential emergency (FAO, 2009c).

just livelihood. The ecosystem approach to fisheries and aquaculture (EAF/EAA)[3] provides the strategies and tools for implementing the FAO Code and implies a holistic, integrated and participatory approach to managing fisheries and aquaculture systems (see Box 10.4).

Box 10.3
A brief overview of the ecosystem approach to fisheries and aquaculture

The EAF/EAA is a holistic strategy for managing capture fisheries and aquaculture in ways that integrate ecological, socio-economic and institutional dimensions. The EAF/EAA focuses on fisheries and aquaculture management, but its perspective covers more than a narrow focus on the production and management of commercially important species. The EAF/EAA includes interactions between the core of the productive fish system and the people who depend on it, as well as the system's other social and ecological elements. It is aligned with more general ecosystem approaches and supports the sector's contributions to broader multi-sectoral applications.

The purpose of the EAF/EAA is to plan, develop and manage fisheries and aquaculture in a manner that addresses different societies' multiple needs and aspirations, without jeopardizing the options for future generations to benefit from the full range of goods and services provided by aquatic ecosystems. EAF/EAA strives to balance diverse societal objectives by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems and their interactions and applying an integrated management approach within ecologically meaningful boundaries.

Within the overall objectives of human and ecosystem well-being, the application of the EAF/EAA should address the following principles:

- apply the precautionary approach when faced with uncertainty;
- use the best available knowledge, whether scientific or traditional;
- acknowledge multiple objectives and values of ecosystem services;
- embrace adaptive management;
- broaden stakeholder participation with due consideration to gender;
- ensure equitable distribution of benefits from resource use; and
- promote sectoral integration and interdisciplinarity.

Sources: FAO, 2003 and 2009b

As EAF/EAA calls for a broader and more holistic approach to analysis and management actions (Figures 10.2 and 10.3), the process itself can assist in monitoring climate change and its impacts.

Using EAF/EAA's broad and integrated monitoring system would allow for the monitoring of changes in the aquatic ecosystems and their impacts pathways through the fisheries and aquaculture systems. A key step in any EAF/EAA process includes the identification of issues (and their prioritisation through a risk assessment) that need to be addressed by management, including all direct and indirect impacts of production, processing and supply chains on the broader aquatic and coastal systems. Also covered in this process is the identification of any non-sector issues (external to the management system), such as global demand, input prices, climate variability and change, that are affecting, or could affect in the future, the performance of the system and its management.

[3] See FAO 2003, 2009b and 2010b.

Figure 10.2
Using the EAF issue identification process to identify climate change impacts

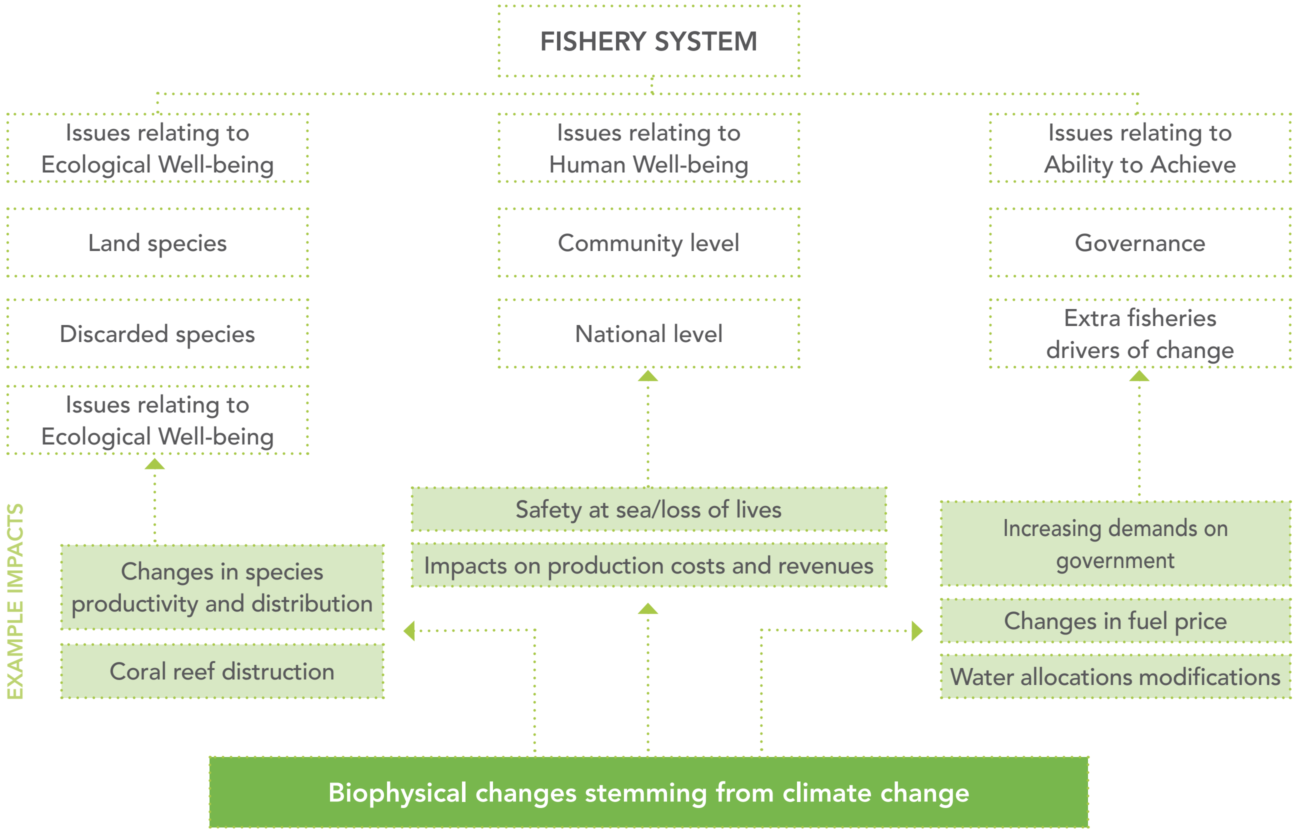
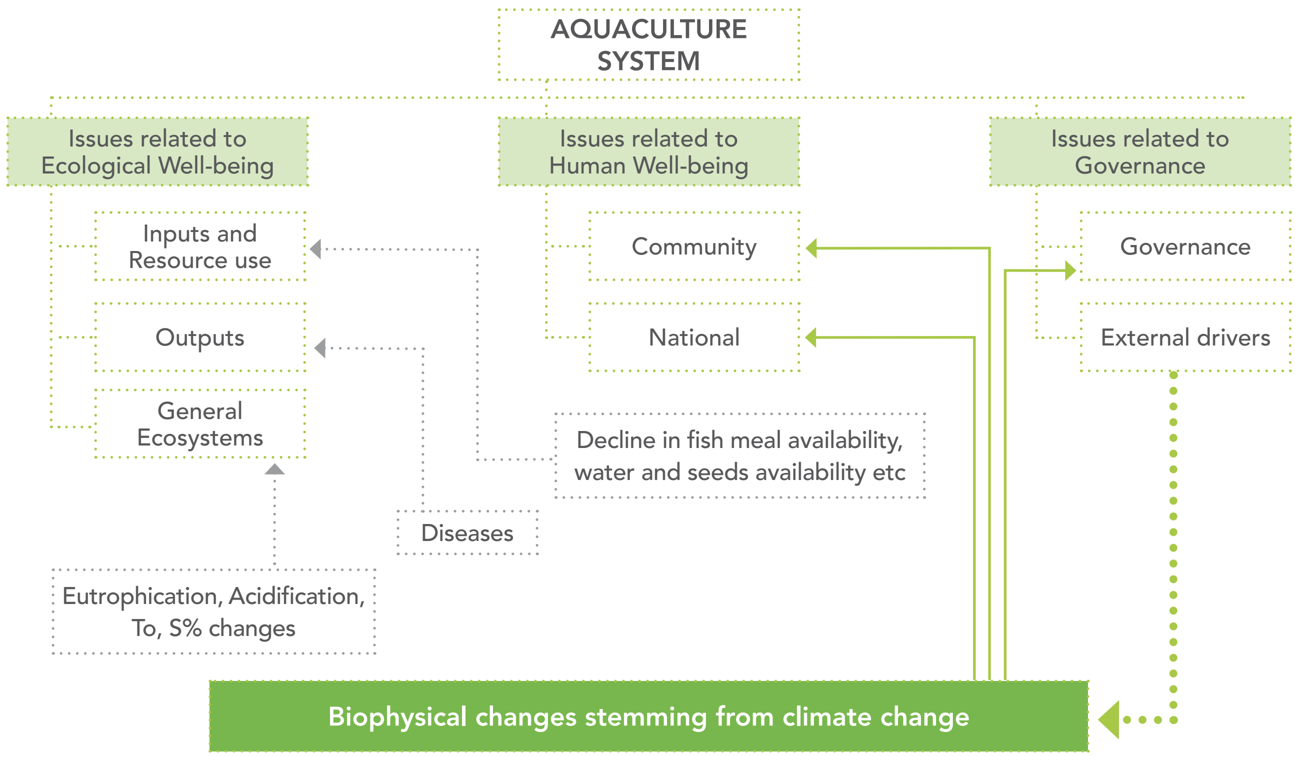


Figure 10.3
Using the EAA issue identification process to identify climate change impacts



Continuous green lines represent similar impacts to those described for fisheries.

Using EAF/EAA to build resilience to climate change

To build the resilience of the fisheries and aquaculture sector to the effects of climate change and to ensure the sector delivers sustainable benefits, it is essential to adopt and adhere to best practices such as those requested by the FAO Code of Conduct for Responsible Fisheries and whose implementation is facilitated by the EAF/EAA. Making progress in this direction would contribute to maintaining biodiversity, preserve the resilience of human and aquatic systems to change, and improve the capacity to anticipate and adapt to climate-induced changes in ecosystems and fisheries production systems. Direct benefits of implementing the EAF/EAA include:

- supporting ecosystems, communities and governance structures that are resilient by: decreasing the exposure of the sector by increasing the aquatic systems' potential to absorb and recover from change; decreasing the human communities' sensitivities to change; and increasing the sector's adaptive capacity;
- improving the efficient use of natural and human resources for food and livelihood security;
- supporting inter-sectoral collaboration (e.g. integrating fisheries and aquaculture into national climate change adaptation and disaster risk management [DRM] strategies and supporting integrated resource management, such as integrated coastal zone or watershed management and water planning);
- promoting integrated monitoring and information systems that incorporate scientific and local knowledge sources;
- improving general awareness of climate change inside and outside the sector;
- promoting context-specific and community-based adaptation strategies;
- avoiding 'maladaptations' (e.g. overly rigid fishing access regimes that inhibit fisher migrations and adaptation actions that would increase fishing in an overfished fishery);
- embracing adaptive management, decision-making under uncertainty and the precautionary approach; and
- promoting natural barriers and defences rather than hard barriers that would affect the ecosystem.

Improving the general resilience of fisheries and aquaculture systems will reduce their vulnerability to climate change. Biodiversity-rich systems may be less sensitive to change than overfished and biodiversity-poor systems. Healthy coral reef and mangroves systems can provide many benefits, including natural barriers to physical impacts. Fisheries- and aquaculture-dependent communities with strong social systems and a portfolio of livelihood options have higher adaptive capacities and lower sensitivities to change. Larger-scale production systems with effective governance structures and adequate mobility of capital tend to be more resilient to change.

10.3 Practical themes for developing climate-smart fisheries and aquaculture

Three key interlinking objectives for developing climate-smart fisheries and aquaculture are discussed below. The first objective is connected closely to the broader food sector goal of sustainable intensification. It concerns the provision of the primary means by which outputs can be expanded without placing excessive pressure on fishery resources, including land, water, feed and fertilizing inputs. The second objective focuses on the need to reduce the vulnerability associated with climate change impacts and to build the resilience required to cope effectively with potential changes over the longer term. The final area concerns the means by which the sector can be more strongly engaged in GHG mitigation processes.

Theme 1: Sustainably increasing output productivity/efficiency

There are two principle approaches for increasing productivity and efficiency. For capture fisheries, the essential issues are the reduction of excess capacity and ensuring the fishing effort is linked with improved fisheries management and the maintenance of healthy and productive stocks and systems. Though total output might not be increased to any significant extent, costs could be reduced, particularly fuel costs, and economic efficiency would improve. Better stock conditions may also improve the catch quality. The better use of by-catch would also enhance sectoral performance. By applying ecosystem approaches to resource management, climate change impacts can be better accommodated into management responses. This would reduce the potential risks of overfishing and the collapse of key stocks. For aquaculture the issues of increasing output and efficiency are more similar to those of agriculture. The primary emphasis is on intensifying production, using better integrated systems, improving stocks, making feeding more efficient and reducing losses from disease (De Silva and Soto, 2009). Dependence on fishmeal and oil is often cited as a primary constraint to future outputs and growth for aquaculture. This dependence is declining as alternative feeds are being developed and as a wider range of species is being cultivated at lower trophic levels that are closer to the levels of primary production (Tacon and Metian, 2008). However, it is increasingly likely that there will be constraints related to land and water resources in both inland and coastal areas. These constraints are due to competition from other sectors and changing agro-ecological conditions, which in some cases may lead to the relocation of the production system.

More broadly across the sector, efforts should be made in reducing losses and wastes, increasing yields and productivity in fish and aquatic food processing and other areas where value can be added, and enhancing efficiencies in product distribution. The overarching principles of sustainable approaches for expanding output are found in the FAO Code of Conduct for Responsible Fisheries. These principles may be progressively elaborated upon with more specific guidance as climate-smart experience is gained. Tools and best practices for improving social, economic and ecological efficiency and sustainability are under development.

Box 10.4
The environmental costs of New Zealand food production

Hilborn and Tellier (2012) offer a comparative environmental overview of fisheries production systems. In New Zealand, when compared with dairy and meat production, fisheries had a lower impact in terms of water and fertilizer use, eutrophication potential and antibiotics. Most fisheries also had lower GHG production levels than the meat industry, and some were lower than those for average dairy production. The dairy and meat industries were more efficient in energy inputs and production per unit, but the good state of major fish stocks ensured relatively efficient fuel consumption scores. The New Zealand quota management system also discouraged excessive vessel capacity and largely eliminated competitive open access fishing, which reduced fuel consumption. The New Zealand dairy and meat industries were more efficient in energy use and GHG production than comparable industries around the world. The authors attribute this relative efficiency to high year-round productivity and the ability to raise both dairy animals and other livestock on pasture for most of the year, which reduces the need to use feed crops.

Environmental indicators per 40 g protein portion in New Zealand food production systems

	Inputs						Outputs		
	Energy	Fresh Water	Fertilizer	Pesticides	Antibiotics	Surface Area Impacted	GHG gases	Eutrophication potential*	Acidification potential**
	(Megajoules)	(litres)	(g)	(kg)	(mg)	(m^2)	(kg CO_2)	(g)	(g)
NZ Dairy	1.56	171	26	24	1.17	1.24	0.86	3	8.4
NZ Meat	4.9	262	188	129	1.17	18.14	3.7	13.3	36.8
NZ Squid	7.11	0	0	n/a	0	17	0.62	1.7	3.9
NZ Hoki	7.11	0	0	n/a	0	100	0.64	1.7	4
NZ Jack Mackerel	7.69	0	0	n/a	0	57	0.68	1.8	4.3
NZ Rock Lobster	99.53	0	0	n/a	0	n/a	8.75	23.6	55.1
NZ Orange Roughy	14.4	0	0	n/a	0	104	1.27	3.4	8
NZ Barracouta	5.55	0	0	n/a	0	n/a	0.49	1.3	3.1
NZ Southern Blue Whiting	5.88	0	0	n/a	0	24	0.52	1.4	3.3
NZ Ling	7.26	0	0	n/a	0	36	0.64	1.7	4
NZ Snapper	12.6	0	0	n/a	0	n/a	1.11	3	7

* Eutrophication potential = measure used in life cycle assessment to calculate impacts due to excessive levels of macronutrients in the environment caused by emissions of nutrients to air, water and soil. Expressed as equivalent kg of phosphate (PO4).

** Acidification potential = contribution to acidic substances to air, water and soils that are implicated in a range of environmental threats including acid rain, soil acidification and changing pH of soils and water. Typical substances are: sulphur dioxide (SO_2), nitrogen oxides (NO_x), ammonia (NH_3). Expressed as tonnes of SO_2 equivalents.

Source: Hilborn and Tellier, 2012

Some specific technical and management measures can be identified to improve efficiency and broaden production and supply options under changing conditions. However, the potential to apply these measures, and the context in which the relevant decisions are made, will be strongly influenced by the availability of data and information, and the means by which these data may be securely interpreted and used. In changing physicochemical, bioecological and socioeconomic conditions, making data and information accessible to all stakeholders in a timely manner becomes a major challenge. This is especially the case in areas with fewer resources, where issues may be more critical and the capacity to address them is more limited. The difficulties and costs of assessing aquatic systems pose an additional burden. The development of effective adaptive management strategies in data poor situations is a special challenge that must be overcome across the fisheries and aquaculture sector.

Theme 2: Reducing vulnerability and increasing resilience

As with other food sectors, there are a number of aspects to vulnerability in the fisheries and aquaculture sector. These range from the specific issues related to individual households and communities to the more strategic areas dealing with sustaining industry performance and national food supply. The impacts of climate change are potentially significant and will require specific responses. These responses will have to address both the increasing risks of human, physical, social and financial losses associated with short-term events, and strategic investments and operational changes required to adjust to longer-term change. Social and economic vulnerability is already a concern in a number of communities that are dependent on fisheries and aquaculture, particularly those involved in small-scale production. Building climate-inclusive resilience is a recognised need. For the commercial sector, increased uncertainties of supply, associated with impacts on stocks and their distribution and production risks in aquaculture, add to financial vulnerability within the supply and value chain. These impacts may be felt in the national food supply, food security and trade.

Specific issues for fisheries and aquaculture

There are a range of generic risks for the sector that are associated with climate change. However, the incidence and severity of these risks are yet to be determined. As mentioned above, a range of negative outcomes are expected. These will involve direct physicochemical and bioecological impacts, as well as social, economic and political consequences. Effective and well measured protection against these outcomes will be a major challenge. There may also be positive opportunities in fisheries, as changing conditions may improve ecosystem functions and increase productivity. Rising sea levels could create more opportunities for aquaculture in salinised coastal margins and higher temperatures could improve conditions for cultivating local stocks. Climate change may also put stresses on some pathogens or predators, which might also improve productivity. With regards to the processing of fish and aquatic animals, changing stock or production locations in some cases might also improve rather than reduce distribution efficiency. Better or more consistent catches of key species in specific locations could improve local profitability. Consequently, the impact of climate change on markets and economies may be either negative or positive. However, in most scenarios, even if net outputs across an ecosystem or region are relatively stable, changing spatial and economic distributions of supply and demand will create an additional development burden. This burden will be particularly felt by poorer or more vulnerable groups.

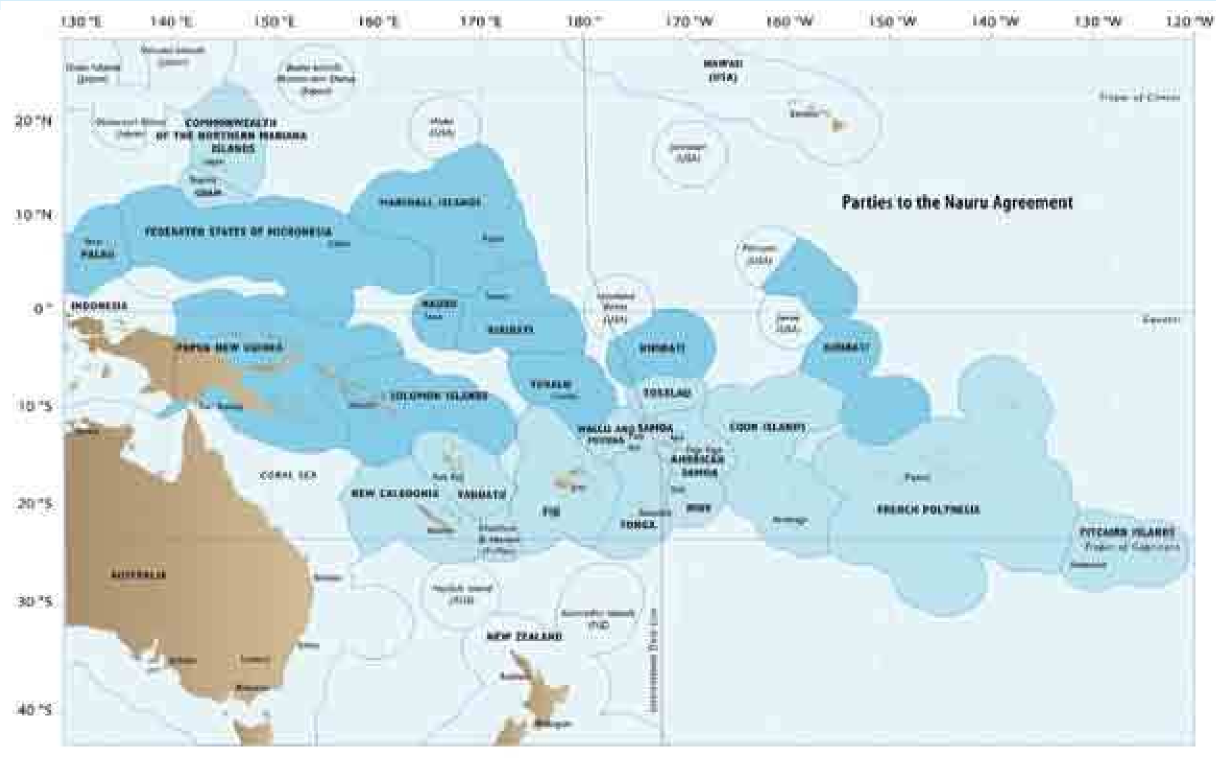
Changing locations, management and data needs, social and policy responses will all require effective institutional arrangements. Change will also need to be made in current systems, and new systems will need to be developed. For transboundary resources, changing species mixes and location characteristics may require new and adaptive systems of management and more effective operational procedures, and the need for effective resource management in ABNJ will become increasingly important. More generally, the processes currently being advocated for fisheries reform will need to be taken up to reduce excess fishing pressure, improve efficiency and returns to fishing enterprises and incorporate uncertainty into decision-making. These actions would sustain supplies and, at the same time, maintain or enhance the essential human and social capital that is created through adequate access to food and employment in small-scale fisheries.

Box 10.5
Climate-smart tuna fishing in the western Pacific

The industrial purse seine fisheries for skipjack and yellowfin tuna in the equatorial waters of the western Pacific Ocean make important contributions to global fish supplies. They are also vital to the economies of Pacific Island countries (PICs). The 1.3 million tonnes of tuna caught each year from the EEZs of PICs supply 25 percent of the world's canned tuna. Licence fees from foreign fishing fleets contribute up to 10-40 percent of government revenue for several small island nations. Locally based tuna fishing vessels and canneries account for as much as 20 percent of the gross domestic product of some PICs.

The effects of the El Niño Southern Oscillation (ENSO) on the distribution and abundance of these species make it difficult to know when and where the benefits derived from these fisheries will be greatest. During La Niña events, tuna catches are highest in the western part of the region. During El Niño episodes, the best catches are made further east. To keep catches within sustainable bounds, and optimise distribution of economic benefits, the eight PICs where most of the tuna are caught control and distribute the fishing effort through the 'vessel day scheme' (VDS). These eight countries are known as the Parties to the Nauru Agreement (PNA).

The exclusive economic zones of the PNA, which produce 25 percent of the world's canned tuna.



PNA members are: Federated States of Micronesia, Kiribati, Marshall Islands, Nauru, Palau, Papua New Guinea, Solomon Islands and Tuvalu (PNA, 2013)

The VDS sets a total allowable effort within PNA waters. This is allocated among the EEZs of PNA members, based on historical average patterns of fishing. Members are able to trade fishing days between themselves to accommodate situations where fish, and hence vessels, are unusually concentrated either in the west or east due to ENSO events. The VDS is therefore similar to the 'cap and trade' schemes designed to limit emissions of carbon dioxide. The trading component aims to ensure that all PNA members continue to receive some level of benefits from the fishery, regardless of where tuna are concentrated.

The VDS not only deals with climatic variation, it has the flexibility to allow the fishery to adapt to climate change. Allocation of vessel days to PNA members based on fishing effort history is adjusted regularly. As the projected redistribution of tuna to the east occurs under the changing climate, the periodic adjustment of allocated vessel days will reduce the need for members to trade fishing days.

Source: Bell *et al.*, 2011

In a number of contexts, interactions with other sectors, themselves affected by climate change, are also likely to be important. Inland fisheries are particularly sensitive to policies and actions outside the sector. In the same vein, many coastal environments are also increasingly subject to changes in freshwater runoff, agricultural intensification, growth in the industrial and energy sector, expanded urbanization, transport and tourism development. For aquaculture, there are similar issues of interaction and tradeoffs with other sectors, particularly regarding land and water use, aquatic and terrestrially derived feeds, and the negotiation of coastal space.

Defining and valuing the role and needs of the fisheries and aquaculture sector, raising awareness about the sector and negotiating balanced outcomes across sectors are key challenges (see Module 2 on landscape approach). There may also be important issues for GHG mitigation, which would be best addressed through integrated sectoral approaches.

Box 10.6
Options for culture based fisheries to improve climate resilience

Culture-based fisheries (CBF) is typically a perennial and seasonal stock enhancement process. It is practiced in smaller water bodies that under normal conditions are incapable of supporting a fishery through natural recruitment. In CBF, the stocked fish are managed communally with ownership rights. It therefore falls within the realm of aquaculture. Recently, the practice has gained momentum due to the increasing demand for fish and improvements in seed stock production and availability. CBF has also become a major part of government strategies to increase food fish production and improve livelihoods, particularly in impoverished rural communities (Amarasinghe and Nguyen, 2009).

CBF as an environmentally friendly food production system
In many instances, CBF is seen as a practice with a small environmental footprint and a good example of multiple, effective use of water resources (De Silva, 2003).

CBF does not consume water or external feed resources. The only input is the seed stock. The stocked species are selected in such a manner that all food niches are filled and that the natural food production is adequate to maintain growth and well-being of the stock. Consequently, the yields are much less than in most intensive aquaculture practices. However, CFB is environmentally friendly and the cost input is minimal with no feed related GHG contribution. This semi-intensive to extensive form of aquaculture often utilizes communal water bodies. For governments in developing countries, the practice is an attractive means for increasing food fish production and food security among rural communities.

The possibilities of the stocked fish mingling with wild counterparts are higher than in normal aquaculture practices. For this reason, whenever possible, indigenous fish species are advised for CBF. Also, hatchery bred stocks should originate from well managed broodstocks. Ideally, the broodstocks would originate from wild stocks; however, some form of risk assessment is always recommended before stocking.

In China, it is estimated that in 2008 CBF contributed to a catch increase of 120 000 tonnes, with a value of US$ 225 million. The cost/benefit ratio of resource enhancement is around 1:5. This translates into 1.5 million professional fishers increasing their profits by US$ 150 per capita. The large-scale jellyfish release programme carried out in China's Liaoning Province significantly increased the catch of jellyfish. In 2009, the catch volume reached 23 500 tonnes. As a result, 130 000 fishers increased their profits by nearly US$ 150 per capita (Liu, 2009).

CBF sensitivity to climate change and adaptation potential
The stocking and harvesting in CBF is almost entirely dictated by the elements. Stocking is best done when the water body is at full supply level, and harvesting takes place when the water level recedes. As a result, the practice will be affected by climate change, particularly changes in rainfall patterns. Also, in areas where a large number of water bodies are used for CBF, there could be an unexpected glut in the availability of food fish. Consequently, there will be a need to put in place strategies to minimize these effects through staggered harvesting and a coordinated marketing strategy. If done using an ecosystem perspective, good climate forecasting and proper CBF planning are climate-smart strategies. Watershed authorities or lake and reservoir authorities should be aware of CBF practices in order to improve water management and ensure the coordinated use of water resources.

Understanding and reducing vulnerability
Vulnerability to climate change in the sector is experienced across a range of productive, social and political dimensions and will also depend on timing and locations of changes. For example, climate risks may be felt

at a very specific location and in a targeted manner (e.g. through increased storm events in a small fishing location), or at a broader scale, as in the impacts of a shift in temperature and freshwater balances across a major river delta and its associated coastal system, or as a range of risks impacting on a range of people and communities with different capacities to cope with and adapt to the potential impacts. As with other sectors, vulnerability is also highly connected with other factors, such as the availability of human, social and political capital, access to services and other resources, and options for alternative livelihoods. Options for reducing vulnerability are commonly defined by the nature and severity of the risks involved; the comparative costs of physical and other responses required to reduce impacts by definable amounts; and the capacity of individuals, communities and organizations to analyse, prioritize and implement the appropriate actions.

Tools and best practices for reducing vulnerability in specific conditions are still being developed and validated within the fisheries and aquaculture sector. However, in addition to the general resilience-building actions described in the following section, a number of practical options can be identified. These are outlined in Table 10.1.

Table 10.1
Overview of practical options for reducing vulnerability in fisheries and aquaculture

Impact area	Potential responses
Capture fisheries	
Reduced yield	Access higher value markets; shift/widen targeted species; increase fishing capacity/effort; reduce costs/increase efficiency; diversify livelihoods, exit fishery
Increased yield variability	Diversify livelihoods; implement insurance schemes; promote adaptive management frameworks
Change in distribution	Migrate fishing effort/strategies and processing/distribution facilities; implement flexible allocation and access schemes
Sea level change, flooding, and surges	New/improved physical defences; managed retreat/accommodation; rehabilitation and disaster response Integrated coastal management; early warning systems and education
Increased dangers of fishing	Weather warning systems; improved vessel stability/safety/communications
Social disruptions/ new fisher influx	Support existing/develop new local management institutions; diversify livelihoods.
Aquaculture	
Extreme weather events	Improve farm siting and design; individual/cluster insurance; use indigenous or non-reproducing stocks to minimize biodiversity impacts;
Temperature rise	Better water management, feeds, handling; selective breeding/genetic improvements; adjust harvest and market schedules
Water stress and drought conditions	Improve efficacy of water usage; shift to coastal aquaculture, culture based fisheries; select for short-cycle production; improve water sharing; improve seed quality, efficiency,
Sea level rise and other circulation changes	Shift sensitive species upstream; introduce marine or euryhaline species (wide salinity tolerance); use hatchery seed, protect broodstock and nursery habitats,
Eutrophication/upwelling, harmful algal blooms	Better planning; farm siting; regular monitoring; emergency procedures
Increased virulence of pathogens, new diseases	Better management to reduce stress; biosecurity measures; monitoring; appropriate farm siting; improved treatments and management strategies; genetic improvement for higher resistance.
Acidification impact on shell formation	Adapt production and handling techniques; move production zones, species selection
Limits on fish and other meal and oil supplies/price	Fish meal/oil replacement; better feed management; genetic improvement for alternative feeds; shift away from carnivorous species; culture of bivalves and seaweeds

Impact area	Potential responses
Post-harvest, value addition	
Extreme event effects on infrastructure/ communities	Early warning systems and education; new or improved physical defences; accommodation to change; rehabilitation and disaster response
Reduced/ more variable yields, supply timing	Wider sourcing of products, change species, add value, reduce losses, costs; more flexible location strategies to access materials; improve communications and distribution systems; diversify livelihoods
Temperature, precipitation, other effects on processing	Better forecasting, information; change or improve processes and technologies
Trade and market shocks	Better information services; diversify markets and products

Source: adapted from Daw *et al.*, 2009; De Silva and Soto, 2009.

Note: Some adaptations to declining and variable yields may directly risk exacerbating overexploitation of fisheries by increasing fishing pressure or impacting habitats.

Decisions as to which options to select will depend on the location and scale of change; the impacts and the perception of their effects; and the cost, complexity and time required to implement countermeasures. Priorities may be given to small and inexpensive changes in systems or practices that can bring about additional risk reduction. However, if larger climate change risks emerge, these actions may quickly become redundant, or more dangerously, offer a false sense of security. In these circumstances, when time may be required to develop new techniques and/or gain access to investments required, a more strategic approach may be needed. However, early over-investment in expensive forms of protection may pose dangers in that they may deprive communities of important financial resources and protect only some sectors of the population. In some cases, tradeoffs may be required to support decisions to protect and strengthen one area, community or activity, while leaving others relatively unprotected. Over longer periods, infrastructure development and the relocation of people towards safer or more attractive areas may be required.

Tables 10.2, 10.3 and 10.4 extend these concepts to show how climate change responses may be developed in different fisheries, aquaculture and associated sectors, depending on the potential level of severity of change. The levels of disturbance are categorized as: minor disruptions, which are relatively easily to accommodate through normal patterns of operations, but may merit some adjustments to reduce risks and impacts; significant disruptions, which are sufficient in frequency and magnitude to require adjustments outside the normal patterns of operations, but usually only require modifications to these familiar patterns; and major disruptions whose frequency and/or magnitude expose the system to unsupportable levels of risk and for which it is imperative to make modifications, some but not all of which could be based on existing systems.

In the broader response to uncertain vectors of change, climate-smart disaster risk management approaches are also relevant. This approach originated in post-disaster interventions (e.g. storms, floods or tsunamis) where there was the need to reduce or manage similar risks. However, the approach can be applied much more proactively and can be used to anticipate and respond to the complete climate change impact profile in a given context. In this way, better links to response needs can be made in areas where storms are also associated with sea level surges and salinisation or the destruction of nursery habitats (read more about disaster risk reduction in Module 10).

Table 10.2
Climate change impacts and response options in specific fisheries systems

System	Significance of system	Climate disturbance level – example issues (I) and responses (R)		
		Minor*	Significant**	Major***
Inland/ coastal casual fishing, usually traps, lines, gathering	Major importance for subsistence food and secondary income; opportunistic in range of water bodies; approx 10% global output, 200 million people US$5billion or more	I - Changing species mix with differing tolerances, ecosystem disruptions, fishing conditions change; R - Adapt to catch different species, use different locations, timing, possible brood- stock/ nursery areas	I - More flood and drought impacts, increased die-offs, some weather risks possible reduced access by poorer groups, less household food R - more marketing of output, possible stocking/ restocking	I - Flood, drought, temperature and salinity impacts, losses of stocks in range of locations; R - fewer substitution options (species, location) for local beneficiaries, may need food security support measures
Inland/ coastal recreational fishing	Fishing for food and/ or leisure activity in many areas; strong economic multipliers in wealthier markets; approx 10% output, 200 million people, US$30billion	I - Changing species mix with differing tolerances, shifting locations; R - adapt to different practices, places, timing, adjust stocking/restocking, improve habitats, adjust management	I - Wider impacts; R - more use of stocking, habitat modification, protection of key stocks; political influence to regulate, invest in eco-system protection and/ or improvement, reserve areas, reduce take for food.	I - Wide range of impacts, losses of stocks in specific locations, changes of use of key water areas; R - greater development of designed/ managed fisheries, limited access to biodiversity reserves
Small-scale fishing with passive gear – traps, gill nets, longlines	Significant global sector; mainly coastal; major source of market and domestic supply; low capital and energy needs; around 15% global output, 40 million people, US$25 billion	I - Shift of species mix, timing, locations; R -adapt gear, timing, access/ develop alternative markets, possibly adjust management – e.g. size restrictions, close seasons	I - Larger disruptions to stocks, locations, timing; higher fishing risks; R - further adaptation/ development of gear, timing, access; possible advantages to those with greater research and development (R&D) options, more use of management controls	I - Further disruptions, higher fishing risks but low cost, ease of use of gear maintain its preferred usage; may become more significant in e.g. Low Impact and Fuel Efficient (LIFE) fishing; R - further adaptation, shifting markets, more management controls
Small-scale fishing with active gear – dredges, seines, trawls	Important globally; mainly coastal; range of fish, shellfish species, key source of higher-value market supply; higher capital and energy needs; around 10% global output, 15 million people, US$15 billion	I - Changing species mix, timing and locations; more effort required per catch; R - adapt gear, timing, adjust management, reduce energy costs by improving returns	I - More disruptions to stocks; higher risks, poor catches and high cost may make some fishing unviable; more management limits; R - possible move to passive fishing options or need to develop alternative livelihoods	I -Further disruptions and higher risks of non-viability of some systems; greater pressure on management, R - alternative fishing options, develop higher value markets, move to alternative livelihoods.
Commercial driftnet, long-line fishing	Key pelagic and other fisheries/species activity in some regions, commonly open seas, international scope; around 1% global output, 0.5 million people, US$ 1.5 billion	I - Changes in distribution across wider zonal areas, more effort per catch, time taken R - expand gear size; develop markets for bycatch	I - Greater disruptions and unpredictability; R - extend effort responses, improve stock monitoring/location options, move to higher values, improve bycatch options	I - Further disruptions, greater chance of non-viability; R - better targeting possibly smaller units, higher value and market quality;
Commercial dredge, trawl fishing	Important demersal and shellfish species activity in many regions, more localized; around 5% global output, 1 million people, US$ 7.5 billion	I - Changes in species, timing, location; more effort per catch, time taken; R - adjust or develop gear, practices; add value to product; develop markets for bycatch	I - Greater disruptions of stocks, timing, location; extend responses, R - improve stock monitoring/location options, move to higher values, improve bycatch options	I - Further disruptions, greater chance of non-viability; R - better targeting possibly smaller units, higher value and market quality;

System	Significance of system	Climate disturbance level – example issues (I) and responses (R)		
		Minor*	Significant**	Major***
Commercial purse-seine fishing	Important for major pelagic stocks in key regions, mainly marine, highly efficient if effectively targeted; around 10% global output, 0.1 million people, US$ 0.1 billion.	I - Changes in distribution across wider zonal areas, more time to locate catch, possible dispersal; more time and effort per catch, but efficiency still relatively good; R - increase stock protection	I - Further disruptions, stock unpredictability, dispersal problems; R - improve stock monitoring/location options, possibly move to higher market quality and values,	I - More extensive disrupt-ions, stock dispersal issues; R - increase stock monitoring/ location efficiency, move to higher value and market quality; greater chance of non-viability, capacity reduction;
Freezer/ trawler /factory vessel fishing	Linked to a number of commercial fishing types, may also take up small-scale fishing inputs, in many areas, around 1% global output, 0.1 million people, US$ 0.05 billion	I - Distribution and fishing activity changes; R - adjust operations for changing patterns of activity/catches, change trip length, landing locations	I - Wider disruptions of species/locations; R - more flexible operations, further develop processing/ product options; possible reduction in viability	I - Further disruptions for stocks and catch options, greater chance of non-viability; R - possibly aim for higher value and market quality; may need to decommission.

Notes:
* minor disruptions – relatively easily accommodated within normal pattern of operations, may merit some adjustments to reduce risks/impacts;
** significant disruptions – sufficient in occurrence/magnitude to require adjustments outside the normal pattern of operations, but usually only requiring modifications to these
*** major disruptions – occurrence and/or magnitude exposing the system to unsupportable levels of risk, imperative requirement for modifications, some but not all of which could be based on existing systems.

Table 10.3
Climate change impacts and response options in specific aquaculture systems

System	Significance of system	Climate disturbance level – example issues (I) and responses (R)		
		Minor*	Significant**	Major***
Seabed based mollusc culture, artisanal and commercial	Traditional in wide range of coastal areas, some mechanized, household consumption or markets; around 2% global output, 1 million people, US$ 1.5 billion	I -Small changes in productivity, spatfall, substrate quality, disease and predator interactions. R-adjust seeding locations (if done) and harvesting patterns, better health monitoring	I-Greater changes in productivity, substrate quality, ecosystems, etc, some stocks less viable R- adjust locations, manage substrates, adjust seed options (if used), change predator management, harvest patterns	I-Notable changes in productivity, greater damage risks, safety issues in some sites, stock viability changes R-adjust sites, practices, select better seed, improve value and returns, possibly shift to suspended culture systems
Commercial suspended mollusc culture	Expanded in coastal zones in many latitudes, commercial markets; around 3% global output, 0.5 million people, US$ 3 billion	I-Small changes in productivity, natural spatfall, more exposure risks, change in disease (inc red tides) and predator interactions R-slightly adjust locations, modify systems, adequate monitoring and early warning in place, management practices, harvest cycles	I-Greater ecosystem changes, extreme events, spatfall, disease and predator issues; higher risks, some sites less viable, others more so; R- Improve monitoring systems strengthen farming systems, adjust locations, management practices, ensure reliable hatchery seed production, harvesting	I- Much greater ecosystem changes, damage risks, safety issues, some areas become unviable R- Move to new areas needed for production, strengthened systems, better management approaches, reliable seed production from hatcheries, insurance; ensure alternative livelihoods and options

System	Significance of system	Climate disturbance level – example issues (I) and responses (R)		
		Minor*	Significant**	Major***
Extensive warm-water coastal pond/ lagoons	Traditionally unfed some fertilisation, wild or stocked fry, traps or nets; some molluscs, around 0.5% output, 0.2 million people, US$ 0.5 billion	I- Slight changes in productivity, species, temp ranges, possible runoff, fertility, some disruption to natural spawning, algal biomass R-change harvesting, greater inputs/stocking, management, possible expansion with sea level rise	I-More changes, less predict-ability, runoff, salinity changes, possible anoxia, fish kills; other areas less productive; some damage risks R-change harvesting, where feasible greater management, stocking, small cages, other inputs, water exchange	I-Greater ecosystem disruptions, flood and storm damage potential, productivity risk, species changes R-change harvesting, if feasible greater physical protection, intensified management, small cages and other subsystems, water exchange
Partially fed inland/coastal pond systems	Mainly inland, intensified with increased stocks and yields; range of practices and species mixes, water exchange, aeration; around 15% output, 1 million people, US$ 25 billion	I-Slight changes in temp ranges, salinity, water exchange, productivity, species performance, disease risks; R- adjust stocking/ feeding/harvest strategies, more water management / backup systems, monitor system/health more closely,	I- More water quality changes, less stability, possible anoxia fishkills, disease and productivity loss, some damage risks; R- change stock/feed/ harvest strategies, more physical protection, water management, possible reuse; possibly intensify stocking, management, monitor environmental conditions and early warning systems	I-More ecosystem disrupt-ions, flood and storm damage potential, productivity risk; R-if feasible to continue, increase physical protection, Improved monitoring and early warning systems, intensify water management, production, shorten production cycles, change species mix
Integrated farm units	Usually inland ponds/ paddies, with plants, animals; range of options; around 0.5% output, 0.2 million people, US$ 0.5 billion	I- Slight seasonal/ ecosystem changes, marginal shifts in productivity, disease risks in some/all components; R-adjust integration mix, possibly increase use; improve management	I-Greater changes, temperature and water balance, greater instability potential; R-possible new aquatic/ other species mixes, timing, consider wider options for adapting other systems, monitor environmental conditions and early warning systems	I-Larger disruptions, flood and drought risks, R-possible relocation/ reorganization, develop new components and markets, reduce crop cycle times, Improved monitoring and early warning systems,
Completely fed inland/ coastal pond systems	Gradually intensified or purpose planned; highly stocked fish, shrimp, water exchange, aeration, treatment; around 3% output, 0.5 million people, US$ 5 billion	I - Temperature, salinity and other water quality instabilities, disease risks; R - better system management, backup systems, adjust species, possibly intensify and/ or reduce crop cycles, monitor environmental conditions and early warning systems	I - More challenging instabilities, greater infrastructure risks; R - modify structures, higher levels of feed and water management, possible water reuse, link with integrated systems, monitor environmental conditions and early warning systems	I - Greater risks of physical and ecological disruptions, R - possible redesign/ reconstruction/relocations; possible expansion in salinised land areas, improved monitoring and early warning systems,
Intensive tank and raceway systems	Highly intensified, controlled, high water exchange, mainly hatcheries and high value fish, inland and coastal; around 0.05% output, 0.02 million people, US$ 0.01 billion	I-Localised management issues of temperature and water supply R- modify production cycles, feed regimes, more water treatment; better health and hygiene management, possible species/strain adjustments	I-Possibly greater challenges of water supply and quality; R-greater water(full recycle) and feed management, shifts in species/strains and timing of production cycles; less use for ongrowing, mainly hatcheries and nurseries	I-Much greater potential disruptions/supply/quality risks; R-possible shifts in species/ seasonal cycles, Full water recycle; flow-through ongrowing less common.

System	Significance of system	Climate disturbance level – example issues (I) and responses (R)		
		Minor*	Significant**	Major***
Intensive cage systems	Widespread globally inland and coastal, mainly fish, intensive fully fed, wide range of systems, species; around 5% output, 0.5 million people, US$ 10 billion	I-Temperature, salinity, oxygen level changes, possible algal blooms, pathogen interactions, marginally increased risks R-better stock, feed and disease management, proper (risk based) site selection, some relocations; monitor environmental conditions and early warning systems	I- Greater range of ecosystem variability, higher risks; also storm damage, losses. R- closer monitoring, local/ system-wide early warning; change species/strains, short-cycle production, more relocations	I - Wider range of disruptive effects, some areas too risky unless very short-cycle, high value crops; R - possible new areas in lower-risk zones with system wide risk reductions; improved monitoring and early warning systems,
IMTA systems	Coastal, linking intensive fish cages/ ponds with molluscs and marine plants at range of scales; <0.05% output, 0.01 million people, US$ 0.001 billion	I-Temperature, salinity, oxygen level changes, marginally increased risks R-Some adjustments to balance components, timing and outputs, ensure interacting component physically secure, avoid negative environmental feedbacks	I- Greater range of ecosystem variability, higher risks; also storm damage, losses. R-Further adjustments to component mixes, cycle times, more robust physical systems, possible relocations in some areas; also possible scope for expansion as risk-reduction strategy.	I- Increased disruptive effects R-More targeted integrated design and component choice across a range of systems to manage range of risk and ensure resilience. Could be expanded further if these can be better developed.
Recycle aquaculture systems	Fresh or salt water, tanks or ponds with substantial water treatment/reuse; mainly hatcheries or high value species; 0.05% output, 0.01 million people, US$ 0.3 billion	I-Relatively small risks associated with intake water supplies, power and infrastructure security R- may require system/ operating adjustments. Some open systems may use more recycle to stabilize water quality and supply.	I-Increased risks related water supply, power and infrastructure R-More open systems may turn into higher water reuse. Higher external variability may require greater system control, backup provision, high recycle rates. Tradeoffs with energy costs likely to become more important.	I- High risks related water supply, power and infrastructure R-Maximum recycle rates to maximize independence from external environment. External factors such as site, infrastructure security more important, possible relocations to purpose designed systems.

Table 10.4
Climate change impacts and response options in specific post harvest/production systems

System	Significance of system	Climate disturbance level – example issues (I) and responses (R)		
		Minor*	Significant**	Major***
Small landing facilities	Inland or coastal, various small structures, some with shelter, water, ice, fish handling areas, cool or cold storage, some with vessel/ gear repair/store; handling some 30% of global output	I - Possible access disruptions, risk of physical damage, breakdown of facilities, higher costs of protection, maintenance or repair; some may become non-viable if more distant from fishing areas. R - options to select and concentrate landings need to be investigated.	I - More significant disruptions with greater consequences; greater possibility of dislocation from fishing areas, higher costs and lower local value retention. R - Investment in facility upgrades would require effective climate-proofing.	I - Potentially major dislocations from resource areas, greater physical risks increasing potential for non-viable operations R - may need specific investments in climate-proofed facilities and infrastructure networks.
Commercial port/handling unit	Larger, more developed, higher specification facilities for landing, marketing, distribution, normally in cold chain, with defined standards; services for vessels/ gear etc; some 70% global output.	I - Risks of resource access/higher costs of supply, balanced by continued potential to add value, protect investment, maintain supply chain expectations; risks of physical damage and quality disruptions. R - Aquaculture may gain in importance.	I - Greater risks of disruptions, non-viability, particularly from reduced throughput in multiple-sourced centres; R - possible greater aquaculture role; some relocations, or more flexible systems/ operations; costs of improving infrastructure may need to be recovered	I - More extreme impacts of resource dislocation, physical risks, R - potential shifts to vessel-based handling and processing, landing to less specialized centres. New, lower-risk centres may also develop, and numbers of risks may reduce.
Fresh product supply systems	Range of inter-connected storage, handling, transport elements linking first sale to markets, retail outlets; around 30% global supply	I - Resource access changes R - some relocations, adjustments, potentially added costs. Impacts of shifts to aquaculture.	I - Greater disruptions to supply and quality, R - reorganization of elements, more aquaculture material, some systems may be less viable, more processing needed to protect quality.	I - Further extension of disruptions, R - need for relocation, re-organization, changing product streams, markets, process options. More investment and competition impacts.
Small-scale drying/smoking activities	Primarily linked with artisanal fishing, simple racks, kilns, packaging, local transport; around 10% of global supply	I - Resource access issues, also water, fuel wood other inputs R - some shifts in location, markets, improved systems/operating procedures.	I - Greater impacts in similar issues/themes R - greater potential for change in locations, supply chains, impacts on producers and communities.	I - Further extension of risks and disruptions, greater livelihood impacts; R - options for improving markets, adding value, improving prices, more significant.
Commercial processing systems	Wide range of facilities operating to defined health/ hygiene standards meeting market needs; range of secondary products; around 30% supply	I - Resource access and quality changes R - some relocations, adjustments, potential added costs, possible shifts to aquaculture.	I - More disruption to supply and quality, more aquaculture material, some systems may be less viable R - need to develop wider range of products, byproducts, other options.	I - Further disruptions, R - need for relocation, reorganization, changing product streams, markets, process options. More investment and greater competition impacts.
Prepared food manufacturing and distribution	Specialist food centres using/adding value to aquatic products, linking by range of transport to highly co-ordinated distribution systems	I - Resource access/quality changes; impacts of other raw material R - some relocations, adjustment, potential added costs, possible shifts to aquaculture, changes in product forms	I - More disruption to supply/ quality, more aquaculture material, some units may be less viable; R - need to develop wider range of products, adjust aquatic food content; new markets.	I - Further disruptions R - possible need for relocation, reorganization, changing process options, product streams, markets. More investment and greater competition impacts.

Building resilience

By targeting specific areas of vulnerability, the resilience of households, communities and nations can be increased. However, if these areas of vulnerability are addressed only selectively or partially, remaining vulnerabilities may jeopardize or even negate any positive effects. Moreover, in many areas, unresolved issues outside the fisheries and aquaculture sector may limit the potential for building resilience. In this regard, there are several key principles on which to base analysis and action, including:

- Systems with more diversity tend to have greater resilience.
- Initiatives to build resilience can connect across scales. Actions to build resilience at the local-level can reinforce each other to create greater resilience on a broader scale. National resilience, which can be improved, for example, through market and economic strategies, can create a more positive environment for building local resilience.
- Perspectives for resilience need to acknowledge all the elements in the impact pathway for development. Where possible, tradeoffs between the risk to resilience and costs of building resilience should be identified.
- Climate change-induced drivers can be important, but they may not be the only factors that need to be addressed. In some circumstances, they may be relatively insignificant.

Theme 3: Reducing and removing GHGs

As for the terrestrial food systems, fisheries and aquaculture GHG emissions, mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), are associated with various aspects of production and distribution; while management of the aquatic ecosystem itself has important potential for reducing net GHG flux to the atmosphere through the natural sequestration of carbon. There are also possible options for aquatic biofuel production, which could be linked with the fisheries and aquaculture sector. In addition, there may be interactions with GHG mitigation efforts in the energy sector in areas such as hydropower and coastal and offshore renewable energy generation. Three areas of interaction can be articulated: the sector's own contribution to GHGs and the potential for reducing these emissions; the sector's potential role in supporting the natural system's removal of emissions; and the sector's role in providing alternative energy sources.

The role of the sector in reducing its emissions

Although there are still substantial areas that need to be addressed, information on GHG emissions and their potential reductions from aquatic food production and distribution systems is becoming more clearly understood (Poseidon, 2011; Muir, 2012). For capture fisheries emissions are primarily related to fuel use. The nature and levels of emissions depend not only on technical aspects, such as types of vessels and gear used (e.g. active/passive gear, trawl, dredge, seine, gillnet, longline, light-attraction fishing, traps) (Muir, 2013) but also on driving market forces and management of fishing capacity – too many vessels chasing after fewer and fewer fish tends to increase fuel use. Emissions of particulate 'black' carbon could add significantly to current estimates, but this issue needs further investigation. For aquaculture, feed is considered to be the primary determining factor for emission levels and fertilizers are a secondary factor. Therefore, GHG emissions tend to increase as an aquaculture system moves from being extensive (untreated or partially fertilised), to semi-intensive (fertilised and/or partially fed) to intensive (completely fed and fertilized). Fuel and energy use for water exchange and treatment, service vessels and vehicles, and husbandry equipment also add to CO_2 emissions, but is usually much less significant. The relatively undetermined effects of CH_4 in sediments and N_2O in sediments and the water column are also potentially important and need to be further defined.

Processing fish and aquatic animals ranges from simple artisanal drying and smoking to highly controlled seafood preparation using high-specification packaging and labelling. In this regard, energy use is the primary determining factor for GHG output. There are wide variations in emissions depending on local practices, input variations (species, sourcing, quantity and quality) and operating efficiency. Water used in food processing and its links to GHG emissions may also be important. As the most widely traded global food product, aquatic foods may travel considerable distances in a range of forms and in various states of perishability. In this regard, GHG outputs are usually directly related to fuel use and to energy use in handling and cold and freezer storage. The specific choice of refrigerants is also important. Leakage from old or poorly maintained equipment can be critical, as many low ozone depletion gases have significant global warming potential. The most perishable fresh products require transport methods (e.g. local trucks, live fish vessels and air transport) that emit higher levels of GHG. Cooled and frozen products require less time-critical transport methods (e.g. ship-borne reefer and freezer containers) that emit fewer GHGs. More stable products (dried, smoked and salted products), particularly those processed in artisanal supply chains, require methods for transport that are not time-sensitive and produce low levels of GHGs.

Overall, the ratios of GHG output per tonne of fish and aquatic foods at the production, distribution and retail stages are similar to those for other foods. GHG levels at first sale accounts for typically 25-40 percent of total outputs. However, these figures vary widely. Limited numbers of comparative assessments of CO_2 equivalents per kilo across the different food production systems suggest that high fuel-use fisheries (e.g. poorly catching trawl or dredge fisheries) together with high-energy use post-harvest systems can be among the most GHG-intensive global food systems. Passive fishing gear systems or low-trophic level aquaculture (e.g. bivalves, seaweeds) can produce foods at lower GHG levels than most forms of meat or related animal protein production.[4] Such systems have the potential to contribute to strategic shifts in consumption and to reductions in global GHG emissions.

The role of the sector in supporting the natural removal of emissions

The highly significant role of the oceans and coastal margins in capturing and sequestering carbon is becoming increasingly understood and recognized. Around 93 percent of global carbon is estimated to be stored in aquatic systems and around 30 percent of annual emissions are estimated to be sequestrated in aquatic environments, primarily in mangroves, seagrasses, floodplain forests and coastal sediments (Nellemann *et al.*, 2008). To improve the sector's role in removing emissions, it is of primary importance to halt the disruption of carbon sequestration caused by habitat destruction and inadequate management of fisheries and aquaculture. Secondly, there may be valuable prospects for enhancing sequestration through expanding planted areas of mangroves and floodplain forests. Development of carbon funds to support GHG sequestration in the aquatic systems needs to ensure fisheries and aquaculture communities are properly represented and able to benefit from such funds.

There is also wider potential for exploring the role of aquaculture in carbon sequestration. Primary options include integrated multitrophic aquaculture (IMTA), where molluscs and seaweeds are grown as byproducts using waste inputs from more intensive aquaculture and systems where aquaculture cage or pond sediments are managed to enhance sequestration. These offer potentially valuable means of storing carbon. However, removing the carbon in longer-term conditions would require more secure means of disposal. This would involve either a biochar-type system or the disposal of carbon-enriched materials below oceanic thermoclines and into deep sediments. The physical and economic practicalities of this are yet to be demonstrated.

The role of the sector in providing alternative energy sources

There are major technical and environmental interests in developing the potential of renewable aquatic energy. This includes aquatic substrate biofuels and creating links to other aquatic-based energy systems that exploit the energy potential of tides, currents, waves, wind and hydropower. There are also options for physical integration of aquatic-based energy systems with newly developing infrastructure such as offshore wind and wave installations. Currently, there is particular interest in algal biofuels, which are based on either microalgae that are typically cultivated in coastal ponds or intensive stirred tank systems or macroalgae (seaweeds) that is grown in conventional culture systems. Using microbial enzymes to produce fuels such as bioethanols and biodiesels is an already established practice, which is increasing in efficiency and yield. This is particularly the case with genetically engineered (GE) bacterial enzyme systems capable of digesting celluloses and in some cases providing direct conversion to biofuel. GE algae are also a possibility, but they would require more expensive containment and biosecurity systems. The costs of producing and harvesting algal raw materials are currently too high to make production viable for any of the proposed systems and fuel routes. However as oil prices rise and production efficiencies improve, this procedure may become more viable. It should be noted that, as is the case for terrestrial biofuels, algal biofuels will provide an emission displacement function only and they will not lead to a net sequestration of carbon (more discussion on energy questions in Module 5 on energy).

[4] See De Silva and Soto, 2009 for a comparative description of energy use in aquaculture systems.

Box 10.7
Improving small-scale operators' incomes through the introduction of fuelwood saving fish processing technology in a FAO programme in Liberia

Baseline information has shown that post-harvest operations in small-scale fisheries in Liberia are characterized by mishandling and poor fish processing methods. This was the case in Grand Kru and Montserrado, two fishing centres that participated in the Food Security through the Commercialization of Agriculture(FSCA) project. The poor quality products, especially the smoked products, are less competitive and fetch lower prices. Even when wood was available for smoking, prices for wood had risen significantly. For those who could not afford to buy wood, it has become necessary to walk much further to gather wood for fish-smoking operations.

In Grand Cess, an important fishing centre on the Western southern coast of Liberia in Grand Kru County, the proximity of the lucrative border market with Cote D'Ivoire represents a business opportunity. However, the operators who wanted to tap into this market faced significant challenges as they had to compete with better quality products from other fishing villages.

Traditional oven uses more fire wood.

Women use their fuel-efficient oven to produce good quality fish products

The FSCA project started its work in Grand Cess in 2009. The project developed post-harvest fish technology platforms, constructing Chorkor fish smoking ovens and insulated containers for fresh fish storage. In total, 241 operators benefited from the project, out of which 179 worked in Grand Kru. The Good Father Fishery Based Organization (GFFBO) was a successful example of an organization that benefited from project support. This Fishery Based Organization (FBO) has 38 members: 11 men and 27 women. The Chorkor oven is well-known for its fuel efficiency performance, reducing by two-thirds the ratio of wood used to fish produced compared with traditional ovens. It also produces less smoke and produces good quality products. In Grand Kru, the Chorkor oven introduced by FSCA is now being widely used as the best means of fish preservation. This technical intervention, combined with the development of organizational and entrepreneurial skills, has increased the self-esteem of beneficiaries. They now feel confident in selling their goods at cross-border markets. In 2011, a report presented at the FAO-organized expert meeting in fish technology, safety and quality assurance, highlighted the socio-economic improvements that have been achieved through this assistance. With improved incomes from increased sales and better management, the GFFBO initiated some initiatives to boost self-reliance. It procured a canoe, a 25 horse power outboard engine and an assortment of fishing gear and met all other variable costs during one operational year. This FBO then embarked on a plan to construct decent houses for members, which is in line with their expressed objectives for improved sustainable livelihoods. With training sessions, practical experience and the outcomes achieved during the project period, members are now waiting to open personal accounts with local banking institutions as soon as banks are opened in Grand Kru.

Box 10.8
LIFE fishing - gaining benefits by reducing footprints?

- Low Impact and Fuel Efficient (LIFE) fishing refers to fishing gears and practices that ensure that fish are caught using the minimal possible amount of fuel with minimal impact on the environment.
- The global fishing fleet is estimated to consume some 41 million tonnes of fuel per year at a cost of US$ 33 billion at an average price of US$ 800 per tonne.
- Between 2002 and 2008 the price of oil rose from US$ 20 per barrel to over US$ 130, severely affecting the profitability of the catching sector. Though prices have since fallen, they remain substantially higher, continue to be volatile and pose further threats to the sector.
- Each type of fishing gear and practice has advantages and disadvantages in terms of fishing selection, supply and energy efficiency.
- The suitability of each gear largely depends on fishing area and species, and optimal solutions vary among fisheries.
- Success of transition to LIFE fishing will heavily depend on:
- developing acceptable technology for vessels, gear and operating systems;
- creating appropriate incentives for change;
- avoiding rigid regulatory regimes that can discourage fishers from innovating and adopting new technologies;
- developing close cooperation between the fishing industry, managers, scientists and other stakeholders to develop and introduce cost-effective and practical LIFE-fishing technologies; and
- using global research and development to support the development and uptake of LIFE fishing.

Source: Suuronen *et al.*, 2012

10.4 Strategic climate-smart approaches for the sector

The previous section has described the three main thematic areas of climate-smart approaches for fisheries and aquaculture. To create an effective framework for response, these thematic areas need to be addressed at a range of strategic scales and levels. The following practical and operational options can be considered, grouped according to their different entry points and scales. At this stage, the list of options is not exhaustive. They will be developed and detailed further as experience is gained and as best practices become more clearly established.

National and regional level approaches

- Build the capacity for developing strategic national and supranational perspectives on combined mitigation and adaptation (including disaster risk reduction and management) approaches for the fisheries and aquaculture sector. Link this work with sectoral and other development programmes, funding mechanisms (including climate change and GHG options). Define the most critical approaches, timelines for mobilization and indicators of outcome.
- Develop clearer perspectives on the tradeoffs between costs and policy related to energy and the profitability, output, competitiveness and trade of the fisheries and aquaculture sector. Explore and define links between food security and the sector.
- Develop practical perspectives on national and regional aquatic food supply potentials under climate change scenarios to inform economic and trade strategies. This would address the following questions: Are adaptation costs too high for production and profits to be ensured? Is it strategically more effective to increase imports or invest in production elsewhere? If supply potential is increased (e.g. movement of stocks, growth conditions for aquaculture, other locational advantages) what and how much investment is required to benefit from this, and what might be the trade and value-added opportunities?
- Carry out strategic institutional and human capital analyses and development. Identify potential sources of data and information. Gain a better understanding of decision-making at various levels. Develop awareness, preparedness and skills. Improve political interactions. Develop risk-related financial instruments with market and product perspectives to increase supply and demand flexibility, and broaden sector supply resilience.

Strategic industry and subsector levels

- Assess and define strategic investments (e.g. infrastructure for protection and enhancement of production and supply chain components). Define tradeoffs between 'hard' and 'soft' engineering strategies (e.g. classic infrastructure, such as roads, harbours, power, market and processing facilities and the service sector) and macro-level aquaculture protection, water supply and drainage systems, versus adaptation actions with minimal infrastructure costs.
- Define and develop landscape-level interactions with other sectors that address hydrological planning, coastal protection works, and their links with aquatic habitats. Define and establish rules, tools and models for achieving this integration in ways that cover bioecological, physicochemical and sociopolitical issues. Develop 'smart' geo-engineering approaches for building resilience and enabling productive transformation.
- Provide strategic opportunities for newer forms of integration, such as managed aquatic systems and habitats that are linked with renewable energy and other forms of energy development.
- Undertake subsector initiatives to identify and promote best practices, resilient supply strategies, and focused R&D to reduce risk.

Local and enterprise levels

- Define the local social, economic and policy context (e.g. economic dependence, livelihood options, human, social and financial capital, institutional context and capacity building options).
- Use capital and operating cost models to explore implications of different scenarios (e.g. incidence and levels of flooding, rainfall and water exchange, temperature, salinity, aquatic system features, such as algal blooms, and disease transmission on aquaculture production). Generate viability profiles under different scenarios, and where relevant, develop locationally based (e.g. geographic information system [GIS]) risk maps for key aspects.
- Identify practical aspects of risk reduction, including physical modifications (e.g. physical structures and storm and flood protection), changing operating strategies, environmental management, diversified and segmented supply chains, cross-investments, diversified species mixes, input options and markets. Link old knowledge to new options and build capacities.
- Where necessary, define and specify relocation options, policy and investment opportunities, livelihood alternatives and opportunities for diversification.

Individual and community levels

- Identify stakeholders and their roles and dependences, key risks and options, and their connections to current and emerging development objectives.
- Define and develop local learning processes and exchanges of information that can be validated with clear performance indicators.
- Develop and use information and communication technology for specific exchanges of ideas, information and options. Where possible, establish relationships with other communities to permit comparisons and the development of good practices.
- Support effective participation in cross-sectoral negotiations and planning processes.
- Develop external partnerships to provide specific technical and social support investment and resilience building.

Box 10.9
Impacts on and the role of trade in supporting climate change adaptation in the fisheries and aquaculture sector

The overall implications of climate change for fisheries trade are not well known. However, climate change will increase uncertainties in the supply of fish from the sector. Climate-induced changes in natural resources used for fishing and aquaculture will require fishing communities, producers, processors, fish traders and exporters to adapt. Changes in total fish catch, the composition of the catch, and the distribution of fish resulting from climate change could affect global import and export patterns. Moreover, fisheries export revenues could be affected as well as the contribution of fisheries sector exports to total exports. Likewise, the potential occurrence of sea level rise and greater frequency of extreme events will have an impact on ports and other physical infrastructure that support trade fisheries operations. These events are likely to add to the costs of fishing and could affect the competitiveness of exports.

Trade policy can play an important role in reducing vulnerability. Appropriately designed trade policies and rules can contribute to eliminating economic distortions, such as harmful subsidies, which encourage overcapacity and overfishing. Such reforms would also enhance the supply-side capacities and competitiveness of sustainably managed fisheries. Reforms that discourage economically unviable fishery operations can stimulate economic diversification. Trade policies can equally be important in supporting adaptive capacities.

Trade-related assistance and climate change financing mechanisms could be used in a complementary and reinforcing manner, as parts of efforts to render developing countries' fisheries sector and economies more resilient to climate impacts and other external shocks. For example, assistance to strengthen trade-related infrastructure could enhance both the trade-related supply-side capacities and the climate change adaptation needs of developing countries. Key complementary policies should also effectively promote the diversification of production and exports; foster the production of higher value-added processed goods; and develop the supply-side capacities of small-scale and artisanal fisheries and other vulnerable actors within the sector.

Developing countries should continue to argue for the elimination of distorting fisheries subsidies and the reduction of tariff escalation and other barriers to trade. This may promote more efficient use of fisheries resources and enhance market access for their fisheries products and increase their development opportunities. Moreover, they should maintain enough policy space that could allow them to adopt measures to restructure their economies. This will be instrumental to make developing countries' fisheries and their economies at large more resilient to climate change and other external shocks.

In addition, some measures being proposed to address climate change may have negative trade implications for developing countries. Initiatives to reduce carbon emissions and mitigate climate change, like the 'food miles' campaign, for instance, may negatively impact developing countries' fish exports, given their distance from import markets. Food miles refer to the distance food travels from its production until it reaches the consumer. However, the concept only centres on one part of the carbon footprint, namely transport, ignoring other parts of the production process. But if the entire supply chain is considered, fisheries exporters operating in developing countries may produce goods with a lower carbon footprint. Finally, eco-labelling could provide new market opportunities and increase the value added to fishery and aquaculture products.

Combined with efforts to reduce overcapacity and overfishing, trade and trade policies could be instrumental to foster resilience to climate change in developing countries. Appropriately designed trade rules can discourage economically unviable and environmentally damaging fishing, provide support mechanisms to preserve supply-side capacity in developing countries and create policy space in support of adaptation to climate change in developing countries.

Below are some essential steps for supporting the role of trade in climate change adaptation in fisheries and aquaculture:

- Eliminate non-tariff barriers to fish trade that distort world supply and demand.
- Eliminate tariff escalation for high-value fisheries imports that distort world supply and demand.
- Encourage domestic and regional trade in fish and fisheries products to reduce the carbon imprint of fish trade.
- Support research on the impacts of climate change and climate change policies on trade in fish products.
- Develop options for product and export diversification through appropriate economic and trade policies.
- Market and label goods produced following recognized energy efficient standards (e.g. eco-labelling)

Source: ICTSD, 2009

10.5 Progress of fisheries and aquaculture towards CSA

At this stage, the definition and validation of CSA approaches for fisheries and aquaculture are in early processes of development and dissemination. Consequently, there is little experience as yet that can be used as a widely tested foundation for good practices. However, a number of underlying principles can be identified and applied, both to define concepts and to measure progress towards meeting agreed aims. To define progress in meeting CSA criteria, it will be important to select and use practical indicators that address the common needs of relevance, accuracy, accessibility and cost-effectiveness. Measures of 'pressure-state-response' as developed for sustainability indicators may be useful. These measures would establish connections between the nature and extent of climate change drivers, the state of the impacted system, and the response generated and applied through the CSA approach.

It will also be useful to apply generic indicators for CSA that cover such areas as the demonstrated continuation or expansion of output and quality, resource accessibility, food security, human nutrition and health, together with direct or indirect measures of GHG impacts. At the subsectoral level, various measures of resource use and impact efficiency such as fuel, energy, land or water use per unit of output, and GHG emissions per unit of output will also be applicable. A number of more sector-specific indicators may also be relevant. These may be used to varying extents in composite indicators, for example in cases where there may be social or environmental tradeoffs with more conventional production-defined indicators. These indicators would include criteria such as aquatic biodiversity, ecosystem status, gender equity and social dependence indices. Based on a defined range of such indicators, normative scenario building will be helpful for specifying the current conditions of the sector and the desired status over a specified period (assessments, monitoring and evaluation are discussed in Module 12).

Clearer definitions will also be required for the status and function of primary resources and their use in the fisheries and aquaculture sector. This will serve to determine the current status of the sector, trends, potential acidification and climate change impacts and how changes in the efficiency of resource use are delivering social and economic benefits.

10.6 Transitioning to CSA

The current characteristics and vulnerabilities of the aquaculture and fisheries sector to acidification, climate variability and change can be identified. However, it is less easy to define the broad priority areas for action based on the potential impacts and adaptive capacity of different systems and the specific pathways and mechanisms for moving towards more robust and resilient systems. Nonetheless, based to some extent on equivalent issues in other food production and natural resource sectors, a number of points can be noted:

- It will be critical to build capacity and improve performance in basic aquatic resource management to ensure underlying resilience in the face of uncertainty.
- Incentives will be the key to CSA transitioning through social, legal, institutional, or economic and market-based incentives. Ideally, financial or other benefits will make CSA self-sustaining so that it will only require an additional impetus during the transition period. This impetus could be provided through access to improved fisheries and aquaculture techniques and materials, institutional change and strengthening, capacity building and the development of participatory monitoring systems.
- Some elements necessary for the transition to CSA will require longer-term strategic investments in infrastructure, productive capacity, and improved products and services, including aquaculture stocks and feeds. This will be necessary to meet emerging needs and avoid losses. The case for these investments, and the rate at which these investments need to be deployed, will need to be assessed and tools for doing so will need to be refined.
- Smaller-scale changes and response can be carried out locally with current resources and knowledge. These changes can be extended relatively simply by supporting the sharing of knowledge and experience and through additional institutional strengthening.

- Fisheries and aquaculture are embedded within complex ecosystems, for which it will be very difficult to predict responses to climate change. Adaptive and low-cost monitoring systems to help define potential consequences and test responses will be necessary. These systems will need to be interactive and capable of building a strong and well shared knowledge base across user groups.
- Markets and trade may help buffer changes in production that have an impact on food security, consumer prices and supply-demand gaps. However, implications of climate change impacts and climate change policies through the supply and value chain need to be better understood. Appropriate policy measures need to be defined and implemented.
- Public and private sector investment and collaboration will be needed to meet future demands and ensure the sector meets CSA objectives and delivers longer-term benefits. Including multiple stakeholders in CSA planning will foster creative options for action and help to minimize unintended consequences of chosen options.
- Many of the components of CSA can be strategically matched with broader development objectives, such as sustainability, social equity and biodiversity. These different goals need to be effectively integrated.
- Improved basic fisheries and aquaculture management, including the reduction of overcapacity and over-fishing, are key to building the resilience of fisheries and aquaculture socio-ecological systems as well as supporting the sector's GHG mitigation efforts.

10.7 Conclusions

The issues and practical approaches outlined in this module provide the framework within which the fisheries and aquaculture sector can define and apply climate-smart processes and actions. This will reduce the impacts of climate change, improve the sector's mitigation potential and increase the resilience of producers, supply chains and communities. It should be noted that optimizing all variables of CSA at the same time is not likely to be a realistic option and may not even be necessary. Prioritizing actions will depend on the context and objectives for the fisheries and aquaculture sector in a given area and on the production system as a whole.

Developing rapid and effective responses to climate change in the fisheries and aquaculture sector, and mainstreaming climate-responsive approaches within wider development goals represents a significant strategic and operational challenge. Conventional approaches for building and validating evidence within traditional disciplines and contexts may not always be feasible. Experience will need to be built up through an adaptive management process based on action learning with broad participation and information sharing among stakeholders. In addition, the nature of climate change vulnerability will need to be further explored. Practical means need to be developed to ensure that the most vulnerable states, production systems, communities and people have the potential to develop and apply sound CSA approaches.

Case study 10.1
Catfish farming in Viet Nam – the challenges of change

The farming of catfish (Pangasianodon hypophthalmus), also known as tra, sutchi, Pangasius, and striped catfish in the Mekong Delta of Viet Nam is hailed as a global success in aquaculture production. The sector currently produces over 1.2 million tonnes in a pond acreage of less than 6 000 ha. It employs over 170 000 people, and in 2009 generated an export income of over 1.4 billion US$. This success has triggered the development of subsidiary sectors for feed production, food processing and waste recycling. It is important to note that this boom in production has occurred within a short period of a decade or less. During this period, traditional backyard farming has been transformed into a highly vibrant commercial activity, with over 97 percent of the final product destined for export to over 100 nations and territories (De Silva & Phuong, 2011). Catfish production has provided an acceptable alternative 'white fish' in the global market place (Duc, 2010; Little *et al.*, 2012).

An increasingly efficient farming system with a comparatively lower carbon footprint

The catfish farming sector is the highest yielding primary production sector. The global average is 250 to 400 tonnes per ha/crop. Details on the estimated protein and fish meal usage in the sector are given in the following table. It indicates that only 146 600 tonnes of fish meal and no fish oil is used in the sector.

Total Production	1,200,000 t	De Silva and Phuong, 2011
Average FCR (feed conversion rate)	1.45	Phan *et al.*, 2009
Total feed used	1,740,00 t	
Average protein content in feed	26-30%	
Total protein used for production	487,200 t	
Estimated fish meal used in production	146,160 t	If 30% of protein derived from fish meal

From 2005 to 2010, the processing sector improved significantly. About 1 kilogram (kg) of processed product was derived from 1.69 kg of fresh fish and overall 'waste' was reduced. This waste is not put in landfills and other forms of disposal, but is converted into fish oil and meal. The meal is used as animal feed. At least three of the country's biggest processing plants are involved in this activity.

The sector has attracted much criticism from environmentalists who claim that there is an excessive usage of feeds and effluent discharge. However, this criticism has not been backed by explicit scientific evidence. On the contrary, Little *et al.*, (2012) shows that from a comparative perspective, catfish farming in Viet Nam has a comparatively low environmental impact. It has also been demonstrated that the overall emissions from tra catfish farming contributed less than 1 percent of total suspended solids, nitrogen and phosphorous in the Mekong Delta as whole. For a sector that produces over a million tonnes of food and generates a revenue in excess of US$ 1 billion, this level of discharge is miniscule (De Silva and Phuong, 2011).

The mean water consumption was of farm volume of 6.4 ± 0.8 megalitre per tonne (megaL /t) and a discharge of 3.4 megaL/t. This level of water consumption is much lower than in shrimp farming in ponds, which ranges from 11-43 megaL/t) and the tank culture of salmonids, which is 252 megaL/t (Beveridge *et al.* 1991). Phan *et al.*, (2009) estimated the total water consumed in 2007 was that 4,371 gigaL of water (based on 683 000 tonnes of catfish production in the whole of the Mekong delta). Out of this total, 2 754 gigaL was discharged back to the river. The amount of water used for the production of a tonne of catfish was 4 023 m3, or 4 m3 per kg. Other estimates for water use in pond culture are around 40 m3 per kilo (catfish farming in North America). The reduction in the case of catfish is due to the intensification of production. It is interesting to note that water lost through evapotranspiration in rice cultivation is estimated to be around 1.7 m3 per kg of rice, but productivity of rice is 4.5 tonnes per ha and with an export of 115 kilograms of nitrogen per hectare.

The water and nutrients lost through drainage from aquaculture ponds can be used to irrigate or fertilize crops, either on the dike or in adjacent fields (Prein, 2002). In stagnant systems, such as ponds that are extensively fed or aerated, drainage is irregular and limited at maximum to a few days per year. This makes the use of drainage water from such systems impractical for crop production, unless the drainage water can be stored in a deep reservoir for later use (Mires, 2000). Nevertheless, small-scale farmers often consider their pond primarily as a reservoir, from which daily water is drawn for crop or animal production and household use (Luu, 1999). By integrating water storage and aquaculture, the water needs for aquaculture is shared with other on-farm activities, which greatly reduces water use directly related to aquaculture.

The resilience of this sector has been tested mostly by market forces. As mentioned above, the sector has also faced criticism about its purported negative environmental impact. This criticism, which has been widely disseminated though the internet, has so far been shown to have no scientific basis. Nevertheless, the sector continues to thrive. It provides a classic example of the effective recycling of waste and has a relatively low carbon emission scenario compared to most primary production sectors.

The Mekong River has the eighth highest discharge of all major rivers in the world. Catfish farming is done in the lower reaches of the delta, which has plentiful water resources. This enables the sector to operate effectively and reap high yields. However, further expansion of the farming area and greater intensification of production may not be possible. A further reduction of the discharge levels to the Mekong River will be the key to the sector's sustainability.

Is catfish farming in Viet Nam well adapted to climate change?

This very productive aquaculture system may not be well prepared to face climate change. Rising sea levels are a real threat in the lower Mekong. The catfish farms may be exposed to increased salinity in the mid and long term. In the short term, catfish farming may be sensitive to some climate change variability and trends. For example, increasing temperatures and changes in the hydrological patterns may trigger disease outbreaks. A tight biosecurity framework is currently not in place, and given the high density of farms and very high density of fish production, a disease outbreak could devastate the sector.

Catfish farming can become more climate-smart through better planning of farm locations, improved water and nutrient management, and enhanced integration with other farming systems. However, a more urgent measure is a tighter biosecurity framework. Catfish farming can also become more climate-smart by implementing an EAA that would ensure the participation of all stakeholders and improve their understanding of climate change-related risks and prevention measures. For example, increasing salinity could be addressed by moving farms upstream, although this is an unlikely scenario. A more long-term approach to adaptation would to develop catfish varieties that are more resistant to salinity.

Case study 10.2
Integrated multitrophic aquaculture as a means of improving resilience

Integrated aquaculture systems share the management of resources, such as water and feeds with other farming systems. Usually, a new aquaculture species is integrated into an agricultural or agro-industrial system. Outputs from one subsystem, which otherwise may have been wasted, become an input to another subsystem. This leads to greater efficiency in the use of outputs produced from the land and water resources that are under a farmer's control. Integrated aquaculture has been widely practiced by small households, mainly in Asia, as a low-cost and efficient food production system in freshwater environments. In recent years, the idea of integrated aquaculture has been often considered as a mitigation approach against excess nutrients and organic matter generated by intensive aquaculture activities. This has led to the emergence of integrated multitrophic aquaculture (IMTA). Multitrophic refers to the explicit incorporation of species from different trophic positions or nutritional levels in the same system (Chopin and Robinson, 2004).

Two-season farming model of integrated shrimp culture with Manila clam and rabbit fish in Southeast China
This farming system produces two seasons or cycles annually, and is mainly used by shrimp farmers in Fujian and eastern Guangdong provinces of China. Shrimp (Penaeus monodon in Spring, Marsupenaeus japonicas in Autumn), Manila clams (Ruditapes philippinarum) and rabbit fish (Siganus fuscescens) are farmed together in the same pond. The pond size typically ranges from 0.5 to 3 ha, with muddy-sandy sediment and marine water depth of 1.0-1.5 m. Two aerators (1.5 Kw) are equipped per ha. Only the shrimps are artificially fed with commercial shrimp feed or trash fish. The Manila clam and rabbit fish eat the byproducts inside the pond (Shao, 2007; Weng, 2006; Feng *et al.*, 2009).

Inputs and yield of the system (according to Shao, 2007; Weng, 2006; and personal survey in 2011)

Table 1.
Seasonal seeding of the farming model

Season	Species	Seeding amount (/ha)	Size
Autumn (August)	Ruditapes philippinarum	2.6 tonne	1180-1290 ind/Kg
	Marsupenaeus japonicus	0.3×106 individuals	0.8~1.0 cm
	Siganus fuscescens	15×103 individuals	400 ind/Kg
Spring (March)	Ruditapes philippinarum	1.9 tonne	400-460 ind/Kg
	Penaeus monodon	0.4×106 individuals	0.7-0.9 cm
	Siganus fuscescens	15×103 individuals	400 ind/Kg

Table 2.
Annual production* and potential for increasing yield

Species	Average annual yield (t/ha) in monoculture	Estimated yield in the integrated farming system (t/ha)
Marsupenaeus japonicus	1.8	2.4 - 3.0 by intensive feeding and disease control
Penaeus monodon	2.2	2.8 - 3.5 by intensive feeding and disease control
Ruditapes philippinarum	14.2	14.6 - 16.0
Siganus fuscescens	1.1	1.4 - 1.8
Penaeus monodon	0.4×106 individuals	0.7-0.9 cm
Siganus fuscescens	15×103 individuals	400 ind/Kg

* The shrimp production in Table 2 represents the average yield in monoculture model for these two species in Southeast China. This figure could be lower because the possibility for disease outbreaks is much higher than it is for IMTA. However, the production level of L. vannamei is much higher (average 6-8 tonne/ha) but not included in the current IMTA model.

Carbon footprint and energy use Carbon input (ton/ha)	Carbon output / harvest (tonne/ha)	Carbon balance (tonne/ha)	Energy use (KW*H)
Seeding 0.18 Feeds 0.70	Shrimp & fish 0.35 Manila Clam 0.57	-0.04	900 - 1200

Carbon content of fresh Manila clam: 4 percent (Lu *et al.*, 2005); carbon content in shrimp feed: 10 percent; carbon content in shrimp and fish: 6.8 percent. Energy use according to Shao, 2007. 2005.dile lowing.3.

Ecosystem services

Manila clam filter feeds on phytoplankton and organic detritus. Rabbit fish feed on macroalgae. Because of these feeding habits the system acts as a carbon sink of 0.04 t/ha. The average electricity use of the farm is about 1 200 kilowatt hour (kWh). This is equal to about 0.2 tonnes of carbon. Electricity use is much lower than in normal semi-intensive monoculture of shrimp. There are nearly no organic pollutants and nutrients discharged. To make this IMTA system carbon neutral, the shrimp stocking intensity could be reduced in favour of increased stocks of bivalve shellfish and integrated with macroalgae culture. However, current levels of shrimp stocking are determined by the profits that can be earned, which is the strongest factor for determining the composition of farming systems.

The system employed 0.5 -1 person per ha during routine farm management. But more than 20 persons per ha are employed during the calm harvest. These figures only take into account direct employment. Indirect employment can be an order of higher magnitude.

Species	Yield (t/ha)	Price(US$/kg)	Annual value (10^3US$/ha)
Marsupenaeus japonicus	1.8	12.7 - 16	26
Penaeus monodon	2.2	4.4 - 8.0	14
Ruditapes philippinarum	14.2	1.0 - 1.2	13.5
Siganus fuscescens	1.1	2.5 - 4.0	3.5
Sum	19.3	-	≈57

Case study 10.3
Mussel farming: a food system with minimal GHG emissions

Cultured filter feeders (e.g. bivalves, such as mussels and oysters, and some echinoderms, such as sea cucumbers) and algae do not need external feeds. They can live on carbon and other nutrients in the environment. Mussel farming can be done with no or minimal GHG emissions and low or minimum environmental impacts. The impacts of mussel farming are most often related to the production of feces or pseudofeces, which when they accumulate in sediments can cause Hypoxia (lack of oxygen). However, well planned, well situated and appropriately sized shellfish culture seems to have little effect on the community of organisms which live on, in, or near the seabed (benthos), even when large areas are occupied. On the other hand, the benefits of biological absorption of nutrients for control of eutrophication[5] symptoms have been documented in many parts of the world. It is clear that the existence of significant filter feeder aquaculture (e.g. in China) has been instrumental in controlling coastal eutrophication, probably on a national scale (Ferreira *et al.*, 2013).

In countries such as China, mussel farming provides an important source of food and protein and supports associate livelihoods. In countries with lower seafood consumption, such as Chile, mussel farming provides jobs and livelihoods and a large proportion of the production is exported. In general, the ecosystem services of extracting nutrients and reducing eutrophication risks in the water column have not been properly evaluated. However, Bunting and Pretty (2007) build the case for the culture of mussels (Mytilus edulis) on rafts in Killary Harbour, Ireland, (as described by Rodhouse and Roden, 1987). They estimate that 10.8 tonnes of carbon per year would be assimilated[6] in mussel production and that the removal rate of carbon during harvest was 0.008 tonnes of carbon m-2 per year 1, which is equivalent to 80 tonnes of carbon per ha per year.

The great majority of mussel farming is carried out in floating or underwater holding systems that facilitate the mussels' permanent filtration of phytoplankton from the water. These systems use two types of techniques: suspended lines from a floating tray or individual long lines tied to a weight on the bottom; and a floating system on the surface. Mussel seeds attach to these lines and individuals grow by feeding on the available phytoplankton. Most bivalve farming can be carbon-friendly and is comparatively energy efficient. However, these farming systems are sensitive to several threats related to climate variability and climate change. The most common climate-related threats include changes in water quality (e.g. temperature and salinity) and increased frequency and prevalence of red tides.

Mussel farming in Galicia and in Southern Chile

Mytilus galloprovincialis is the main species of mussel farmed in the Galicia Rias in Spain. Mussel growth is very fast. Normally is takes about 18 months for mussels to reach commercial size, but in many cases, mussels can grow to commercial size in one year. The Ria Arousa is the most productive area for mussel farming. It benefits from an upwelling system, that regularly contributes cold water and nutrients, which causes exceptional phytoplankton production that can sustain more than 2 000 floating rafts. The rafts or floating platforms are a rectangular wood frame of about 500 m2. Usually one raft is one farm and is owned by a single family. Estimated annual yield for the Ria Arousa is about 60 tonnes per ha without shell. The annual estimated production for Galicia is around 250 000 tonnes (with shell). Current preliminary estimates of employment indicate that about 10 000 people live directly or indirectly from the mussel farming in Galicia.

In Chile, the most common farmed species is *Mytilus chilensis.* Farms can be of different size and operate at different scales of production. The farming is done using long lines. A 'mother line' normally about 100 m in length is held by floats and tied to the bottom. Many vertical lines hang from the mother line. Farming density can range from 10 to 12 long lines per ha in protected bays, channels or fjords in a water column that can reach from 10 to 40 m in depth. Estimated yield ranges from 60 and 70 tonnes per ha without shell. In 2011, Chile produced 221 000 tonnes of mussels. Although there is no current available quantitative information, it is claimed that mussel farming activities generate significant local direct and indirect employment not only through farming but also in the processing, an economic activity that employs mostly women.

[5] A condition of excessive algae production due to excessive nutrient availability, which usually leads to a situation of hypoxia and losses of biodiversity.

[6] Mussels feed on particles and assimilate carbon.

Mussel farming sensitivity to climate change and adaptation potential

Mussel farming in both southern Chile and Galicia is very sensitive to red tides, which have been increasingly associated to climate change and climatic variability. The best approach for reducing exposure to red tides is the implementation of permanent food safety monitoring programmes. These programmes lower health risks and improve preparedness. In both countries, aquaculture systems have such programmes in place. Since mussel farming tends to be carried out in more protected coves and bays where higher phytoplankton productivity can be ensured, it is generally less exposed to weather events than other aquaculture systems. Nevertheless, these farming systems are sensitive to extreme weather events. Ocean acidification can be a major climate change threat for all bivalve farming as lower levels of pH in the water can interfere with the formation of the calcium rich valves and other physiological processes in the mussels. Adaptation to such a threat may involve activities such as selecting resistant strains of mussels and increasing hatchery-produced larvae under more controlled conditions. Another potential threat is the lack of available wild seeds. The production of wild seed can be strongly affected by coastal oceanographic conditions and nutrient availability. In this area climate variability and climate change play key roles. Again the production of larvae in hatcheries and adequate management of the broodstock are essential adaptation measures.

Notes

This module was written by Cassandra De Young (FAO), Doris Soto (FAO) and James Muir (FAO consultant) with contributions by Randall Brummett (World Bank) and Matthias Halwart (FAO) and in coordination with the Global Partnership for Climate, Fisheries and Aquaculture (PaCFA). Box 10.6 on climate-smart tuna fishing was written by Johann Bell (SPC). Box 10.7 on culture based fisheries was written by Sena De Silva (Deakin University) and Doris Soto (FAO). Box 10.8 on fuelwood saving fish processing technology was written by Yvette DieiOuadi (FAO). Box 10.9 on LIFE fishing was written by Petri Suuronen (FAO) and James Muir (FAO consultant). Box 10.10 on the role of trade was written by Victoria Chomo (FAO) and Cassandra De Young (FAO). Case study 10.1 on catfish farming was written by Sena De Silva (Deakin University) and Doris Soto (FAO). Case study 10.2 on integrated multitrophic aquaculture was written by Changbo Zhu (South China Sea Fisheries Research Institute) and Joao Ferreira (Universidade Nova de Lisboa). Case study 10.3 on mussel farming was written by Ana Farias (Universidad Austral), Jose Luis Rodriguez (Instituto Gallego de Formación en Acuicultura), Doris Soto (FAO) and Iker Uriarte (Universidad Austral).

Acronyms

ABNJ	areas beyond national jurisdiction
CBF	culture-based fisheries
CH_4	methane
CO_2	carbon dioxide
CSA	climate-smart agriculture
DRM	disaster risk management
EAA	ecosystem approach to aquaculture
EAF	ecosystem approach to fisheries
EEZ	exclusive economic zone
ENSO	El Niño Southern Oscillation
FCR	feed conversion rate
FBO	Fishery Based Organization
FSCA	Food Security through the Commercialization of Agriculture
GE	genetically engineered
GFFBO	Good Father Fishery Based Organization
GHG	greenhouse gas
GIS	geographic information system
ICTSD	International Centre for Trade and Sustainable Development
IMTA	integrated multi-trophic aquaculture
IPCC	Intergovernmental Panel on Climate Change
IUU	Illegal, unreported and unregulated
kg	kilogram
kg N/ha	kilograms of nitrogen per hectare
kWh	kilowatt hour
LDC	Least Developed Country
LIFE	Low Impact and Fuel Efficient
megaL /t	megalitres per tonne
NH_3	ammonia
N_2O	nitrous oxide
NO x	nitrogen oxides
PIC	Pacific Island Countries
PNA	Parties to the Nauru Agreement
PO_4	phosphate
R&D	research and development
SO_2	sulphur dioxide
VDS	vessel day scheme

References

Allison, E.H., Perry, *A.L.,* Badjeck, M.C., Adger, W.N., Brown, K., Conway, D., Halls, S., Pilling, G.M., Reynolds, J.D., Andrew, N.L. & Dulvy, N.K. 2009. Vulnerability of national economies to the impacts of climate. Fish and Fisheries, 24 pp.

Amarasinghe, U.S. & *Nguyen, T.T.T.* 2009. Enhancing rural farmer income through fish production: secondary use of water resources in Sri Lanka and elsewhere. In S.S. De Silva & F.B. Davy, eds. Success stories in Asian aquaculture: 115–133. Doredecht, Springer.

Badjeck M.-C., Allison, *E.,* Halls, A. & Dulvy, N. 2010. Impacts of climate variability and change on fishery-based livelihoods. Marine Policy, 34: 375–383.

Beveridge, M.C.M., Phillips, *M.J.* & Clarke, R.M. 1991. A quantitative and qualitative assessment of wastes from aquatic animal production. In D.E. Brune & J.R. Tomasso, eds. Aquaculture and water quality, 3: 506–533. Baton Rouge, World Aquaculture Society.

Bell, J., Johnson *J.* & Hobday, A. 2011. Vulnerability of tropical Pacific fisheries and aquaculture to climate change. Noumea, New Caledonia, Secretariat of the Pacific Community. (available at http://www.spc.int/climate-change/fisheries/assessment/e-book/)

Brander, K.M. 2007. *Global fish production and climate change.* Proceedings of the National Academy of Sciences of the United States of America, 104(50): 19709–19714.

Bunting, S.W. & *Pretty, J.* 2007. Global carbon budgets and aquaculture: emissions, sequestration and management options. Centre for Environment and Society Occasional Paper 2007-1. UK, University of Essex.

Cheung, W.W.L., Lam, *V.W.Y.,* Sarmiento, J.L., Kearney, K. Watson, R., Zeller, D. & Pauly, D. 2009. Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Journal of Global Change Biology, 16: 24—35.

Chopin, T. & *Robinson, S.* 2004. Defining the appropriate regulatory and policy framework for the development of integrated multi-trophic aquaculture practices: introduction to the workshop and positioning of the issues. Bulletin of the Aquaculture Association of Canada, 104: 4-10.

Cinner, J., McClanahan, *T.R.,* Graham, N.A.J., Daw, T.M., Maina, J., Stead, S.M., Wamukota, A., Brown, K. & Bodin, O. 2012. Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Global Environmental Change, 22 (1): 12–20.

Cochrane, K., De *Young, C.,* Soto, D. & Bahri, T. 2009. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. Fisheries and Aquaculture Technical Paper No. 530. Rome, FAO. 212 pp. (available at ftp://ftp.fao.org/docrep/fao/012/i0994e/i0994e.pdf)

Daw, T., Adger, *W.N.,* Brown, K. & Badjeck, M.-C. 2009. Climate change and capture fisheries: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto & T. Bahri, eds. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge. pp. 107–150. FAO Fisheries and Aquaculture Technical Paper No. 530. Rome, FAO. 212 pp. (available at www.fao.org/docrep/012/i0994e/i0994e00.htm)

De Silva, S.S. 2003. *Culture-based fisheries: an underutilized opportunity in aquaculture.* Aquaculture, 221: 221–243.

De Silva, S. S. & *Phuong, N.* T. 2011. Striped catfish farming in the Mekong Delta, Vietnam: a tumultuous path to a global success. Reviews in Aquaculture, 3: 45–73.

De Silva, S. & *Soto, D.* 2009. Climate change and aquaculture: potential impacts, adaptation and mitigation. In K. Cochrane, C. De Young, D. Soto & T. Bahri, eds. Climate change implications for fisheries and aquaculture: overview of current scientific knowledge, pp. 151–212 FAO Fisheries and Aquaculture Technical Paper No. 530. Rome, FAO. 212 pp. Available at www.fao.org/docrep/012/i0994e/i0994e00.htm

Duc, N.M. 2010. *Application of econometric models for price impact assessment of antidumping measures and labelling laws on global markets: a case study of Vietnamese striped catfish.* Reviews in Aquaculture, 2: 86–109

FAO. 1995. *Code of conduct for responsible fisheries.* Rome, FAO. 41 pp. (available at http://www.fao.org/docrep/005/v9878e/v9878e00.htm)

FAO. 2003. *The ecosystem approach to fisheries.* FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2. Rome, FAO. 112 pp. (available at ftp://ftp.fao.org/docrep/fao/005/y4470e/y4470e00.pdf)

FAO. 2008. *Report of the FAO Expert Workshop on Climate Change Implications for Fisheries and Aquaculture.* FAO Fisheries Report. No. 870. Rome, FAO. 32 pp. (available at ftp://ftp.fao.org/docrep/fao/010/i0203e/i0203e00.pdf)

FAO. 2009a. *Environmental impact assessment and monitoring in aquaculture.* FAO Fisheries and Aquaculture Technical Paper No. 527. Rome, FAO. 649 pp. (available at http://www.fao.org/docrep/012/i0970e/i0970e00.htm)

FAO. 2009b. *Fisheries management.* 2. The ecosystem approach to fisheries. 2.2 Human dimensions of the ecosystem approach to fisheries. FAO Technical Guidelines for Responsible Fisheries. No. 4, Suppl. 2, Add. 2. Rome, FAO. 88 pp. (available at http://www.fao.org/docrep/012/i1146e/i1146e00.pdf)

FAO. 2009c. *Disaster risk management in food and agriculture.* (available at http://www.preventionweb.net/files/13247_i0772e001.pdf)

FAO. 2010a. *FAO and aquatic biodiversity.* Information brief. (available at ftp://ftp.fao.org/docrep/fao/010/i0112e/i0112e17.pdf)

FAO. 2010b. *Aquaculture development.* 4. Ecosystem approach to aquaculture. FAO Technical Guidelines for Responsible Fisheries. No. 5, Suppl. 4. Rome, FAO. 53 pp. (available at http://www.fao.org/docrep/013/i1750e/i1750e.pdf)

FAO. 2011. *Review of the state of world marine fishery resources.* FAO Fisheries and Aquaculture Technical Paper No. 569. (available at http://www.fao.org/docrep/015/i2389e/i2389e00.htm)

FAO. 2012. *SOFIA: the state of world fisheries and aquaculture.* FAO, Rome. 209 pp. (available at http://www.fao.org/docrep/016/i2727e/i2727e00.htm)

Ferreira, J., Ramos, *L.* & Costa-Pierce, B.A. 2013. Key drivers and issues surrounding carrying capacity and site selection, with emphasis on environmental components. In L.G. Ross, T.C. Telfer, L. Falconer, D. Soto & J. Aguilar-Manjarrez, eds. Site selection and carrying capacities for inland and coastal aquaculture, pp. 47–86. FAO/Institute of Aquaculture, University of Stirling, Expert Workshop. Stirling, UK. FAO Fisheries and Aquaculture Proceedings No. 21. Rome, FAO. 282 pp.

Feng, G., Zhang, *L.,* Zhuang, P., Liu, L., Zhao, F. & Yuan, W. 2009. Status quo and prospects of studies on biology and aquaculture technology of Siganidae. Fishery Modernization, 36 (2): 43–46 (in Chinese).

Ficke, A.D., Myrick, *C.A.* & Hansen, L.J. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries, 17(4): 581–613.

Hilborn, R. & *P.* Tellier. 2012. The environmental cost of New Zealand food production. New Zealand Seafood Industry Council Ltd Report. (available at www.seafoodindustry.co.nz)

International Centre for Trade and Sustainable Development (ICTSD). 2009. *Climate change and fisheries : policy, trade and sustainable development issues.* Information Note No. 15. Geneva.

Intergovernmental Panel on Climate Change (IPCC). 2001. *Climate change 2001: impacts, adaptation, and vulnerability.* IPCC third Assessment Report. (available at http://www.grida.no/publications/other/ipcc_tar/)

Little, D.C., Bush, *S.R.,* Belton, B., Phuong, N.T., Young, J.A. & Murray, F.J. 2012. Whitefish wars: pangasius, politics and consumer confusion in Europe. Marine Policy, 36: 738–745

Liu, L. 2009. *Effects of fishery stock enhancement on China's small-scale fishing fisheries.* APFIC Regional Consultative Workshop: Practical implementation of the ecosystem approach to fisheries and aquaculture in the APFIC region. Colombo, Sri Lanka.

Lu, Z., Du, *Q.,* Qian, X., Xu, C., Cai, Q., & Fang, M. 2005. Study on the culture capacity of shellfish in Zhaoan Bay. South China Fisheries Science, 1(5): 1–9.

Luu, L.T. 1999. *Status and role of aquaculture in rural development in Viet Nam.* FAO

Fisheries Report No. 611, *Supplement.* Paper presented at the FAO/NACA consultation

on Aquaculture for sustainable rural development. Chiang *Rai, Thailand.*

Merino, G., Barange, *M.,* Blanchard, J.L., Harle, J., Holmes, R., Allen, I., Allison, E.H, Badjeck, M.-C., Dulvy, N.K., Holt, J., Jennings, S., Mullon, C. & Rodwell, L.D. 2012. Can marine fisheries and aquaculture meet fish demand from a growing human population in a changing climate? Global Environmental Change, 22(4): 795—806. (available at http://www.sciencedirect.com/science/article/pii/S0959378012000271)

Mires, D. 2000. *Development of inland aquaculture in arid climates: water utilization strategies applied in Israel.* Fish. Manage. Ecol., 7: 189–195.

Muir, J.F. 2012. *Typologies for GHG framework and strategy for the aquatic food sector.* p. 77 – 84. In FAO Report of the Expert Workshop on Greenhouse Gas Emissions Strategies and Methods in Seafood. 117 pp. Rome, FAO.

Muir, J. 2013. *Fuel and energy use in the fisheries sector: approaches, inventories and strategic implications.* FAO Fisheries and Aquaculture Circular No. 1080. 89 pp.

Nellemann, C., Corcoran, *E.,* Duarte, C. M., Valdés, L., De Young, C., Fonseca, L. & Grimsditch, G. 2009. Blue carbon: a rapid response assessment. United Nations Environment Programme, GRID-Arendal. (available at www.grida.no)

Phan, L.T., Bui, *T.M.,* Thuy, T., Nguyen, T., Gooley, G.J., Ingram, B., Nguyen, H.V., Nguyen, P.T. & De Silva, S.S. 2009. Current status of farming practices of striped catfish, Pangasianodon hypophthalmus in the Mekong Delta, Vietnam. Aquaculture, 296: 227–236

Parties to the Nauru Agreement (PNA). 2013. *Cooperation through strength.* (available at http://www.pna-tuna.com/)

Poseidon. 2011. *Lifecycle analysis and greenhouse gas emissions methods in seafood production systems.* Background paper for FAO Expert Workshop on GHG and LCA methodologies in the fisheries sector. Rome, FAO.

Prein, M. 2002. *Integration of aquaculture into crop-animal systems in Asia.* Agricultural Systems, 71: 127–146.

Rodhouse, P.G. & *Roden, C.M.* 1987. Carbon budget for a coastal inlet in relation to intensive cultivation of suspension-feeding bivalve molluscs. Marine Ecology Progress Series, 36: 225-236.

Shao J. 2007. *Experimental study on twice-season farming model of integrated shrimp culture with Manila clam and brown rabbit fish.* Journal of Fujian Fisheries, 4: 17–19 (in Chinese).

Suuronen, P., Chopin, *F.,* Christopher, G., Løkkeborgc, S., Matsushitad, Y., Queiroloe, D. & Rihanf, D. 2012. Low impact and fuel efficient fishing—looking beyond the horizon. Fisheries Research, Vol. 119–120, pp. 135–146.

Tacon, A.G.J. & *Metian, M.* 2008. Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: trends and future prospects. Aquaculture: 146–158.

Weng, G. 2006. *Study on polyculture technology of Japanese tiger shrimp with Manila clam.* Journal of Fujian Fisheries, 3: 42–44 (in Chinese).

MODULE 11:

DEVELOPING SUSTAINABLE AND INCLUSIVE FOOD VALUE CHAINS FOR CLIMATE SMART AGRICULTURE

Overview

More efficient food systems are desirable from an economic, social and environmental perspective. This module will look at the sustainable and inclusive food value chain concept and framework and how this approach contributes to climate-smart agriculture (CSA) (section 11.1). Furthermore, information on possible technologies and practices along the value chain is provided and possible interventions of different stakeholders are outlined (section 11.2). Finally, a step-by-step approach is provided to help chain actors identify where improvements along the chain can be made to achieve sustainable and inclusive objectives (section 11.3).

Key messages

- The application of the sustainable and inclusive food value chain approach directly links to CSA and can help to improve performance along the value chain from input supply, to food production, to post-harvest handling and storage, processing, distribution, marketing and retail, consumption and disposal patterns of waste.
- Value is captured and determined by consumers when they buy the product, which trickles down to production and support provider levels. In this regard, consumers, in particular those in developed countries, have a large degree of power. Consumers' awareness should be raised regarding reduction, reuse and recycling of foodstuffs that are still fit for human or animal consumption or other purposes, including waste as compost or to generate energy from, such as biogas.
- Public support and investment, as well as public-private partnerships, are needed to ensure that sustainable technologies and practices are adopted. This may be necessary because, for example, green technologies may not be profitable in the short term, but socially and environmentally beneficial. In order to overcome these short-term trade-offs, support should be provided to contribute to the transformation towards an agriculture that is climate-smart. Capacity building should also be supported to help smallholders adopt more sustainable production practices as well as to help them find other uses (reuse or recycling) for their food waste, which can generate social (i.e. job creation) and environmental benefits.

Table of Contents

List of Figures

List of Tables

List of Boxes

11.1 Introduction to sustainable and inclusive food value chains

This module addresses the following questions: What is a sustainable and inclusive food value chain? How does this framework contribute to CSA? As food losses and waste occur along the entire chain, how does analyzing the sustainable and inclusive food value chain help to identify possible interventions to improve the performance of the chain? Which kind of technologies, practices and interventions by different chain actors can help to improve the sustainability and inclusiveness of the chain?

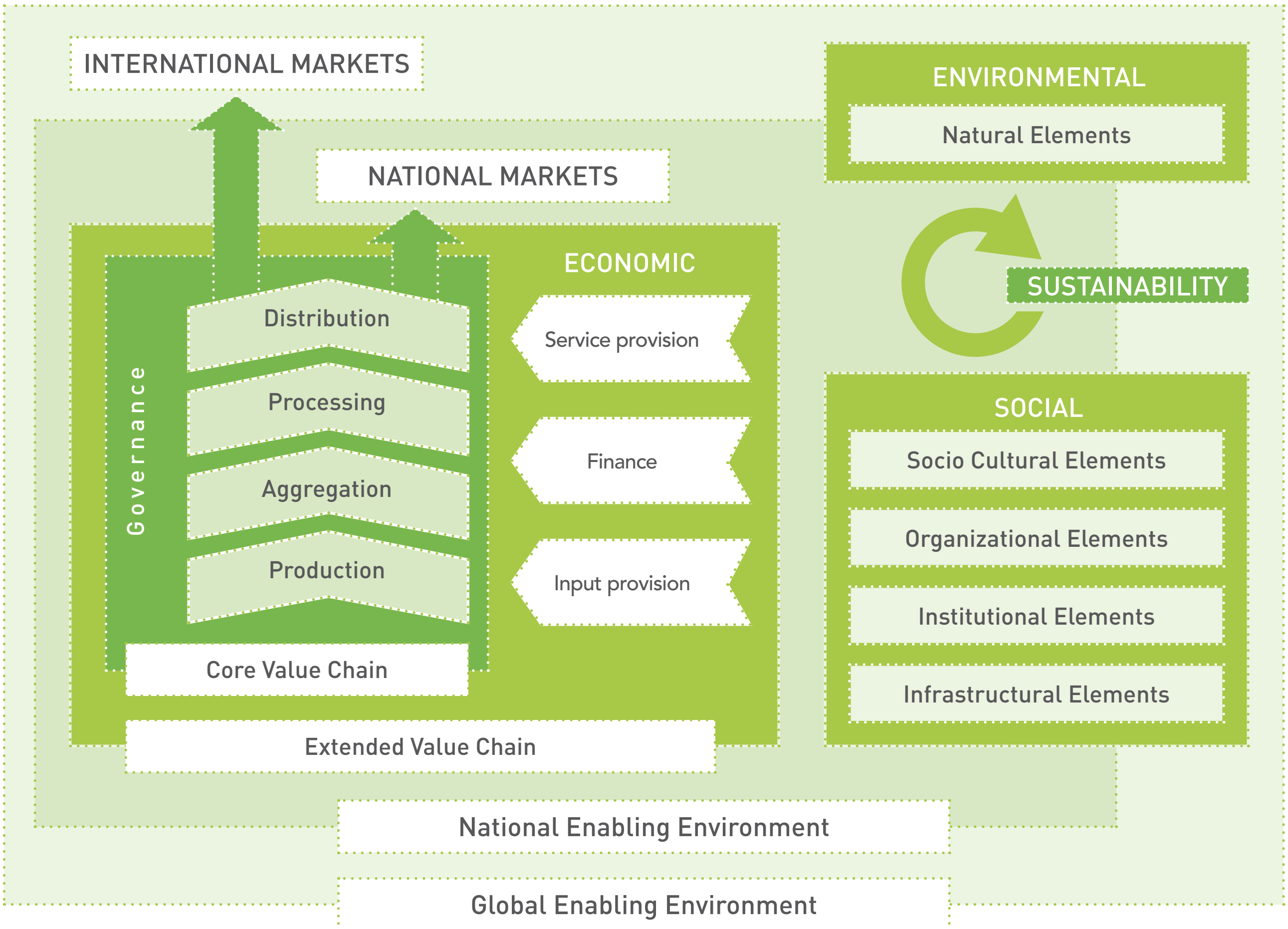
The sustainable and inclusive food value chain framework

The sustainable and inclusive food value chain can be defined as:

> *"the full range of farms and firms and their successive coordinated value-adding activities that transform raw agricultural materials into food products that are sold to final consumers and disposed after use, in a manner that is profitable throughout the chain, has broad-based benefits for society and does not permanently deplete natural resources."*
>
> (FAO, 2013)

One of the characteristics of the sustainable value chain is its inclusiveness, which implies that value chain development should be inclusive of the poor. However, it does not necessarily mean a focus on the poorest of the poor, rather smallholder farmers that have the capacity and those that are commercially oriented.

Figure 11.1
The sustainable food value chain framework



Source: Adapted from FAO, 2013

The sustainable value chain framework (see Figure 11.1 above) consists of the core value chain, which includes:

- **the value chain actors:** these are mainly private sector actors, but can also consist of public sector organizations. They are heterogeneous and vary with regard to size different ways;
- **four core functions or stages**: this includes production (farming), aggregation, processing and distribution (wholesale, retail). The aggregation stage is where basically post-harvest handling and food storage takes place; and
- **governance structure**: refers to the government mechanisms and linkages between the different chain actors in the chain.

The extended value chain includes:

- **business development support providers**: they facilitate the value addition process and can be divided into three groups: input, service and financial providers.

Another characteristic of the value chain is that value is determined in end markets. This means that if additional value is added to the product due to, for example, use of a green technology, the value is determined and captured by the chain actors only when the consumer buys the product. There are different ways in which value is added to a product, for example when a product is processed or packaged. Value can also be subtracted at any stage in the value chain, such as when post -harvest losses occur during storage and packing.

Furthermore, value chain actors and business support providers operate in a national and global enabling environment, which contains social and natural elements. The social elements can be categorised into socio-cultural (e.g. customs, beliefs, values), organizational (e.g. partnerships, cooperatives, associations), institutional (e.g. laws, regulations, policies) and infrastructural (e.g. roads, rail lines, electrical grids, telecommunications) issues (see Module 12 for more information on institutional context analysis).

The sustainability of the food value chain revolves around three dimensions.

1. **An economic dimension**, which focuses on activities that each actor or service provider provides that is commercially viable (profitable) or services that are fiscally viable.
2. **A social dimension**, which refers to social and cultural aspects regarding societal acceptance of the distribution of benefits and costs associated with the increased value that has been created. For example, it takes into account how food is consumed, the amounts of energy and water used when food is prepared or cooked as well as whether consumers reduce, reuse or recycle their food waste.
3. **An environmental dimension**, which refers to the sustainable use of natural inputs and resources throughout the chain as well as any impact on biodiversity, the amounts of greenhouse gas (GHG) emissions released, and the carbon sequestration and reduction potential of GHGs in the process of value creation.

How does the sustainable and inclusive food value chain contribute to CSA?

The agricultural sector, including crop and livestock production, fisheries and forestry, must transform and become climate-smart in order to successfully tackle current food security and climate change challenges. The sustainable and inclusive food value chain approach can be applied for this transition as its three sustainability dimensions – economic, social and environmental are directly linked to three pillars of CSA.

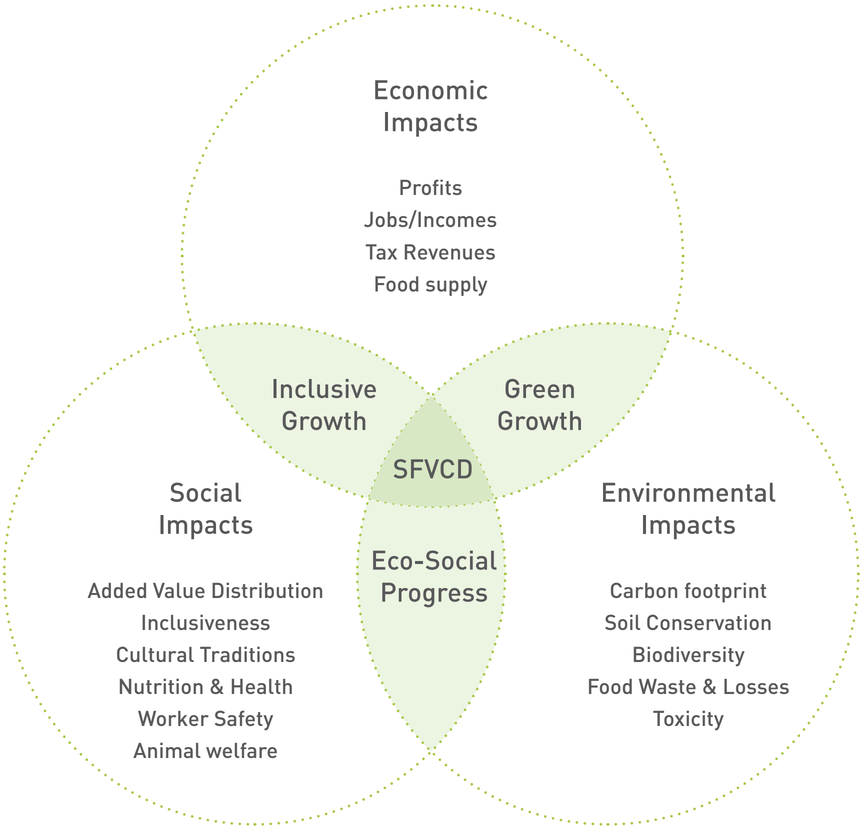
There are many similarities between the two approaches. Both approaches focus on increasing productivity, profitability and incomes. The sustainable and inclusive food value chain focuses, in particular, on how increased value is captured at end markets as consumers are willing to pay for this value addition. Moreover, it includes a distributional principle, which implies that profits and incomes should be equally distributed, thereby aiming to increase people's resilience to shocks and variability, which is the second pillar of CSA. The only difference between the two approaches is that sustainable and inclusive food value chain looks at environmental impacts in a broader sense, for example it also considers the water footprint of food products and not merely GHG emissions.

Practices and technologies, many of which already exist, need to be not only profitable, but should also be socially beneficial and reduce the impact on the environment in order to be sustainable. Sustainability that is achieved across this triple bottom line can therefore also contribute to reaching the objectives of CSA as the two approaches are complementary.

Trade-offs and synergies

In the sustainable and inclusive food value chain approach, sustainability is achieved in the overlapping area indicated with 'SFVCD' of the three sustainability dimensions in Figure 11.2

Figure 11.2
The three sustainability dimensions in food value chain development



Source: FAO, 2013

Regarding these three dimensions there often are trade-offs, such as between achieving food security, poverty alleviation and environmental objectives. For example, the transformation of food systems can cause unintended environmental damage and environmental protection policies can have negative impacts on certain societal groups like the poor. Another example is the introduction of a new technology, which can be environmentally sustainable, but may not be commercially viable in the short run. Or, when consumers decide to buy more local food instead of imported food, this may result in lower GHG emissions from transport and can result in increased incomes of local producers, but may erode incomes of producers in developing countries.

Trade-offs exist when components of a system, such as the three sustainability dimensions, are competing with or are exclusive of each other. In this regard, trade-off decisions do not result in a win-win situation, but rather result in a win-lose situation. In economics, trade-offs are mostly discussed in the context of the opportunity to realize different objectives such as economic, societal or environmental objectives. Trade-off analysis helps to take decisions with information related to economic arguments ('efficient allocation'), distributional arguments ('fair distribution') and scale arguments ('sustainable scale') (Daly, 1992). In economics, trade decisions are usually supported by a cost-benefit analysis, in which the monetary valuation of costs and benefits is outlined.

In a cost-benefit analysis, costs are analysed, including investment and operating costs, but also opportunity costs, which may include the income producers forego during the transition to sustainable agricultural development practices and approaches. It can take several years until these practices become profitable again and many producers are not able to bridge the gap in the income that they lost. Moreover, transaction costs, which are the costs related to transport, communication and coordination should be taken into account as well as risk, insecure access to resources and uncertainty.

Appropriate institutions and policies can greatly reduce opportunity costs, such as social safety nets and programmes to reduce risk and strengthen resilience (see also Module 16 on the role of safety nets). Institutions that promote effective collective action greatly reduce transaction costs in public investment and public-private partnerships aimed at expanding agricultural research and improving extension services, combined with capacity building which helps support smallholders adopt more sustainable production practices (see also Module 12 on institutions). The costs, as well as the distribution of the benefits, should be equally shared in order to successfully achieve the transition to sustainable agricultural consumption and production. Multi-stakeholder and multi-sectoral coordination and cooperation is therefore crucial.

Synergies

The traditional view is that improving the environment often negatively affects a firm's performance. According to Clemens (2006), research has shown that this is not the case as a positive relationship between green and financial performance was found, in particular for small firms, and those that perform better environmentally were also the most financially successful.

Moreover, improving social and environmental sustainability has increasingly become a strategic issue, because it determines market access (standards compliance), competitiveness (market differentiation). Furthermore, inclusiveness and greenness are also becoming sources of value creation.

However, there is still the challenge to avoid trade-offs and to capture potential synergies among the three sustainability dimensions. At times, interventions may need to be planned and implemented in a coordinated manner to counterbalance these trade-offs.

The sustainable and inclusive food value chain development and its ten basic principles

As previously mentioned, the sustainable and inclusive food value chain approach and CSA are complementary, but how are we able to use this approach to contribute to CSA?

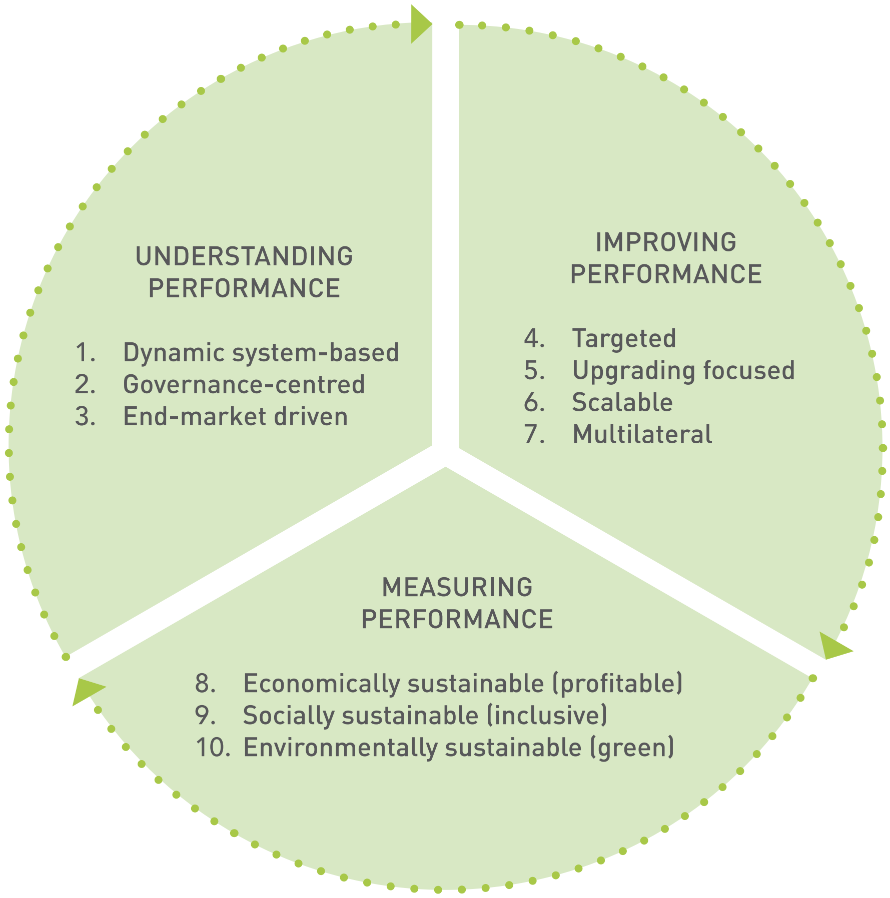
It is important to understand what value chain development is. The aim of value chain development is to achieve a positive or desirable change in a value chain. A value chain development intervention can range from improving business operations at production, processing, storage level or the relationship between different actors or the access to knowledge, information and innovation (UNIDO, 2011).

This section takes an in-depth look into the sustainable and inclusive food value chain development (SIFVCD) framework and the ten basic principles that guide this approach.

The SIFVCD can be divided into three phases:
1. understanding performance
2. improving performance
3. measuring performance

Within each phase different principles apply as shown in Figure 11.3 below.

Figure 11.3
The ten principles of SIFVCD



Source: FAO, 2013

Everything in a value chain is directly or indirectly linked. Because of this interdependence between every activity and actor, the value chain should be understood in a holistic way. Not only is everything linked within the value chain system, it is also connected to other systems, like market, farming, financial, global trade and infrastructural systems as well as the natural environment and the political, social, legal and regulatory systems. As a result, the value chain system may also be influenced by these systems.

Understand performance:

1. **Dynamic systems based**
   This principle refers to the fact that the value chain is a dynamic system as it evolves over time due to certain factors, which can result in desirable or undesirable directions. The main factors that can push the system in certain directions can include changes in profitability, market demand, technology, barriers to entry, risk and policies.
2. **Governance-centered**
   Chain actors are linked to each other via various governance mechanisms, which include contracts, agreements and partnerships. These government mechanisms are linked to the firms' degree of market power and collective action of chain actors, the type of service providers and the broader enabling environment (e.g. laws and regulations, policies and public infrastructure). Trust, in both the actors and enabling environment, can have a positive or negative impact on the performance of the entire value chain.
3. **End-market driven**
   This principle refers to the fact that value addition is eventually determined in the end-market. It is based on the consumer's decision to buy the product. This decision could be based on the price of the product, intrinsic qualities like physical appearance, nutritional value, attributes of the brand or how the product was produced taking in considerations such as carbon footprint.

Improve performance:

4. **Targeted (vision, right stakeholders and strategy driven)**
   This principle refers to strategic actions to improve the performance of the chain, which should firstly include a vision and have realistic and quantifiable objectives that address the triple bottom line as well as be in line with national development plans. In addition, these objectives also need to be acceptable and inspiring to stakeholders as well as to generate buy-in, political will and entrepreneurial drive. Secondly, the strategy needs to involve the right stakeholders (inclusiveness) so that poverty and hunger can be addressed not on a short-term basis, but in a sustainable manner. Thirdly, strategic actions need to be undertaken where the largest impact can be achieved in economic, social and environmental terms.
5. **Upgrading focused**
   In order to improve the performance of a value chain, upgrading has to be undertaken. The aim of upgrading is to realise one, two or all of the triple bottom line objectives: 1) increasing profits through efficiency measures or value addition; 2) increasing inclusiveness by improving social impact; 3) reducing environmental impacts of the entire chain. Upgrading can take place in different forms, e.g. a technology, organizational, network, institutional, process, product/market or a functional upgrade. Successful upgrading involves the integration of individual upgrades along the chain as well as actions to improve the enabling environment.
6. **Scalable**
   This principle aims to achieve impact at scale. Scale is crucial, because a larger impact is highly desirable, but also because upgrading is often enabled due to an increase in scale.
7. **Multilateral**
   Improving the entire performance of a value chain requires a coordinated and collaborated effort by the private sector, as the driver in the value addition process, and the public sector, including donors and civil society, as facilitators of the enabling environment.

Measure performance:

8. **Economic sustainability**
   Refers to a value chain performance that provides equal or higher profits or incomes for each stakeholder.
9. **Social sustainability**
   Refers to a value chain performance where additional value is created (additional profits and wage incomes) that benefits a large number of poor households, which is equitably distributed along the chain and has no impacts that would be socially unacceptable, including no socially objectionable practices like unhealthy work conditions, child labour, violation of strong cultural traditions, etc.
10. **Environmental sustainability**
   Refers to a value chain performance where the additional value created does not permanently deplete natural resources (water, soil, air, biodiversity).

11.2 Sustainable and inclusive food value chains in practice: the case of food losses and waste

Food is lost and wasted at every stage within the food value chain. In medium- and high-income countries, food is largely lost and wasted after the farm gate and in particular at the retail and consumption stage, while in low-income countries food is mostly lost during the production, post-harvest and processing stages of the food chain and much less is wasted at the consumer level (FAO, 2011b; Hodges et al., 2010).

One of the major components of SIFVCD is reverse channels or backward channels. Waste streams are created at every level of the agri-food value chain and it is important that these are managed appropriately, so as to reduce the waste stream impact on economic, social and environmental aspects. The strategy of the 3 Rs (reduction, reuse and recycle) is commonly adopted, especially the reduction strategy. As a result of the large quantities of food loss and waste that occur at many levels of the agri-food value chains, food losses and waste need to be considered as an integral part of SIFVCD that can successfully lead to CSA.

It should be kept in mind that while reducing food losses and waste may be desirable from social and environment points of view, it may not always be economically desirable or feasible as the economic costs of reduction may be higher than the production costs. An analysis of whether and how food losses and waste can be sustainably reduced should take into account these three dimensions: economic, social and environmental.

In order to identify opportunities to sustainably reduce food losses and waste along the chain, it is important to understand the functioning of these chains, in particular how value which can then be captured by the chain actors is increased.

Food losses and waste volumes

It is estimated that approximately 1.3 billion tonnes a year, which is roughly one-third of the food produced globally for human consumption, is lost annually (FAO, 2011b). Fresh fruits and vegetables are among the most lost and wasted food, due to their highly perishable nature (Parfitt et al., 2010). While similar amounts are disposed of in both developed and developing countries (670 and 630 million tonnes respectively), the per capita food loss in Europe and North-America (around 280-300 kilograms per year) is more than double that of Sub-Saharan Africa and South/Southeast Asia (about 120-170 kilograms per year) (FAO, 2011b).

There are currently no published studies available related to the exact amount of food waste in developing countries, where much less is wasted by consumers compared to developed countries. Various studies have been undertaken at country level in developed countries, such as in the United Kingdom (Cathcart and Murray, 1939; Osner, 1982) with food waste estimations as high as 25 percent (WRAP, 2009). Similar figures were found in other developed countries, around 15 percent in the United States (Kader, 2005) and Australia (Morgan, 2009) and slightly lower numbers ranging from 8 to 11 percent in the Netherlands (Thőnissen, 2009). The total amount of food wasted by consumers in industrialized countries is nearly as high as the total net food production in Sub-Saharan Africa.

Causes of food losses and waste

In developing countries, food is mostly lost and wasted, because of the way food is:

- produced;
- handled after harvest;
- stored;
- preserved; and
- processed.

In addition, food is lost and wasted due to people's lack of access to food, as a result of:

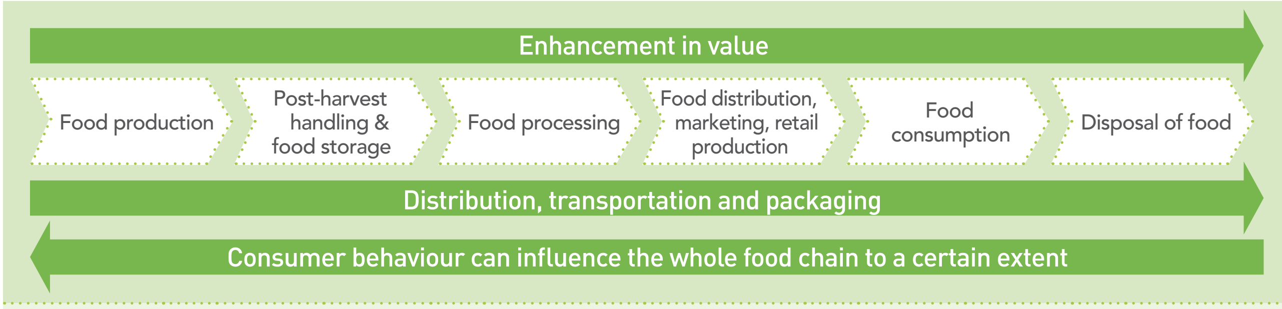
- insufficient income;
- lack of or limited markets; and
- lack of or inadequate infrastructure, such as roads, railways, waterways, port infrastructure.

In developed countries it is due to among others:

- how food is stored;
- prepared and cooked; and
- the food choices that people make (e.g. people buy more food than they need, put more food on their plates than what they eat).

Figure 11.4 provides an overview of a simplified food value chain, where the causes of food losses and waste at the various stages are identified, as are possible interventions by chain actors aimed at increasing efficiency, sustainability and value addition. The various types of actors that are often involved at the different stages are also introduced. Note that 'distribution, transportation and packaging', may be undertaken at several stages within the chain, depending on the product. In addition, consumer behaviour can have a certain amount of influence on the whole chain, as the choices they make feed back into the production stages.

Figure 11.4
Causes of food losses and waste; possible interventions that can be undertaken by chain actors depicted in a simplified food value chain



Causes of quantitative and qualitative food losses and waste:

Food production

Vegetable commodities and products e.g.:

- Poor production practices;
- Poor choice of crop varieties;
- Pest and disease damage;
- Poor ecological and soil conditions;
- Poor water management;
- Physiological and mechanical damage;
- Premature harvesting;
- Timing of harvest is not optimal

Livestock and dairy products e.g.:

- Poor feeding or diseases during breeding may lead to animal death;
- Poor milking techniques, diseases affecting milk production

Fish commodities, e.g.:

- Bycatch and discards during fishing;
- Insect infestations

Post-harvest handling & food storage

Vegetable commodities and products e.g.:

- Edible crops left in the field, ploughed into the soil and/ or eaten by birds/ rodents;
- Spillage, degradation and damage during handling, i.e. using poor quality containers;
- Poor storage and cooling conditions involving pest and diseases, spillage, contamination, drying out of food;
- Trimming due to selection products;
- Lack of or inadequate transportation infrastructure;

Livestock and dairy products e.g.:

- Animal death during transport to slaughterhouse;
- Spillage, unhygienic milk handling during transport and storage;
- Inadequate chilling and storing of meat after slaughtering.

Fish commodities e.g.:

- Spillage, spoilage as a result of poor and inadequate handling or mishandling, lack of storage and chilling facilities and transportation after landing.

Food processing

Vegetable commodities and products e.g.:

- Spillage or degradation during processing, such as during washing, peeling, slicing and boiling of fruits, vegetables and due to packaging;
- Trimming due to the selection of products with the right shape, weight, size and appearance;
- Physical, mechanical or physiological damage due to processing or packaging;

Livestock and dairy products e.g.:

- Trimming, spillage during slaughtering, additional industrial processing and packaging;
- spillage during milk treatment, i.e. pasteurization and milk processing, to products (e.g. cheese and yoghurt) and spoilage due to lack of cooling facilities.

Fish commodities e.g.:

- Poor and inadequate industrial processing, such as canning or smoking;
- Poor and inadequate preservation and trimming.

Food distribution, marketing, retail production

Vegetable, livestock and dairy and fish commodities and products e.g.:

Distribution:
- Poor transport and marketing infrastructure;
- Lack of or inadequate storage and cooling facilities;
- Lack of or insufficient access to markets;
- Lack of markets: supply exceeding demand;
- Inadequate market facilities leading to unsanitary and unhygienic practices, inadequate proper garbage disposal, clogged sewage vents;

Packaging:
- Improper and insufficient packaging leading to physical and chemical damage during distribution, transport and marketing; and inadequate protection against insects, rodents, and other contaminants from entering the food

Retail:
- Developing countries: e.g. poor and unhygienic handling; lack of or inadequate storage and cooling conditions.
- Developed countries: e.g. large quantities and varieties on display; packages in large quantities; high quality and safety regulations.

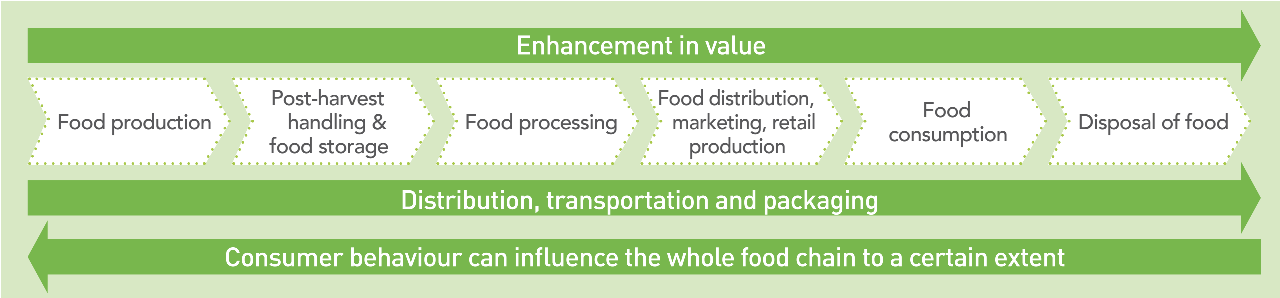
Food consumption

Developed countries:

- Buying more than is consumed, which results in spoilage and contamination;
- Poor storage/ refrigeration practices;
- Confusion between production date and expiry date written on the product.

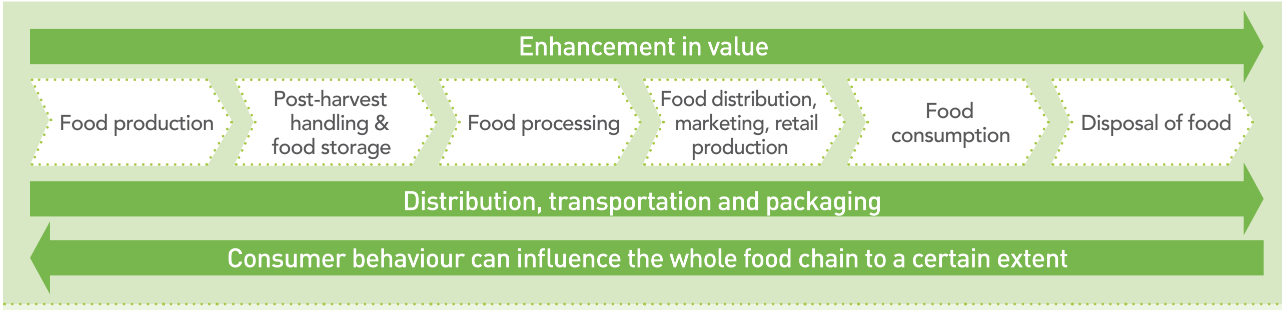
Disposal of food

- Disposal of food waste at different stages of the food chain due to poor handling, poor processing and poor packaging.



Possible interventions to reduce food losses and waste:

Vegetable commodities and products e.g.: • Improvement in production and cultivation practices, including soil and water; and pests and disease management; • Improvement in harvesting practices Livestock and dairy products e.g.: • Improvement in livestock production and dairy farming practices, including proper management and housing, nutrition, feed, water, milking hygiene, animal health Fish commodities, e.g.: • Improvement in bycatch and discards management through input and control measures; special and/or temporal measures; design improvements and use of fishing gear and bycatch reduction devices; use operational techniques to reduce bycatch; use of techniques to increase survival rate of released catches; use of vessel and fishing gear position monitoring and habitat mapping systems.	Vegetable commodities and products e.g.: • Investment in storage and cooling facilities, e.g. low cost storage and cooling structures for successful long-term storage; • Improvement in handling to improve quality (storing, trimming, quality grading and packing in the field) and use of improved containers to reduce mechanical damage of horticultural crops (plastic crates, liners in rough containers, smaller packages) Livestock and dairy products e.g,: • Improvement in animal handling during transport; • Improvement in milk handling during transport and storage; • Improvement in storage of chilled meat after slaughtering Fish commodities, e.g.: • Improvement in post-harvest handling and transportation after landing; • Investment in storage and cooling facilities	Vegetable commodities and products e.g.: • Improvements in packaging and processing techniques including threshing and solar drying of produce; • Improvements in cooling through i.e. low cost cooling practices to maintain quality and extend post-harvest life; • Livestock and dairy products e.g,: • Improvement in slaughtering techniques, processing, and packaging; • Improvements in cooling, packaging and milk treatment, i.e. pasteurization and milk processing to products (e.g. cheese and yoghurt) • Fish commodities, e.g.: • Improvements in processing and preservation techniques	Developing countries: • Investment in transport, infrastructure and marketing systems; • Investment in cooling and storage facilities; • Improvement in hygiene practices; • Improvements in access to markets through collective marketing, increase accessibility and availability of market information; • Exploring possible 'niche markets' for product diversification; • Improvement in packaging practices Developed countries: • Offering smaller packages; fewer varieties on shelves; improvements in packaging material to increase shelf life; • Alternative markets and food uses; • Coordinated and coherent regulatory frameworks (e.g. policies), including food labeling and legislation; • Optimized communication from producers to consumers	• Improvements in-home food storage, preparation and cooking techniques; • Reduction in the amount that consumers buy through awareness raising, education (i.e. food litreacy)	• Improvement in the separation of waste, • Improvement of various waste management practices, which results in a higher efficiency rate



Involved chain actors:

• Farmers, agricultural labourers, commodity producers, livestock holders, fisherfolk	• Packers, millers, crushers, refiners	• Processed foods manufacturers, artisan to global	Importers, exporters, brokers, wholesalers, small grocery shops; supermarkets, restaurants, fast food companies	• Consumers	• Consumers, waste management companies, local authorities

Source: adapted from IFPRI, 2011; Parfitt *et al.*, 2010

Possible practices and solutions to improve the sustainability along the food value chain

Food production stage

Vegetable commodities and products

Pre-harvest cultivating and harvesting practices influence the post-harvest life of products due to decisions made regarding what, when and how to plant and when to harvest (FAO, 1998). Pre-harvest production practices and factors, including cultivation practices, quantity of water, type of soil used, may all affect post-harvest quality, shelf life and post-harvest losses. Good post-harvest practices can also prolong the post-harvest life of particular fruits and vegetables. However, this also depends on the conditions when and how the produce is harvested. In developing countries and sometimes in developed countries, food may be lost due to premature harvesting as farmers may decide to harvest crops earlier, because they are food insecure or need to generate income. It may also happen that harvesting is undertaken too late or that losses occur during harvesting due to damage and/or spillage. As a result, food may be lost and wasted during the production stage (FAO, 1998; FAO, 2011b; Prusky, 2011).
In the context of food loss and waste reduction, adopting good agricultural practices is key as well as following specific rules when harvesting crops (see Box 11.1 below).

Good agricultural practices and rules of harvesting

Good agricultural practices involve adequate soil management, including management of weeds, crop protection and maintenance of crop hygiene. The latter involves the collection and removal of decaying plants, fruits and wood that can lead to infections in vegetables and fruits, which may result in post-harvest losses and waste. In addition, the amount of water provided to the plant, the use of fertilizers, pesticides and herbicides can all influence the post-harvest quality and quantity of the produce and thus provide entry points to reduce post-harvest losses (FAO, 1998; FAO, 2002).

The basic rules of harvesting with the aim to get the crops in the best possible condition to the market are:

- harvest during the lowest temperature of the day: early morning or late afternoon;
- do not harvest produce when it is raining or when there is dew, when the produce is wet it is more likely to decay as well as it is more vulnerable to damage; and
- make sure to protect the harvested produce from sunlight if it cannot be immediately transported.

Livestock production and dairy products

Losses and waste in the livestock and dairy production sector may occur due to various reasons. During livestock production, losses and waste may occur due to poor feeding or diseases, e.g. swine fevers, tick-borne and zoonotic diseases during breeding, which may lead to animal death. During dairy production, losses and waste may occur due to poor milking techniques, illnesses, infection or diseases, which have a negative impact on milk production (FAO, 2011b; FAO, 2011d).

Good livestock production and dairy farming practices

Good livestock production and dairy farming practices include proper management and housing, nutrition (adequate and nutritious) of feed and water, milking hygiene and animal health through vaccinations and drugs, all aimed at minimizing and avoiding food losses and waste. In particular zoonotic diseases, which are diseases that can be passed on from animals to humans, should be controlled in order to prevent animal, and possible human, death (FAO, 2002; FAO and IDF, 2011).

Fish commodities

Fish losses may occur due to infrastructural inefficiencies, infestation or 'bycatch' and discards during fishing (Cheke and Ward, 1998; Kumolu-Johnson and Ndimele, 2011; see also Module 10 on fisheries and aquaculture). According to the International Guidelines on bycatch management and reduction of discards, which were endorsed in February 2011 by the Committee on Fisheries, discards are defined as:

> *"that portion of the total catch, which is thrown away or slipped. They may be comprised of single or multiple species and may be alive or dead. In the context of these guidelines, discards refer to the throwing away or slipping of dead fish and fish that may not survive after live release."*
>
> (FAO, 2011c)

It is estimated that around 20 million tonnes of catch a year is discarded at sea (FAO, 2010a).

There is no standard international definition for 'bycatch' as the term has different meanings and regulatory interpretations in different countries. However, bycatch can be understood to mean catch that a fisher did not intend to catch, but could not avoid.

Good practices to manage and reduce bycatch and discards

Bycatch can be managed and discards can be reduced through, among others:

- input and control measures;
- special and/or temporal measures;
- design improvements and use of fishing gear and bycatch reduction devices (e.g. mesh and hook size, turtle excluder devices);
- use of operational techniques that reduce bycatch (i.e. backdown manoeuvre during purse-seining);
- use of techniques that increase the survival rate of the released catches; and
- use of vessel and fishing gear position monitoring and habitat mapping systems

(FAO, 2011c).

Post-harvest handling and food storage stage and food processing stage

Vegetable commodities, livestock and dairy products and fish commodities

Food losses and waste of crop, livestock and fish products at the post-harvest handling & storage stages and at the processing stage may occur due to:

- spoilage, as a result of lack of or inadequate cooling facilities and lack of adequate infrastructure for transportation;
- spillage, contamination, and degradation, not only as a result of poor and inadequate handling, such as during transport and storage and in the case of bovine, pork and poultry meat inadequate slaughtering, but also due to processing, such as during washing, peeling, slicing and boiling of fruits, vegetables and during canning or smoking of fish;
- inadequate preservation of the products;
- trimming, as a result of the selection of products with the right shape, weight, size and appearance;
- packaging, as a result of damaging due to use of poor quality containers.

(FAO, 1989; Parfitt *et al.*, 2010; FAO, 2010b; FAO, 2011d)

Good post-harvest handling and storage practices

A variety of practices and technologies are available for reducing post-harvest losses related to post-harvest handling and storage. Good handling practices in order to avoid mechanical damages include ensuring that:

- containers are not too full if they need to be stacked on top of each other;
- containers are not dropped or thrown;
- produce is not directly put on the soil, in particular soil with a high moisture content;
- containers and field containers are clean;
- the produce is not brought into contact with oil, gasoline or chemicals that should not be applied;
- produce is largely kept in the shade to reduce the temperature of fresh produce;
- produce is field packaged, which reduces costs by improving the speed of post-harvest handling and reduces losses and waste

(FAO, 1989)

Other possible interventions to reduce food losses include:
- immediate transportation after harvesting of crops, and landing in the case of fish;
- using improved preservation and processing techniques including threshing and solar drying of produce;
- using low cost and efficient storage and cooling structures; and
- using practices, i.e. pasteurization and milk processing into cheese and yoghurt, to maintain product quality and extend post-harvest life.

This section features two case studies, illustrated in Boxes 11.1 and 11.2, of improved post-harvest practices with regard to post-harvest processing.

The improved rice thresher cleaner (ASI) (see Box 11.1) is an affordable and locally constructed rice thresher which increases grain quality and therefore product value, which may ultimately lead to additional income for farmers. It also substantially reduces the amount of labour used and thus increases labour efficiency.

Box 11.1
An improved rice thresher cleaner (ASI) technology

An ASI rice thresher is being used in Mali, AfricaRice http://www.africarice.org/publications/ricetoday/The_little_machine_that_could.pdf

A successful technology to reduce post-harvest rice losses is the improved rice thresher cleaner (ASI) which was introduced in the Senegal River Valley in 1997. The rice thresher was developed in collaboration between the Africa Rice Centre (AfricaRice, previously WARDA) and the International Rice Research Institute (IRRI), which identified a prototype Asian rice thresher-cleaner. National researchers from the Senegal River Valley National Development Agency (SAED) and the Senegalese Institute of Agricultural Research (ISRA) as well as with other partners including artisans, farmers, farmers' organizations and an agricultural machinery factory then developed the first prototype of an improved rice thresher cleaner (ASI), which was commercially released in 1997. It is an affordable technology, which is locally constructed and accepted by farmers in rice-growing areas. Field surveys identified that post-harvest crop losses were estimated to be as high as 35 percent due to the inefficiency of manual threshing (Africa Rice Centre, 2005). As a result, grain is inefficiently separated or damaged, which leads to poor grain quality, lower marketable value or rejection of locally produced rice. The ASI is able to thresh six tonnes of rice per day, while manual threshing would produce only one tonne per day. The grain-straw separation is 99 percent and no additional labour is needed for sifting and winnowing (Africa Rice Centre, 2005; Azouma *et al.*, 2009). The ASI thresher has been widely adopted in Senegal as it improves the quality and marketability of rice and it increases productivity by relieving farmers from manual threshing, which is highly time consuming and labour intensive. It is estimated that currently more than half of total rice produced in Senegal is threshed with the ASI thresher and after using the thresher for 90 days the benefit cost ratio reaches 2.3 (Africa Rice Centre, 2005; World Bank, 2011). Through further modification and adaption to other countries it has been successfully transferred to other West African countries, including Mauritania, Mali, Burkina Faso, Ghana and Côte d'Ivoire (World Bank, 2011). In 2003 the ASI thresher won the special President of Senegal Prize for Science Research (Diagne *et al.*, 2009).

As in the previous example, the following low cost, improved and locally produced processing technology (see Box 11.2) has increased the quantity and quality of the product, thereby increasing incomes. Moreover, due to the use of solar energy, it does not contribute to the release of GHG emissions (see more on energy-smart food systems in Module 5).

Box 11.2
Low cost fish solar dryer

Sun drying is one of the traditional methods to preserve and process fish. During sun drying, moisture is removed from the produce so that the product can be stored for certain periods of time. Sun drying, which is the most common form of drying, has some disadvantages, such as direct exposure to adverse weather conditions, generally lower drying temperatures, longer drying times, poor final quality and the possibility of contamination by insects, birds, animals. An improved practice of sun drying is solar drying.

Solar drying shortens the drying time due to higher temperatures being generated. The solar dryers do not necessarily protect the product against the sun, but they protect it against rain, insects, animals and contamination from other sources. Solar dryers have a simple structure that usually consist of a wooden or bamboo-frame table, which is covered with plastic or glass or other material that is locally available. The material can be painted black so that the heat of the sun will be absorbed. The solar dryer has openings at the top and at the bottom of the drier so that the heated air will flow through the structure and will decrease the moisture content of the fish. Various structures have been established in different countries, including in Bangladesh, Indonesia, Rwanda, the Philippines and Papua New Guinea. Studies have shown that solar driers can increase drying rates and produce lower moisture content in the final products, which results in improvements in fish quality and reduction in losses compared to traditional sun drying techniques (OIA, 1988; Bala and Janjai, 2009; Davies and Davies, 2009; Sengar *et al.*, 2009).

A study undertaken by Sengar *et al.* (2009) showed various benefits of the use of a low cost solar dryer compared to sun drying, including a reduction of the time to reduce the moisture content of prawns by 15 to 16 percent as well as an improvement in colour and texture. It was estimated that the low cost solar dryer was affordable to local fishers, who could recover the investment cost of the solar dryer within a period of 0.19 years. In addition, this is a sustainable method of drying as it does not generate GHG emissions.

Food distribution, marketing and retail stage

Distribution and transportation

In developing countries food is lost and wasted throughout the food chain due to distribution and transportation problems. Issues include whether roads exist at all, whether roads and vehicles are kept in good repair, whether roads are also accessible during the rainy season and whether roads are passable by large vehicles.

Transportation conditions

Poor transport conditions can easily damage products. For example, vehicles that are overloaded, products that are poorly packaged or carried in an unsuitable vehicle and insufficient ventilation and cooling all increase the amount of post-harvest losses. In addition, the amount of time it takes for a product to reach the consumer contributes to losses, because the longer the product is under the sun or in humid or in other weather conditions, the shorter its life span. This is because fruits and vegetables easily spoil and damage as they contain 65 to 95 percent of water and as soon as their food and water reserves are depleted, the product deteriorates and perishes and may become inedible before it reaches the consumer. Therefore, they need to be marketed as soon as they are harvested. Therefore, the transportation of the harvested produce should be planned in advance so that losses can be minimized (Parfitt *et al.*, 2010; Kitinoja, 2011).

Road infrastructure

Transportation costs as well as the price of products increase with poor road infrastructure. A study by Minten and Kyle (1999) in Zaire showed that transportation costs made up one-quarter to one-third of the wholesale price of domestic products due to the poor conditions of rural roads. Increasing efficiency means increasing the efficiency of infrastructural systems (FAO, 2009). Furthermore, not only limited infrastructure, but also the lack of transport is one of the barriers that smallholders face. As a result, some smallholder farmers are not able to access markets and thus are not able to generate income.

Modes of Transportation

Food is transported in many forms, such as in small and palletized field containers, in bulk bins, in hand-loaded sacks, in wooden or plastic boxes and so on. Furthermore, food is transported by different modes of transportation, such as in animal-drawn carts, on bikes, by trucks, trains, boats and planes. The most energy efficient mode of transportation to transport food or other goods is by water, followed by rail, road and air (Pimentel and Pimentel, 1996).

Refrigeration

Food should be adequately refrigerated during transport, this is crucial in terms of reducing losses. Refrigeration helps to reduce the rate that microbiological, physiological, biochemical and/or physical changes occur in food and thus helps to ensure safety and quality of food as well as the transportation of food over long distances (Gac, 2002; James *et al.,* 2006; Tassou, 2009; James and James, 2010). At present, less than 10 percent of all perishable food is refrigerated (Coulomb, 2008). According to the International Institute of Refrigeration (2009) over 200 million tonnes of perishable foodstuffs could be preserved, which is approximately 14 percent of the food currently consumed in these developing countries, if they could attain the same amount of refrigerated equipment as in developed countries (James and James, 2010).

The level of perishable food that is being transported by air has increased by 10 to 12 percent a year since the 1990s (Stera, 1999). Even though food is able to be transported over vast distances within a shorter period of time, there are some disadvantages with air freighting of food. Among others, during a large part of the journey, up to 80 percent of the total transportation time, the food is exposed to temperatures ranging from 15 to 20 degrees Celsius and often unprotected (Dellacasa, 1987).

Carbon dioxide emissions associated with transport

One of the arguments often brought up in relation to reducing carbon emissions is producing food locally, because the amount of 'food miles' (the distance that food is transported from production to consumption) is reduced (Seyfang, 2006). However, the negative impact of these 'food miles' actually varies, depending on the mode of transportation, conservation and seasonality whether the overall environmental impact is lower for local foods. Bentley and Barker (2005) compared the transportation distance of seven locally produced foods with the shipping distance of the same imported food items so that the environmental impact of their transportation could be calculated (DEFRA, 2005). It was estimated that the imported items travelled on average a distance of 5 364 kilometres, which meant that the imported items travelled 81 times further than the local foods. As a result, carbon dioxide emissions were higher for the imports than for the locally produced foods. However, there was one exception: the locally produced food items, which only travelled by truck, generated more carbon dioxide than the pears and apples from Portugal, which travelled 350 kilometres further by boat and truck.

If one looks at the whole food chain, the GHG emissions associated with transporting food is quite small compared to the overall GHG emissions generated within the whole food chain. It was calculated that 22 percent of the United Kingdom's total GHG emissions was emitted by the commercial food sector, with 1.8 percent of total emissions accounting for food transport (DEFRA, 2005).

Eating locally and seasonally produced food to reduce GHGs

Eating more locally and seasonally-produced food will reduce the generated GHG gas emissions that result from food transportation. However, one must not only consider the food travelling distance or the means by which it was transported, but also how the food was produced, processed, stored and distributed. Food produced locally may be less economically and environmentally efficient due to less optimal growing conditions (Fuchs and Lorek, 2000). A study undertaken by Carlsson-Kanyama (1998) shows that tomatoes grown in greenhouses in Denmark, the Netherlands and Sweden had higher carbon dioxide equivalents than imported tomatoes grown under the sun in Spain.

Harvested cassava is transported by cart, Central African Republic

Milk is being transported by rickshaws from the countryside to the milk processing plant, Bangladesh

Market access, lack of markets and inadequate market facilities

Access to markets is essential for producers, in particular smallholder producers, in order to generate income, strengthen food security and contribute to sustainable livelihoods. Improving access to international and domestic markets helps them to sell more produce. With the income that they earn, they may be able to invest in their own businesses and increase their production as well as improve the quality of their produce and/or diversify their production, which contributes to building their resilience. However, besides access to markets, roads, and affordable transportation, access to market information is also crucial.

Food is lost due to several market related issues. Firstly, some farmers, in particular those in developing countries, lack or have insufficient access to markets, due to high transport costs, as a result of remoteness from markets. Therefore, those who live closer to markets or better roads are able to engage more with the market and thus have a higher chance to generate additional income. Besides these physical barriers to access markets, they may also face limitations due to the lack of market information, business and negotiating experience, etc. (see Table 11.1) (FAO, 2005; FAO, 2011b).

Table 11.1
Market access constraints: physical, structural, information and organization

Constraint	Disadvantaged areas
Physical	Poor roads, high transport costs, perishable goods, low value/weight produce.
Structural	Asymmetry of market relations: reliance on monopsonistic traders, agro-processors or marketing boards whose market power allows excess profit shares.
Skills, information and organization	Lack of understanding of how markets operate, lack of information, lack of relevant skills.

Source: IFAD, 2001

Lack of markets

Another challenge related to markets is that food gets lost because of the lack of markets. At certain times there is an oversupply of some crops, such as the seasonal production of many perishable food crops, which means that there is a temporary oversupply of these crops on the markets. One of the ways to reduce food losses and to add value to the produce is to process and preserve these foods so that the waste of food is minimized and the loss of income is reduced (FAO, 1998; FAO, 2011b).

Collective marketing as a way to get access to markets

Collective marketing can encourage market access and take different forms, such as through the creation of a marketing cooperative, which can help to provide smallholder farmers, livestock holders and fishers a place where produce can be prepared and packed to be transported to markets and other distribution centres. However, there have been mixed results and challenges related to these organizations, for example the importance of having good access to transport, a favourable market, marketable products, as well as the need for accountability and transparency among its members. There are different ways to increase accountability and transparency, such as through the establishment of a well-functioning record system that is shared among the members, a dispute system and regular meetings to enhance the exchange of information (ODI, 2005; World Bank, 2011; FAO, 2012a).

Inadequate market facilities

In addition, food is lost as a result of inadequate market facilities, such as lack of storage and cooling facilities, unsanitary and unhygienic practices, lack of or inadequate proper garbage disposal, clogged sewage vents and so on. Improvement of facilities should be supported by appropriate government actions so as to reduce the inefficiency generated by institutional and physical infrastructure facilities (Barrett and Mutambatsere, 2005; FAO, 2011b).

Increasing efficiencies related to access to infrastructure and infrastructural facilities is not easy to overcome. However, addressing these issues can have significant effects on increasing people's physical and economic access to food.

Packaging

Depending on the value chain of a product, a product can be packaged and repackaged at various stages of the food chain. Packaging helps to distribute and transport the product from farm to storage, cooling and processing facilities, to wholesalers, retailers and consumers. Besides that, it should provide protection against physical and chemical damage during distribution, transport and marketing; it should also provide protection against insects, rodents, and other contaminants from entering the food. As a result, packaging practices and technologies can ensure quality and safety of food so that quantitative and qualitative post-harvest losses can be significantly reduced (FAO, 2010b).

However, the type of packaging material used depends on the availability of local materials, which may be highly limited. In addition, these materials should also be affordable as packaging can represent a substantial part of the costs for producers (both in developing and developed countries). Paper, fiberboard, plastic, glass, steel and aluminum are among some of the packaging material that are commonly used. The choice of the packaging material used is made based on a number of trade-offs between various factors, including economic costs, protecting goods, public health and the environment, providing presentation, branding, information about the goods and what consumers need (smaller portions for those who live alone) and the likely product wastage. In addition, there are also environmental impacts associated with the type of packaging being used, e.g. the thinner the packaging material, the less landfill space it will take up, some materials are recyclable (like paper, plastic, glass etc.) and some are not (like the foil-backed wrap).

Knowing the exact causes and the stages of when losses occur within the food chain helps to identify possible packaging interventions. An overview of various packaging options is shown in Table 11.2.

Table 11.2
Packaging solutions for reducing food losses and waste along the value chain

Loss situation and causes	Selected packaging solutions
At production stage	
Unnecessary variety of packaging types	• Universal packaging design
High amount of GHG emissions per tonne of production	• Modified atmosphere packaging • Integrated materials handling and warehouse management systems
Non-recyclable wax-coated boxes for delicate perishables	• Recyclable packages with excellent moisture barrier • Reusable plastic containers
At post harvest stage	
Inefficient product insulation	• Fibre reduction • Microflute technology
Manual case forming and stretch wrapping	• Automated processes reducing labour and material costs
Product spoilage and toxicity	• Anti-microbial packaging
At distribution stage	
Damage due to palletizing and strapping	• Slip sheets and stretch wrapping in lieu of pallets and strapping
Damage due to mixed products on pallets	• Cube utilization via 'pin-wheeled' position
At processing stage	
Damage during transport	• Leak-resistant packaging • Tough, tear-resistant packaging
Product spoilage and toxicity	• Hermetic seals • Vacuum or modified atmosphere packaging
Loss of production	• Efficient equipments systems • System integration and automation
At wholesale stage	
Inappropriate shipping containers	• Optimizing secondary packaging for shipping and shelf impact/appeal
Damage due to high humidity, storage time and stacking height	• Use of new materials with enhanced stacking strength • Modified atmosphere packaging
At retail stage	
In-store preparation losses	• Centralized food preparation • In the bag merchandizing
Product spoilage and toxicity	• Leak-resistant packaging • Vacuum or modified atmosphere packaging
Passed sale date	• Shelf-life extension • Freshness preservation
At consumption stage	
Too much preparation	• Portion control packs • Ready-to-eat entrees
Spoilage	• Resealable packaging • Vacuum or modified atmosphere packaging
Not consumed prior to expiration date	• Shelf-life extension • Freshness preservation

Source: FAO, 2011a

However, even if advanced packaging technologies are available, social, economic and cultural factors, including gender issues, could play a role in explaining why the technology is not upgraded or adopted in developing countries. One of the major factors is the lack of incentives and insufficient support to repair and maintain the facilities (FAO, 2011a).

In addition, even with optimal packaging material and technology, there is no 100 percent guarantee that losses do not take place. For example, food packaging can make it difficult to for a consumer to access the whole product and thereby causes losses (i.e. the product that remains in the package). The way products are packaged has an impact on food being lost and wasted. Andersson *et al.* (1998) undertook a study on the Life Cycle Analysis (LCA) of tomato ketchup. Part of the research included the collection of ketchup bottles of 30 people at the point of disposal. Even though this survey was quite limited, the losses measured significantly varied from 0.5 percent to 26 percent (Andersson *et al.*, 1998). In addition to this, losses may result due to external factors, such as the mode of transportation, the state of roads, regulations and consumer behaviour (FAO, 2011b).

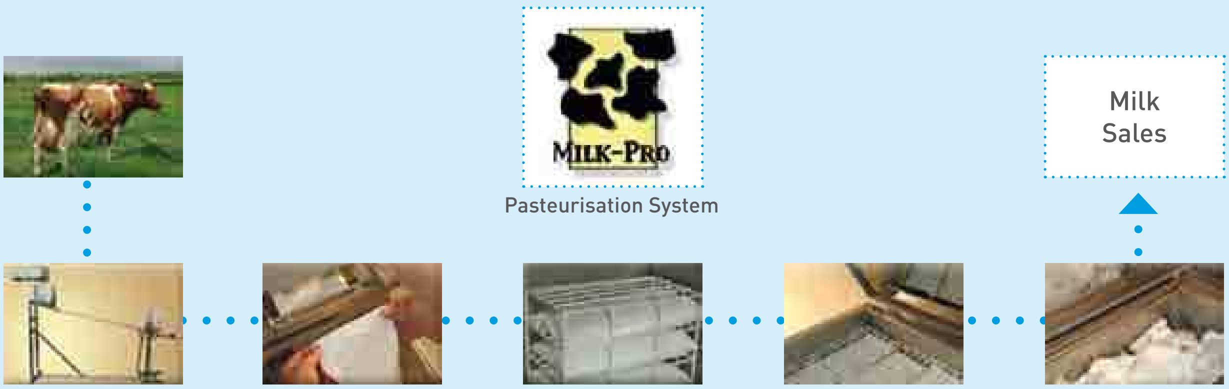
With regard to consumer behavior, it not only depends on how the consumer handles the product and what it done with the packaging material, as some consumers may reuse or recycle it for other purposes, but also whether supermarkets and retailers are putting 'unnecessary' packaging on the product.

The following example is a low cost milk pasteurizing, packaging and chilling system (see Box 11.4), which helps to reduce spillage and spoilage. As this system incorporates these three activities, the value that was previously added to the product as a result of other chain actors engaging in these activities now goes to the small-scale milk producers themselves, possibly resulting in higher incomes.

Box 11.3
Low cost milk pasteurizing-packaging-chilling system – the MILKPRO

Small scale milk processors in developing countries often do not have the equipment to pasteurize and package fresh milk due to the high investment cost and potentially expensive conventional packaging material. They often use cans or boilers in which they can heat their milk. However, high temperatures can lead to post-pasteurization contamination, which is the main cause of spoilage.

The MILKPRO is a low cost, simple milk pasteurizing and packaging unit, which was first field tested in Kenya as part of the FAO Dairy Training Programme for the Small Scale Dairy Sector. The facility helps to fill raw milk into pre-formed polyethylene sachets. These small bags are immediately sealed, pasteurized through treatment at 65 degrees Celsius for 30 minutes and then cooled to 50 degrees Celsius. Post-pasteurization contamination is largely avoided due to the milk being pasteurized within the sachet. The sachet when refrigerated can have a shelf-life of up to 15 days. It is estimated that the unit can manage up to 100 litres of milk an hour. The costs of the system lie below US$ 10 000; when on a daily basis it handles 750 litres. Therefore, the break-even point would be at 12 months. The MILKPRO system has been widely adopted by small farmer groups as well as individual farmers as they benefit from the value addition through the packaging, pasteurizing and chilling of their own milk (FAO, 2000).



Food consumption stage

In developing countries, the amount of food wasted at consumer level is minimal. Poverty, limited income and smaller amounts being purchased are contributing factors to reduced levels of food being wasted. In developed countries, however, food is wasted by consumers. This is not only as a result of consumers buying more than what they can actually consume and inappropriate capacity to correctly interpret date marking, but also due to consumer behaviour and food choices that are made (Stuart, 2009; European Commission, 2010; FAO, 2011b).

Ultimately it is the consumer that decides whether he or she wants to waste food. The consumer may not be driven by economic factors to reduce waste. However, it is still throwing away money, food and the inputs that were used to produce food. Consumer behaviour can be influenced through various means including, for example, educational awareness-raising campaigns, labelling schemes, as well as government-led promotion of making sustainable and healthy food choices through taxation and provision of subsidies.

Consumer interventions to improve efficiency of food systems

Consumers can be agents of change with regards to sustainable consumption and adopting sustainable diets (Spaargaren and Oosterveer, 2010; Lorek and Fuchs, 2011). They can influence the whole food chain to a certain degree by making sustainable dietary choices, which will influence what, where and how producers produce and who produces. In addition, consumer behaviour also contributes to how much food is consumed and wasted. This is due to the duration that food is kept before it is consumed, and how food is stored, prepared and cooked, amongst other things. Therefore, possible interventions related to addressing consumer behaviour include improved planning, in-home food storage, preparation and cooking techniques. Not only the food itself is lost, but also the amount of land, water and energy used to produce the product is wasted.

Raising consumers' awareness

In order for consumers to make food choices and change their behaviour, awareness needs to be raised through provision of information and education. Consumers need to be educated on where their food comes from, how it was produced, how many and which resources were used and what is the impact on the environment, so that they are able to make informed choices that are both nutritious and sustainable. Governments should support educational awareness campaigns (Boer et al., 2007; Tukker et al., 2007).

Labelling schemes

Labelling schemes are needed to guide consumers to make informed choices (Giraud, 2003; Davies, 2011). The food industry and agribusinesses have a responsibility to provide labels that are clear and easy to read and understand so that people can make informed choices. Information that consumers would like to know can be related to production methods, application of pesticides, the distance that food travelled ('food miles') and the carbon footprint. According to a study undertaken by Which? (2010), labels and terms should be used consistently on different products and brands so that confusion is avoided. The study concluded that labelling schemes have a wider outreach if they are connected to government campaigns, supported by validated scientific data, and used to provide interpreted data so that consumers are able to make sustainable food choices (Davies, 2011; Wognum et al., 2011).

There are still certain challenges regarding the development of such labelling schemes, as these schemes are often competing with one another. Different ways to increase transparency include integrated information systems, such as certification and branding (Eden et al., 2008). But as was highlighted earlier, these brands and certification need to be clear and easy for people to understand in order for them to make healthy and sustainable food choices.

Socio-cultural factors influencing consumers' behaviour and food choices

Educating people and providing them with information is not sufficient. This is due to the fact that consumers' attitudes and food choices are formed through their values and beliefs, but also habits, income and knowledge. Not only personal characteristics play a role, but also social and cultural norms need to be taken into account (Boer et al., 2007; Eden et al., 2008; Davies, 2011). According to Tukker et al. (2007) the behaviour of consumers can only change if motivation, ability and opportunity are addressed at the same time. Moreover, there should be an equally attractive alternative opportunity. Thus, an enabling environment should be created in which consumers can make choices, this would involve both promoting and supporting healthy food. It requires supportive legislative, regulatory and fiscal policies implemented by governments.

Taxation

An example of what governments can do with regards to fiscal policies is to raise taxes regarding food consumption. In order for consumers to make more healthy food choices, some governments place taxes on tobacco and alcohol consumption and more recently some countries have started to tax unhealthy food (see Box 11.8). Raising taxes can have an influence on consumer spending, but it requires taxes to be substantially high in order to be 'felt' by consumers. It was estimated that the increase of price on unhealthy food and drinks should be around 20 percent in order to influence consumer consumption, which should also be supported by subsidies on healthy food to shift dietary habits (Campbell, 2012). Some concerns were raised regarding this, namely that the lower income groups spend a relatively larger share of their income on food and thus are more likely to consume unhealthy foods, which are, in general, cheaper. If this measure is adopted, governments should possibly look into compensating these lower income groups for these additional taxes enforced on unhealthy food (Witt, 2011).

Box 11.4
Taxes on unhealthy food

In 2011, Denmark introduced, as the first country in the world, a tax on unhealthy foods that have a high content in saturated fats. This 'fat tax' or 'junk food tax' was later also introduced by Hungary. Through this measure governments try to control obesity levels, which are also increasing rapidly in developing countries. Other countries, like France, tax their food, such as sweets, chocolates, margarine and vegetable fat. In Australia, Finland, Norway, Canada and also in some states of the US, a sales tax is added to soft drinks, sweets and snack foods (Lorek, 2011).

Subsidies

Governments could also provide subsidies for food that is produced in a resource, energy, water intensive way and stimulate local food production. The European Commission developed in 2011 a 'Roadmap to a Resource Efficient Europe', which outlined efficiency indicators and targets for all key resources – ecosystem services, biodiversity, minerals, metals, water, air, land, soil and marine resources across its 27 members states (European Commission, 2011) (see also Module 13 on policy measures supporting transition to CSA).

Other stakeholders

The food industry, packaging industry and retailers also have an important role to play. Public-private collaboration and partnerships among all stakeholders in the areas of environment, agriculture, nutrition, health, education, culture and trade need to be promoted. Cross-sectoral approaches are required to ensure that programme activities and policies adequately promote sustainable consumption and adoption of sustainable diets. There is a need for all stakeholders to undertake action.

Disposal of food stage

Adopting a waste management approach is desirable from a food security, economic and environmental perspective as waste occurs at all stages of the food chain. Waste management is complementary to the CSA approach, because if a certain amount of waste is reused and recovered, it may not need to be disposed at landfills, where the GHG, methane, is produced from waste.

Lansink's 'waste management hierarchy' shows the different types of waste uses. The waste hierarchy includes waste minimization (reduce), reuse, recover (recycling, composting, energy from waste) and safe disposal. It aims to reduce the total amount of waste and save energy and resources and thus increase the efficiency of food systems (Wolsink, 2010; Smith and Ali, 2002).

The following sub-sections focus on reusing waste for human consumption and animal feed, as compost and for energy generation.

Reusing waste for human consumption and animal feed

Food waste that is discarded may still be useable for human consumption (see Box 11.5) or as animal and fish feed. These can be alternative food and feed sources that would not require the expansion of current food production levels. A study undertaken by the United Kingdom estimates that through exploring food reusing possibilities its dependence on raw material can be reduced by 20 percent by 2020 (WRAP, 2009). In the context of increasing efficiency these possible options should be further explored.

Box 11.5
Fermented left-overs and by-products transformed into nutritious food products in Indonesia

Various waste products are fermented into nutritious food products in Indonesia. For example, *tempe-bongrek*, a protein-rich food is made by fermenting peanut and coconut press cake that remains after oil extraction. The final product is similar to the traditional *tempeh,* which is produced through fermenting soya beans. Another example is *ontjom*, which is produced from waste groundnut press cake, tapioca waste and the solid waste of *tahu.* Primarily produced in West Java, *ontjom* is an important daily food consumed as a side dish especially by the lower income groups in the form of deep fried slices. In addition, *semayi* is fermented fresh coconut residue that is left over from the production of coconut cream or milk and extensively consumed in Indonesia.

Source: FAO, 1998

In some countries, developed countries in particular, due to safety and quality concerns, feeding food and animal waste to animals is highly restricted. In general, there is a high concern of food safety so meat and bone meal is forbidden to be used in animal feed due to the potential to spread *Bovine spongiform encephalopathy* (commonly known as mad cow disease). Instead some food waste could be turned into compost or biogas.

Reusing waste as compost

Waste can be both organic and inorganic. Organic waste can be transformed into compost through a bio-oxidation process where the organic materials are broken done. The benefits of compost include:

- The reduction of soil erosion, especially in areas where soils are exposed;
- The increase of water retention in the upper soil layer;
- The release of nutrients for plant growth; and
- The suppression of soil borne plant pest and diseases.

(FAO, 2007a)

As a result of soil related benefits, the need for water, fertilizers and pesticides is thus reduced. Besides economic benefits, composting also has environmental benefits as organic material is diverted from landfills. At landfills, bacteria break down waste in the absence of oxygen, which results in landfill gas that contains, among others, methane, a GHG that is more powerful than carbon dioxide in trapping heat in the atmosphere.

Generating energy from waste

Many items typically thought of as 'waste', such as household waste, animal dung, agricultural residues, and processing water can be used to produce energy. For example, biogas can be produced through a process whereby organic matter is broken down by microbiological activity in the absence of oxygen. Waste products, such as used cooking oil and fish waste, can also be used to produce liquid fuels such as biodiesel. There are additional by-products of biodiesel production, including glycerine which can be used for soap production. About one litre of biodiesel can be produced from one kilogram of fish waste (FAO, 2010c). The benefits of producing energy from products that are typically disposed are the increase in the efficiency of resource use for production and a potential additional revenue stream for producers (see also Module 5 on energy).

Public actions to support food chain interventions to reduce, reuse or recycle food stuffs

Public organizations are not able to directly reduce, reuse or recycle food stuffs. The private sector, including consumers, need to change management practices, technologies and behavior in order to reduce, reuse or re-cycle food stuffs. However, the public sector needs to create an enabling environment in which companies and consumers can adopt affordable, feasible practices that allow them to produce and consume sustainably or to find ways to use waste for other uses.

Creating a policy and institutional enabling environment

An important driver for improved practices along food supply chains is the enabling environment that supports and motivates the private sector to invest and make changes. Factors that are considered to be crucial for the success of food loss reduction, reuse and recycling interventions include: public infrastructure, social and cul-tural suitability, regulations and fiscal policies impacting the feasibility and profitability of required investments, and provision of long-term support by institutions. Another essential component of the enabling environment is the adoption of food laws and standards based on sound and common approaches to interpretations of standards by different actors (officials, food processors, consumers), including their implementation and enforcement. This would include addressing the issue of national requirements, official controls and industry approaches to date marking of food products.

Awareness raising and advocacy

A growing majority of consumers are increasingly concerned about many issues surrounding the food they eat, in-cluding the source of their food, nutritional quality and safety as well as making the best use of the food available to them (minimizing food waste). This is a positive indication that increasing awareness among retailers and consum-ers can lead to a reduction of food waste. Therefore both the public and policy makers need to be informed about the issue, and advised on behavioral change with regard to improved food use. Public awareness can be raised through education and governmental initiatives, which are possible starting points to change people's attitudes.

Consumers have the power to influence quality standards and thus, to a certain degree, the whole food supply chain. Therefore, consumer surveys could be used to show to what extent consumers are willing to buy produce of heterogeneous appearance as long as the taste is not affected. Evidence-based information should eventually influence policy makers and institutional strategies.

Building partnerships and alliances

Alliances can be built within the food supply chains between producers, processors, distributors, retailers and consumers. This could lead, for example, to the development of markets for products that are from a traditional commercial point of view labeled as 'sub-standard', but are nevertheless safe and of good nutritional value. In addition, finding ways to reuse and recycle waste still has an economic value and can be used for other purposes including food processing for human or animal consumption, as natural fertilizer or to generate energy (i.e. biogas). Partnerships should also be formed between food supply chain actors and development organizations, donors, NGOs, etc. to combine forces for waste management along food value chains.

Supporting product and process innovation

Product and process innovation are crucial factors in facilitating compliance with market requirements on quality and safety, supporting product diversification, and fostering development of underutilized resources or products. A key determinant of the ability of value chain actors to undertake innovation are the policies, institutions and services put in place by the public sector to create a supportive environment.

Capacity development

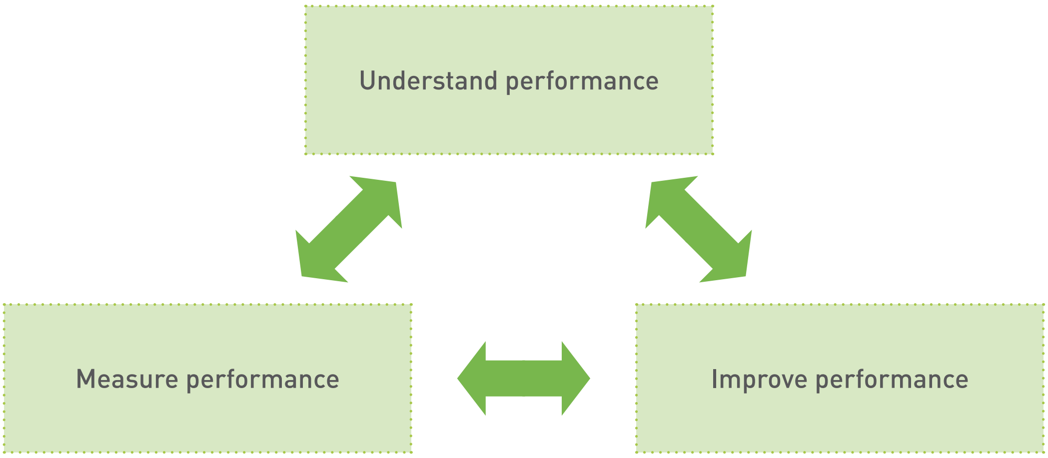
It is essential to develop knowledge and capacity of small- and medium-scale food chain operators (including farmers, herders and fishers) to organize themselves in associations, apply quality management systems, and im-prove business management and marketing. Public services should support agricultural and fisheries producers and small- and medium-sized enterprise to build their capacity to make business and quality management plans.

In addition, it is important to develop capacities of regional institutions, national government officials and development agencies in the use of food loss assessment methodologies and tools, in the establishment and enforcement of food quality and safety standards, and in the design of policies and strategies targeting food waste.

11.3 Step-by-step approach for chain actors to improve their performance along the sustainable and inclusive food value chain

This section outlines a step-by-step approach for chain actors to sustainably improve their performance along the sustainable and inclusive food value chain.
The three steps are visually outlined below in Figure 11.5.

Figure 11.5
Step-by-step approach for how to improve performance along the sustainable and inclusive food value chain



Source: FAO, 2013

Step 1: Understand performance
The core drivers of performance (or the root causes of underperformance are exposed):

- Analyse how value chain stakeholders and their activities are linked to each other and to their economic and social and natural environment;
- Analyse the behaviour of the individual stakeholder in their business interactions; and
- Analyse how value is determined in end markets.

Step 2: Improve performance
Provide for a realistic strategy that has mutually been agreed upon and selects upgrading activities and multi-lateral partnerships that can support the strategy:

- Develop a core value chain development strategy based on the analysis that is undertaken in step 1 and develop a vision that stakeholders have agreed upon; and
- Select the upgrading activities and multilateral partnerships that support the strategy and reflect the scale of impact envisioned.

Step 3: Measure performance

Measure the impact in terms of economic, social and environmental intended outcomes:

- Measure the impact of the development strategy in terms of its economic, social, and environmental outcomes in relation to the vision developed under step 2.

In this way, the impact assessment then contributes to understanding the performance of the chain in a continuous development cycle.

Conclusions

This module has described the sustainable and inclusive food value chain approach. This approach can support the transformation of the agricultural sector to become climate-smart so that current food security and climate change challenges can be successfully addressed.

The sustainable and inclusive food value chain approach focuses on three sustainability dimensions – economic, social and environmental— which are directly linked to three pillars of CSA. This approach can contribute to CSA by helping to identify interventions at every stage of the food value chain to enhance the performance of the chain.

Through understanding, improving and measuring performance, waste streams that occur along the food value chain can be analysed. This includes not only reducing food losses and waste, but also looking at reusing and recycling food stuffs that still have an economic value as they can serve other uses, such as reusing waste for human consumption or animal feed, as compost or to generate energy. This not only provides economic benefits, but also social (i.e. employment generation) and environmental benefits.

This module has provided an overview of different practices and technologies that chain actors can adopt along the chain in order to improve their performance across the triple bottom line. At times, there can be short-term trade-offs, for example, a green technology may not be profitable in the short run, but it may provide social and environmental benefits. If this is the case, public sector support and investment as well as public-private partnerships may be necessary to overcome these trade-offs. Other areas where public intervention may be needed include awareness raising, agricultural research and development as well as capacity building support in order to help smallholders adopt more sustainable practices that are climate smart and help consumers to reduce, reuse or recycle their waste.

Furthermore, this module has outlined a step-by-step approach of how chain actors can analyze their interventions along the sustainable and inclusive food value chain with the aim to improve their performance in all three sustainability dimensions—economic, social and environmental.

Notes

This module was written by Tamara van't Wout (FAO) and Reuben Sessa (FAO) with contributions from Martin Hilmi (FAO), David Neven (FAO), Robert van Otterdijk (FAO), Camelia Bucatariu (FAO), Danilo Meja (FAO), Jogeir Toppe (FAO), Lucio Olivero (FAO), Sandra Corsi (FAO) and Alashiya Gordes (FAO).

Acronyms

ASI	improved rice thresher cleaner
CSA	climate-smart agriculture
DEFRA	The Department of Environment, Food and Rural Affairs
GHG	greenhouse gas
IDF	International Dairy Federation
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IRRI	International Rice Research Institute
ISRA	Senegalese Institute of Agricultural Research
LCA	Life Cycle Analysis
ODI	Overseas Development Institute
OIA	Office of International Affairs
SAED	Senegal River Valley National Development Agency
SIFVCD	Sustainable and Inclusive Food Value Chain Development
UNIDO	United Nations Industrial Development Organization

References

Africa Rice Centre. 2005. *Annual report 2004-2005.* (available at http://www.warda.cgiar.org/publications/AR2004-05/ASI.pdf)

Andersson, K., Ohlsson, T. &Olsson, P. 1998. **Screening life cycle assessment (LCA) of tomato ketchup: a case study.** Journal of Cleaner Production, 6: 277–288.

Azouma, O.Y., Porosi, M. & Yamaguchi, K. 2009. *Design of throw-in type rice thresher for small scale farmers.* Indian Journal of Science and Technology, 2(9): 10–14.

Bala, B.K. & Janjai, S. 2009. *Solar drying of fruits, vegetables, spices, medicinal plants and fish: developments and potentials.* International Solar Food Processing Conference.

Barrett, C. B. & Mutambatsere, E. 2005. *Agricultural markets in developing countries.* (available at http://www.clas.ufl.edu/users/reneemarie/Removable%20Disk/LIT/Barrett/Barrett%202005%20Agricultural%20markets%20in%20developing%20countries.pdf)

Bentley, S. & Barker, R. 2005. *Fighting global warming at the farmer's market: the role of local food systems in reducing greenhouse gas emissions.* (available at http://www.foodshare.net/resource/files/foodmilesreport.pdf)

Boer, J. de, Hoogland, C.T. & Boersema, J. J. 2007. *Towards more sustainable food choices: value priorities and motivational orientations.* Food Quality and Preference, 18: 985–996.

Carlsson-Kanyama, A. 1998. *Food consumption patterns and their influence on climate change.* Ambio, 27(7): 528–34.

Cathcart, E. P. & Murray, A. M. 1939. *A note on the percentage loss of calories as waste on ordinary mixed diets.* Journal of Hygiene, 39: 45–50.

Cheke, R.A. & Ward, A.R. 1998. *A model for evaluating interventions designed to reduce post-harvest fish losses.* Fisheries Research, 35: 219–227. (available at http://www.sciencedirect.com/science/article/pii/S0165783698000745)

Clemens, B. 2006. *Economic incentives and small firms: does it pay to be green?* Journal of Business Research, 59: 492–500.

Coulomb, D. 2008. *Refrigeration and the cold chain serving the global food industry and creating a better future: two key IIR challenges for improving health and environment.* Trends in Food Science & Technology, 19: 413–417.

Daly, H. 1992. *Steady state economics.* London, Earthscan Publications.

Davies, S. 2011. *Making sustainable choices easier.* Nutrition Bulletin, 36: 454–459. British Nutrition Foundation.

Davies, R.M. & *Davies, O.A.* 2009. Traditional and improved fish processing technologies in Bayelsa State, Nigeria. European Journal of Scientific Research, 26(4): 539–548.

Dellacasa, A. 1987. *Refrigerated transport by sea.* International Journal of Refrigeration, 10: 349–352.

Diagne, M., Diagne, A. & Demont, M. 2009. *Adoption and impact of an award winning post-harvest technology: the ASI rice thresher in Senegal River Valley (SRV).* (available at http://ageconsearch.umn.edu/bitstream/50323/2/Contributed%20Paper.pdf and http://www.africarice.org/workshop/grisp-mech/PPT/Diagne,%20africarice.pdf)

Eden, S., Bear, C. & Walker, G. 2008. *Understanding and (dis)trusting food assurance schemes: consumer confidence and the knowledge fix.* Journal of Rural Studies, 24(1): 1–14.

European Commission. 2010. *Special Eurobarometer n°342 on consumer empowerment.* (available at http://ec.europa.eu/consumers/consumer_empowerment/docs/report_eurobarometer_342_en.pdf)

European Commission. 2011. *Roadmap to a resource efficient Europe.* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. (available at http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf)

FAO. 1989. *Prevention of post-harvest food losses: fruits, vegetables and root crops.* Training manual. (available at http://www.fao.org/docrep/T0073E/T0073E05.htm#10.4%20Storage%20structures)

FAO. 1998. *Fermented fruits and vegetables: a global perspective, by M.* Battcock & S. Azam-Ali. FAO Agricultural Services Bulletin No. 134. Rome.

FAO. 2000. *Post paper: the village milk system.* (available at http://www.fao.org/ag/againfo/themes/documents/LPS/DAIRY/ecs/Papers/pp_vms.htm and http://www.fao.org/AG/AGAINFO/themes/documents/LPS/DAIRY/MPR/Milkpro/milkpro.htm and http://www.milk-pro.com/milkpro.htm)

FAO. 2002. *Good agricultural practices.* (available at http://www.fao.org/ag/magazine/GAP-V2-June02.pdf)

FAO. 2005. *Types, levels and causes of post-harvest milk and dairy losses in Sub-Saharan Africa and the Near East.*

FAO. 2007a. *Waste management opportunities for rural communities: composting as an effective waste management strategy for farm households and others.* (available at http://www.fao.org/fileadmin/user_upload/ags/publications/K1455E.pdf)

FAO. 2009. *Rural transport and traction enterprises for improved livelihoods.*

FAO. 2010a. *Fisheries and aquaculture topics: food security and fisheries, by P.* Manning. Topics Fact Sheets. Rome.

FAO. 2010b. *Post-harvest losses in small-scale fisheries: case studies in five Sub-Saharan African countries.* (available at http://www.fao.org/docrep/013/i1798e/i1798e.pdf)

FAO. 2010c. *Fish waste.* (available at http://www.fao.org/bioenergy/aquaticbiofuels/knowledge/fish-waste/en/)

FAO. 2011a. *Appropriate food packaging solutions for developing countries.* (available at http://www.fao.org/docrep/015/mb061e/mb061e00.pdf)

FAO. 2011b. *Global food losses and food waste: extent, causes and prevention, by J.* Gustavsson, C. Cederberg, U. Sonesson, R. van Otterdijk & A. Meybeck. Rome.

FAO. 2011c. *International guidelines on bycatch management and reduction of discards.*

FAO. 2011d. *World livestock 2011: livestock in food security.* (available at http://www.fao.org/docrep/014/i2373e/i2373e.pdf)

FAO. 2012a. *Smallholders in global bioenergy value chains and certification.* (available at http://www.fao.org/docrep/015/i2597e/i2597e00.pdf)

FAO. 2013. *Principles of sustainable food value chain development with a meta guide to value development resource materials.* Draft.

FAO & International Dairy Federation (IDF). 2011. *Guide to good dairy farming practice.* (available at http://www.fao.org/docrep/014/ba0027e/ba0027e00.pdf)

Fuchs, D.A. & Lorek, S. 2000. *An inquiry into the impact of globalization on the potential for sustainable consumption in households.* Paper presented at Workshop on Sustainable Household Consumption. Enschede, the Netherlands.

Gac, A. 2002. *Refrigerated transport: what's new?* International Journal of Refrigeration, 25: 501–503.

Giraud, 2003. *Consumer perception and marketing of origin and organic labelled food products in Europe.* 83rd EAAE (European Association of Agricultural Economics) Seminar. Chania, Crete.

Grolleaud, M. 2002. *Post-harvest losses: discovering the full story.* Overview of the phenomenon of losses during the post-harvest system. Rome, FAO.

Campbell, D. 2012. *'Fat tax' on healthy food must raise prices by 20% to have effect, says study.* The Guardian. (available at http://www.guardian.co.uk/society/2012/may/16/fat-tax-unhealthy-food-effect)

Hodges, R.J., Buzby, J.C. & Bennett, B. 2010. *Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use.* The Journal of Agricultural Science, 149: 37–45.

International Fund for Agricultural Development (IFAD). 2001. *Markets for the rural poor.* Chapter 5. Rural poverty report 2001: the challenge of ending rural poverty. (available at http://www.ifad.org/poverty/chapter5.pdf)

International Food Policy Research Institute (IFPRI). 2011. *Value chains for nutrition.* 2020 Conference Paper No. 4. (available at http://www.ifpri.org/sites/default/files/publications/2020anhconfpaper04.pdf)

International Institute of Refrigeration. 2009. *The role of refrigeration in worldwide nutrition.* 5th Informatory Note on Refrigeration and Food. (available at http://www.iifiir.org/userfiles/file/publications/notes/NoteFood_05_EN.pdf)

James, S. J., James, C. & Evans, J.A. 2006. *Modelling of food transportation systems – a review*. International Journal of Refrigeration, 29(6): 947–957. (available at: http://www.sciencedirect.com/science/article/pii/S0140700706000995)

James, S. J. & James, C. 2010. *The food cold-chain and climate change.* Food Research International, 43(7): 1944–1956. (available at http://www.sciencedirect.com/science/article/pii/S0963996910000566)

Kader, A.A. 2005. *Increasing food availability by reducing postharvest losses of fresh produce, F.* Mencarelli & P. Tonutti, eds. Proceedings of the 5th International Postharvest Symposium. Acta Horticulturae & ISHS. 682 pp.

Kitinoja, L., Saran, S., Roy, S.K. & Kader, A. A. 2011. *Postharvest technology for developing countries: challenges and opportunities in research, outreach and advocacy.* Journal of the Science of Food and Agriculture, 91: 597–603.

Kumolu-Johnson, C.A. & Ndimele, P.E. 2011. *A review on post-harvest losses in artisanal fisheries of some African countries.* Journal of Fisheries and Aquatic Science, 6(4): 365–378.

Lorek, S. 2011. *Taxes to promote sustainable food.*

Lorek, S. & Fuchs, D. 2011. *Strong sustainable consumption governance – precondition for a degrowth path?* Journal of Cleaner Production: 1–8.

Minten, B. & Kyle, S. 1999. *The effect of distance and road quality on food collection, marketing margins, and traders' wages: evidence from the former Zaire.* Journal of Development Economics, 60(2): 467–495.

Morgan, E. 2009. *Fruit and vegetable consumption and waste in Australia.* Victoria, Australia, State Government of Victoria, Victorian Health Promotion Foundation.

Overseas Development Institute (ODI). 2005. *Walking tightropes: supporting farmer organizations for market access.* (available at http://www.odi.org.uk/resources/docs/1858.pdf)

Office of International Affairs (OIA). 1988. *Fisheries technologies for developing countries.* (available at http://www.nap.edu/openbook.php?record_id=1024&page=155)

Osner, R. 1982. *Food Wastage.* Nutrition and Food Science, 82(4): 13–16.

Parfitt, J., Barthel, M. & Macnaughton, S. 2010. *Food waste within food supply chains: quantification and potential for change to 2050.* Philosophical Transactions of the Royal Society of London - Series B: Biological Sciences, 365: 3065–3081.

Pimentel, D. & Pimentel, M. 1996. *Food, energy, and society.* Colorado University Press, Niwot. (available at http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3101478)

Prusky, D. 2011. *Reduction of the incidence of postharvest quality losses, and future prospects.* Food Security, 3(4): 463–474.

Sengar, S. H., Khandetod, Y. P & Mohod, A. G. 2009. *Low cost solar dryer for fish.* (available at http://www.ajol.info/index.php/ajest/article/viewFile/46076/32483)

Seyfang, G. 2006. *Ecological citizenship and sustainable consumption: examining local organic food networks.* Journal of Rural Studies, 22: 383–395.

Smith, N. & *Ali, M.* 2002. Waste from food: review of developing and transitional countries. (available at http://38.111.46.21/App_Uploads/NE2010010688/Files/Waste_from_Food.pdf)

Spaargaren, G. & *Oosterveer, P.* 2010. Citizen-consumers as agents of change in globalizing modernity: the case of sustainable consumption. Sustainability, 2: 1887–1908.

Stera, A.C. 1999. *Long distance refrigerated transport into the third millennium.* Proceedings of the 20th International congress of Refrigeration No. 736. Sydney, Australia, IIF/IIR.

Stuart, T. 2009. *Waste: uncovering the global food scandal.*

Tassou, S.A., De-Lille, *G.,* Ge, Y.T. 2009. Food transport refrigeration – approaches to reduce energy consumption and environmental impacts of road transport. Applied Thermal Engineering, 29(8-9): 1467–1477. (available at http://www.sciencedirect.com/science/article/pii/S135943110800286X)

The Department of Environment, Food and Rural Affairs (DEFRA). 2005. *The validity of food miles as an indicator of sustainable development.* Final report produced for DEFRA. Issue 7. (available at http://archive.defra.gov.uk/evidence/economics/foodfarm/reports/documents/foodmile.pdf)

Thőnissen, R. 2009. *Food waste: the Netherlands.* Presentation to the EU Presidency Climate Smart Food Conference. Lund, Sweden.

Tukker, A., Emmert, *S.,* Charter, M., Vezzoli, C., Sto, E., Andersen, M.M, Geerken, T., Tischner, U. & Lahlou, S. 2007. Fostering change to sustainable consumption and production: an evidence based view.

United Nations Industrial Development Organization (UNIDO). 2011. *A practitioner's guide: pro-poor value chain development.* 25 guiding questions for designing and implementing agroindustry projects. (available at http://www.unido.org/fileadmin/user_media/Services/Agro-Industries/Pro-poor_value_chain_development_2011.pdf)

Which? 2010. *Making sustainable choices easier.* London.

Witt, U. 2011. *The dynamics of consumer behavior and the transition to sustainable consumption patterns.* Environmental Innovations and Societal Transitions, 1(1): 109–114.

Wognum, P.M. 2011. *Systems for sustainability and transparency of food supply chains – current status and challenges.*

Wolsink, M. 2010. *Contested environmental policy infrastructure: socio-political acceptance of renewable energy, water and waste facilities.* Environmental Impact Assessment Review, 30(5): 302–211. (available at http://www.sciencedirect.com/science/article/pii/S0195925510000156)

World Bank. 2011. *Missing food: the case of post-harvest grain losses in Sub-Saharan Africa.* (available at http://siteresources.worldbank.org/INTARD/Resources/MissingFoods10_web.pdf)

WRAP. 2009. *Facts and figures.* (available at http://www.wrap.org.uk/content/facts-and-figures)

Additional Resources

FAO. 2003. *Strategies for sustainable animal agriculture in developing countries.* (available at http://www.fao.org/docrep/004/T0582E/T0582E05.htm)

FAO. 2007b. *Guidelines for rapid appraisals of agrifood chain performance in developing countries.*

FAO. 2011e. *Energy-smart food for people and climate.* Issue paper. (available at http://www.fao.org/docrep/014/i2454e/i2454e00.pdf)

FAO. 2012b. *Global initiative on food loss and waste reduction.* (available at http://www.fao.org/docrep/015/i2776e/i2776e00.pdf)

FAO. 2010d. *Status of water use efficiency of main crops.* SOLAW Background Thematic Report – TR07. (available at http://www.fao.org/fileadmin/templates/solaw/files/thematic_reports/TR_07_web.pdf)

Foresight. 2011. *The future of food and farming: challenges and choices for global sustainability.* (available at http://www.bis.gov.uk/assets/foresight/docs/food-and-farming/11-546-future-of-food-and-farming-report.pdf)

Gerard, J. & Friedman, D. R. 2002. *Ecolabels and the greening of the food market.* Conference proceedings. (available at http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELDEV3101478)

International Labour Organization. 2007. *An operational guide to local value chain development.* (available at http://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/---ifp_seed/documents/instructionalmaterial/wcms_101319.pdf)

Kader, A.A. & Rolle, R.S. 2004. *The role of post-harvest management in assuring the quality and safety of horticultural produce.* (available at ftp://ftp.fao.org/docrep/fao/007/y5431e/y5431e00.pdf)

Kaplinsky, R. & Morris, M. 2000. *A handbook for value chain research*. London, IDRC.

Practical action. 2004. *Packaging materials for foods.* (available at http://practicalaction.org/docs/technical_information_service/packaging_materials.pdf)

The Center for Industrial Research and Service. 2012. *Sustainable supply chains: a guide for small-to-medium-sized manufacturers.* (available at http://www.ciras.iastate.edu/publications/CIRAS_Supply_Chain_Sustainability-2012.02.29.pdf)

UNIDO. 2009. *Agro-value chain analysis and development.* The UNIDO Approach. A staff working paper. (available at http://www.unido.org/fileadmin/user_media/Publications/Pub_free/Agro_value_chain_analysis_and_development.pdf)

MODULE 12

LOCAL INSTITUTIONS

Overview

Improving smallholder agricultural systems is central to achieving climate-smart agriculture (CSA). This module focuses on local-level institutions and their role in facilitating the adoption of climate-smart agricultural strategies. The module demonstrates the importance of local institutions for CSA projects (Section 12.1); outlines priorities, needs, similarities and differences between key institutions (Section 12.2); and discusses considerations to bear in mind when building inter-institutional synergies for CSA initiatives (Section 12.3). Finally, it offers basic, practical guidelines to help practitioners and policy-makers build institutional support for CSA (Section 12.4).

Key messages

- To enable smallholders to make the transition to CSA, strong institutional support is required to improve the dissemination of information, provide financial support and access to markets, and coordinate the work of a large number of farmers over a wide area.
- The needs, priorities and drivers of individual institutions must be understood and managed suitably to successfully establish the needed CSA collaborations.
- Institutional synergies and networks for knowledge exchange are key to establishing, maintaining and scaling up CSA initiatives.

Contents

List of Tables

List of Boxes

12.1 Introduction

Definition

Many people equate the term 'institutions' with 'organizations'. In reality, institutions signify something broader than organizations. They essentially define the 'rules of the game'; the way things are and can be done, as defined by accepted norms, roles and values. Institutions include both formal organizations and contracts as well as informal social and cultural norms and conventions that operate within and between organizations (North, 1990; Ostrom, 2005). Section 12.2 describes different types of institutions and provides some examples.

Why is paying attention to institutions so crucial to CSA?

CSA requires changes in farming households' behaviour and strategies, as well as changes in the usual timing of agricultural practices. Without appropriate institutional structures in place, the innovations required to implement CSA may seem overwhelming to smallholder farmers. Successfully managing change demands accurate and up-to-date information, a degree of financial capacity and, if the changes are to be far-reaching, the ability to cooperate with others on a broad scale (see Box 12.1 for details for a successful CSA initiative). Some of the changes CSA requires include:

Adapting management approaches

As populations expand, competition for natural resources will increase. In addition, environmental and climatic factors threaten to degrade these resources. For this reason, CSA centres on finding new methods for managing soil, water and land. Water tables are dropping considerably in many places (e.g. in parts of India). Water harvesting and water storage techniques need to be able to deal with the likelihood of increasing rainfall variability. Land degradation and declining soil fertility are widespread problems. The uptake of new strategies and approaches are required to improve soil quality (structure, fertility, water regulation) and restore degraded lands.

Climate-smart crop varieties

As climate change alters rainfall patterns, one CSA approach for adapting to new conditions is to switch crops (e.g. planting sorghum instead of maize if rainfall decreases or vice versa if it increases). The move to new crops may involve planting varieties that have a shorter growing cycle, can better tolerate saline soils and extreme weather events (e.g. droughts and floods), and have greater resistance to pest and diseases.

Changing farming schedules

Climate change is forcing farmers to change the schedule of their customary farming activities. In East Africa, for example, many farmers have already begun to plant earlier than they have traditionally done because of shifting rainfall patterns (Kristjanson *et al.,* 2012)

Mitigating while adapting to climate change

As the need to mitigate carbon emissions grows, planting trees on farms and improving the management of livestock and rangelands will also be crucial CSA activities (FAO, 2010). Farmers usually adopt these actions primarily because they help enhance and diversify incomes, not because they lower emissions. Climate change mitigation is an added benefit.

Box 12.1
The Sustainable Agriculture in a Changing Climate (SACC) project

The Sustainable Agriculture in a Changing Climate project (SACC), a partnership between CARE, the World Agroforestry Centre (ICRAF) and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) with funding from the Rockefeller Foundation, began in September 2010. The project was originally intended to deliver payments to smallholder farmers from carbon markets for carbon stored through the adoption of agroforestry practices in the Nyando River Basin in Western Kenya, a mixed crop-livestock farming area with high levels of poverty and significant environmental degradation.

Alongside planting the trees that would generate carbon payments in the long run, the project also introduced interventions designed to provide immediate short-term income and food benefits, as a way of overcoming resource constraints and maximizing the participation of resource-poor women. These shorter-term interventions included: the introduction of early-maturing, drought-resistant and higher-value crops; an emphasis on sustainable agricultural practices; and the formation of linkages with a complementary project on Village Savings and Loans Associations (VSLAs, community-based informal financial groups). Based on lessons learned in the first phase, SACC is transitioning into a 'climate-smart smallholder agriculture' approach, with an emphasis on research and actions aimed at improved agricultural productivity and farm-level adaptation. The income and livelihood benefits from enhanced knowledge and access to tree seedlings, improved seeds and land management techniques are proving to provide the key incentives for entering the scheme, rather than carbon sales (Thorlakson and Neufeldt, 2012).

The project relies on institutions which support people in changing their behaviour. These include small savings and loans groups that help change peoples' attitudes about money and encourage them to start saving, often for the first time ever. Village management committees that mobilize farmers, coordinate resource persons, monitor activities and manage benefit sharing through innovative new means (such as payments via cell phone) are also important. New institutions providing access to markets and inputs are emerging. A professional independent company is being formed to manage the programme in the long-run. The success of the new CSA project is highly dependent on an effective, efficient and equitable governance structure, which will be essential for delivering the product (carbon) to the client (offset markets).

Source: CCAFS and CGIAR, 2012a

How can institutions support CSA?

Institutions can support smallholder farmers in three vital areas:

1. Producing and sharing technical knowledge

For relatively resource-poor smallholder farmers, putting CSA into practice requires knowledge and support. Farmers, herders and fishing communities need easier and more affordable access to the information that underpins innovative CSA practices. Institutions that produce and share information and help people translate this information into knowledge and action are essential. These institutions include: farmer field schools (or similar approaches that train and enable farmers to adopt new techniques); farm radio shows that provide easily accessible, useful and useable (i.e. needs-driven) agricultural and weather-related information to rural households; local agricultural demonstration plots and events; and farmer-to-farmer exchanges.

2. Providing financial services, credit and access to markets

The benefits gained by adopting sustainable land management techniques usually take time to materialize. In the meantime, the farmers must bear the costs in terms of labour, land and cash (McCarthy *et al.*, 2011). As a result, poor farmers lacking access to credit and markets are unable to adopt these techniques. This is why strengthening institutions to support agricultural markets, financing mechanisms and insurance schemes are critical for the CSA's success. These institutions include organizations and institutional arrangements providing credit, insurance, social safety nets, and payments or rewards for environmental services. Module 14 addresses in detail the financial instruments and investments that enable CSA.

3. Supporting the coordination of collaborative action

Collective action is critical for managing communal forests and pastures and lowering transactions costs.

Many CSA activities are only feasible and affordable if people work together (e.g. improved water or rangeland management). Institutional arrangements that make groups function efficiently and effectively are essential. On a larger scale, institutional arrangements are also needed to facilitate coordination across organizations and sectors (e.g. through networks and knowledge-sharing platforms).

To illustrate these areas, Box 12.2 outlines a range of actions that local organizations and institutions can pursue to support CSA.

Box 12.2
Sample CSA actions for local institutions

When establishing CSA, local organizations and institutions can play positive roles in:

1. Producing and sharing technical knowledge

- Identify the main vulnerabilities in local agricultural and food systems, and the most vulnerable households.
- Consider and select the most locally appropriate innovations (both institutional and technical) from the range of potential climate-smart practices.
- Relay rapidly throughout the community new information on weather, climate and options for agriculture.
- Improve the quality and relevance of research on CSA through local participation.

2. Providing financial services (including credit) and access to markets

- Channel micro-finance effectively, to kick-start new practices, technologies and behaviours among farmers.
- Provide credit, insurance, social safety nets, and payments or rewards for environmental services.
- Stimulate local markets, build links with national and international markets, and improve market literacy among smallholder farmers.

3. Supporting the coordination of collaborative action

- Encourage new cultural norms for practice in agriculture, food distribution and household food management.
- Shift the focus of agricultural extension from delivering technology to working in partnership with local farmers to develop solutions.
- Underpin the sustainability of CSA through locally workable mechanisms for benefit sharing, dispute settlements and other governance issues.
- Protect local interests from potentially discriminatory external pressures associated with climate change policy, such as 'land grabbing'.
- Include particularly vulnerable social groups, such as women, youth or immigrants, in the benefits of climate-smart agriculture;
- Ensure that disaster relief in response to climate shocks reaches the right people quickly and effectively.
- Co-deliver wider services in support of CSA (e.g. health and sanitation services, education and knowledge exchange).
- Provide mechanisms for governments and other agencies to be more accountable to local people in their climate policies and investments.

Table 12.1
Examples of institutions and activities that support CSA

Institutions and activities for producing and sharing knowledge, strengthening capacities and enhancing communication	Institutions and activities for supporting markets, financing and insurance needs	Institutions and activities for improving coordination and collective action
Agricultural business hubs	Weather index-based insurance (crop and/or livestock) and outgrower schemes	Water user groups; forest management groups; etc.
Capacity strengthening for demand-driven and gender-sensitive agricultural advisory services (including climate services)	Investments that support agricultural marketing and the food system, including roads and market infrastructure	Brokering links between producer organizations, research services and higher education
Use of information and communication technologies (ICTs), such as cell phones and the internet to improve agricultural information access (e.g. market prices, transportation options, weather information)	Productive social safety nets (e.g. cash transfers, food distribution, seed and tool distribution, conditional cash transfers, food for work)	Strengthening capacity of agricultural research systems for linking with other actors (e.g. through stakeholder platforms, alliances and consortia, technology transfer and commercialization)
Investment in agricultural education and training institutions and curricula reform, including at primary and secondary levels	Payments for environmental services, smallholder agricultural carbon projects	Community-based actions to restore degraded lands, improve management of water, communal lands
Innovative governance arrangements and new regulations regarding quality and safety of food, intellectual property and biosafety	Investments in market value chains (e.g. carbon labels on food from smallholders)	Local seed and genetic diversity fairs, farmer-based labelling schemes
	Strengthening of informal agricultural markets (e.g. certification and training of traders)	Strengthening capacity of farmers' organizations to collaborate

12.2 Key institutions for CSA initiatives

Studies show that agricultural research is more likely to bring about changes in agricultural practices, technologies or policies when dialogue and cooperation is fostered among all the stakeholders who possess, produce, or use different kinds of knowledge. The most effective initiatives allow researchers, community members, private sector actors and policy-makers to jointly define the problems they aim to solve (Kristjanson *et al.*, 2009).

Services

As climate changes so does the role of agricultural advisory and extension services. Demand for new climate services is increasing. Farmers need wide-ranging advice on how to adapt their farming practices and their entire livelihoods, to take advantage of viable, profitable options with manageable levels of risk. Two types of advice are needed: firstly, information about available options (e.g. technology and market) to help adapt farming and livelihood systems; and secondly, information about the climate itself, in the form of weather forecasts, seasonal forecasts and longer-term climate trends (see Box 12.4).

Different players in the agricultural sector need completely different types of climate advice. Improved extension services should not provide 'one-size-fits-all' solutions or static advice (e.g. generic seed and fertilizer packages). They should mediate between different possibilities and market actors. Preference should be given to early warning and early action initiatives that distribute appropriate seeds based on seasonal predictions instead of to initiatives that try to control the damage caused by droughts or flooding. Institutions providing extension services should also consider building their own knowledge of weather index-based crop and livestock insurance schemes.

Today, the provision of agricultural research and extension services is spread across diverse public sector, civil society and private sector institutions. The similarities and differences in such a 'menu' of institutional options (Birner *et al.,* 2009) are explored below.

Box 12.3
Sharing improved seasonal weather forecasting with farmers in West Africa

Seasonal climate forecasts can considerably improve agricultural management and livelihoods for smallholder farmers (Hansen *et al.,* 2011). Nevertheless, constraints related to the legitimacy, salience, availability, and understanding of these forecasts, as well as gaps in data and the limited capacity of farmers to respond appropriately, have so far limited the widespread use of seasonal predictions in the Sahel region. Moreover, better weather forecasts alone will not spur widespread uptake of climate-smart agricultural practices. Strengthened agricultural advisory and input supply services are required, as are improved marketing strategies, enhanced safety net policies to ensure food security, and similar provisions.

There is however potential for making improved weather information accessible to African farmers. For instance, regional climate outlook forums and national meteorological services have been working together to provide useful weather forecast information to rural farmers in both Mali and Senegal. Together with researchers and other stakeholders, farmers are being trained in the use of probabilistic seasonal forecasts. The changes they make as a result of this knowledge is being evaluated, as are the impacts these changes make to the farmers' livelihoods.

Source: CCAFS and CGIAR, 2013a

Public sector institutions

Crucial governmental actions that support CSA include:

- the amendment and enforcement of related agricultural policies;
- the distribution of incentivizing agricultural subsidies;
- the provision of pertinent research and extension services;
- the improvement of relevant infrastructure (e.g. building roads); and
- the collection of national census data useful to CSA initiatives.
  (Reid *et al.,* 2010; Swanson and Rajalahti, 2010)

The institutional structures through which such assistance is delivered stretch from national ministries (primarily Ministries of Agriculture, although ministries with related purviews, such as Fisheries or Land, also play a role) to regional, subregional and local offices. Top-down in structure, the public sector is less likely to make use of bottom-up tools to formulate the needs of specific farmer groups. Civil society institutions are generally well-placed to foster bottom-up engagement.

Public spending on agricultural extension services is justified when the effects of the extension services bring benefits to more than the recipients of the trainings. In the case of CSA, such wide-reaching benefits are easily confirmed. Aside from contributing to the universal 'public good' of environmental sustainability, CSA increases food security because it improves adaptive capacity and resilience. Improved food security leads to poverty reduction and improved health, which in turn fuels economic development, which can ultimately bring about greater political stability (Anderson and Feder, 2003).

However, the peak of public investment in agricultural extension has now passed. The twentieth century saw notable improvements in food security thanks to a heavy government emphasis on the transfer of new agricultural technologies to farmers. Following this success, public spending has decreased substantially. While there has been a corresponding rise of private investment, the long-term effects of decreased public involvement are significant. The prevalent extension systems tend to favour shorter-term, more localized, project-based approaches.

Given that CSA demands context-specific solutions, this tendency towards localized projects is appropriate. However, there is a need to ensure wider coherence and long-term continuity across projects. National Adaptation Programmes of Actions (NAPAs), National Adaptation Plans (NAPs) and Nationally Appropriate Mitigation Actions (NAMAs), are intended to provide national frameworks to guide government actions on adaptation and mitigation under a future international climate agreement. These voluntary proposals to the United Nations Framework Convention on Climate Change (UNFCCC) are still under development, so their precise roles are still emerging. The fact that 60 percent of the countries who have submitted NAMAs mention agriculture as a way to reduce GHG emissions (FAO, 2011) suggests these proposals are pertinent mechanisms for institutionalizing governmental commitment to CSA projects at the policy level (see Module 13 on policies and programs). They should continue to be supported.

Civil society

FAO defines 'civil society' as 'the sphere in which citizens and social movements organize themselves around objectives, constituencies and thematic interests' (FAO, 1999). 'Civil society organizations' include non-governmental organizations (NGOs, 'not-for-profit actors who are not governmental or intergovernmental' (*ibid.*). They also include trade unions, professional associations, research and educational faculties, private foundations, religious organizations, issue groups, the media and similar organizations reflecting civic interests, values and concerns. Such institutions, acting independently of the state:

- voice their members' interests and demands;
- defend their members' rights; and
- take action to meet their members' wishes and needs.
  (Uphoff and Krishna, 2004)

Civil society has considerable potential to exercise influence by using its collective political voice to express local climate concerns to higher authorities and demand the provision of specific measures or services (see Box 12.4). To best realize this potential, it is crucial to understand the interrelationships between civil society organizations, the government and the private sector. Though nominally defined as separate from state control, the effective autonomy of civil society institutions varies depending on a number of factors; (e.g. educational institutions are often wholly or partially funded by the state, blurring the distinction between the public sector and civil society). Similarly, the freedom of expression of the media or religious groups may be state-controlled. A thorough 'stock-taking' or 'mapping' of the institutions and their interdependencies in a given situation is advisable when identifying entry points for CSA initiatives, opportunities for collaboration and potential tensions (Section 12.4 provides some guidelines on how such 'mapping' can be approached).

Box 12.4
Civil society policy advocacy: Fisherfolk get organized in the Caribbean

Climate change poses a considerable threat to fish-based diets and the livelihoods of fisherfolk in the Caribbean. It is expected to decrease the types and prevalence of marine species, and tropical cyclones of increasing intensity are likely to damage fishing boats and infrastructure, resulting in fewer productive days at sea. However, fisherfolk in the Caribbean have a long history of raising their voices collectively in times of crisis. Building on experiences at national level, the Caribbean Network of Fisherfolk Organisations (CNFO) was formed in 2004 to empower fisherfolk in the region to jointly advocate for government action on climate change.

Beyond aiming to secure national and regional fisheries policies which address the current and anticipated effects of climate change, CNFO seeks to stimulate adaptation planning processes across marine-related sectors. Besides facilitating capacity building and peer-to-peer support among its constituency, the network's successes to date include having gained observer status on the Caribbean Regional Fisheries Mechanism, undertaking activities in partnership with the fisheries management agencies in many of its member countries and its ongoing contribution to the drafting of a regional Common Fisheries Policy for the region. These accomplishments indicate a promising shift towards the institutionalization of more equitable, inclusive and stakeholder-driven working processes in the region.

Source: Lay *et al.*, 2013

To provide some background, short summaries of the possible services key civil society institutions can offer are provided below.

Non-governmental organizations

NGOs are typically strong in providing social services, especially when supporting poor communities (Swanson and Rajalahti, 2010). For example, building social capital by organizing farmer groups to articulate their own needs and formulate solutions collaboratively, brings immediate positive effects at the local level. NGOs can also be valuable partners for implementing projects, conducting research and carrying out outreach activities.

Universities and research institutions

Universities and research institutions are good providers of pre-training and in-service training for extension workers. As faculty members often conduct agricultural research of their own, they are obvious focal points for field staff in need of technical and management backstopping (Swanson and Rajalahti, 2010).

Private foundations

Private foundations rarely aim to organize popular movements. However the funding they offer and the expertise they provide in specific activities are usually not influenced by the public sector and for this reason they often have scope for greater innovation (Uphoff and Krishna, 2004).

The media

Mass media can reach large audiences with messages about CSA. Broadcast and electronic media include radio, television, film and the internet; print media includes newspapers, journals, publications; outdoor media includes posters, billboards and other materials placed in public view. An important channel for disseminating informative and educational contents, media can both reflect public opinion and shape it. In recent years, more and more people, even in rural areas have gained access to media hardware such as radios, televisions, computers and smart phones. Innovative technologies, such as solar-powered electronic devices, are also becoming increasingly important in mobilizing the media for development purposes.

Religious institutions and communities

The term 'institutions' does not merely refer to types of organizations; it also encompasses cultural and social norms and conventions. An awareness of public opinions and values is therefore important when formulating a CSA strategy. While religious institutions or issue groups are unlikely to provide CSA-related advisory services, they can offer indispensable insights into prevailing beliefs and values . They can be mobilized as powerful tools for advocacy and endorsement.

Box 12.5
The African Farm Radio Research Initiative

Farm Radio International is a Canadian registered charity that combines radio with other ICTs to serve smallholder farmers across Africa. It transmits information on low-cost methods to improve food security to 360 radio stations across 39 countries. A recent study assessed the knowledge, attitudes and practices of farmers living in 90 communities across 5 countries (Ghana, Malawi, Mali, Uganda and the United Republic of Tanzania). The study looked at specific agricultural improvements that had been featured on participatory radio campaigns (PRCs) in their area. It found that when agricultural producers were actively involved in these radio campaigns, more farmers tested and adopted new practices than when more traditional top-down, externally driven radio campaigns were carried out. One in five farmers who listened to the PRCs adopted the agricultural innovation – an adoption rate five times higher than for farmers not exposed to the radio programme. The cost of a PRC amounts to pennies per farmer reached, making it a cost-effective information dissemination strategy.

Source: Farm Radio International, 2011

Private sector institutions

As markets become increasingly important in developing economies, private sector actors also become significant providers of research and development, education and extension services.

When seeking private sector support for CSA initiatives, it is important to bear in mind that the private sector's main priorities are profit and public perception. CSA works to establish a 'triple win' scenario in which innovative practices produce higher yields, build resilience to climate change (reducing long-term risks) and lower carbon emissions all along the supply chain. By contributing to CSA, private businesses can enhance their brand recognition among key suppliers and consumers. Key private sector actors and the possible support they might provide to CSA initiatives include:

Individual farmers

Household farms and smallholder farmers are of course private sector actors themselves. As it takes too much time and too many resources to reach each individual farmer, approaching producer cooperatives is a good strategy to build a broad base of support for climate-smart practices in the farming community. The effectiveness of word-of-mouth communication among farmers should not be underestimated. Enlisting and maintaining the support of individual farmer 'focal points' or 'local champions' is advisable.

Producer cooperatives

Producers' cooperatives and unions are intended to reflect producers' interests. Along with providing or coordinating demand-driven extension to their members, farmer cooperatives and unions also represent stakeholder interests on a political level. However, such organizations are open to manipulation by governments and elites. Limited in capacity, most cooperatives have little influence on public policy decisions by their members. Nevertheless, close collaboration with producers' cooperatives or unions has high potential payoffs, as their legitimacy and influential capacity reaches wide networks of farmers (see Box 12.6).

Box 12.6
Adapting to climate change by growing medicinal plants: the Jammu & Kashmir MAP Growers' Cooperative

In the Baramulla, Bandipora and Pulwama districts of Kashmir, India, smallholder farmers who traditionally cultivate maize are facing increasingly unpredictable rains, snowfall, temperatures and humidity. With debt from repeated crop failures on the rise, and average annual incomes barely totalling 110 USD per hectare, many have been forced to sell their land to developers and abandon farming.

The Jammu & Kashmir Medicinal and Aromatic Plants Growers' Cooperative, formed in 2009, has demonstrated the viability and profitability of growing lavender, which can be grown on what is locally called 'kandi' (semi-barren, rainfed farmland). Lavender can yield USD 4 000 in yearly profit, has a 20-year lifespan and demands minimal input. It is highly resilient, almost pest-free and unappealing to grazing cattle. Furthermore, legal cultivation of medicinal and aromatic plants in India is a crucial step towards preserving natural biodiversity. Over 90 percent of medicinal and aromatic plants currently traded are sourced from the wild, and two-thirds of these are harvested by destructive methods.

The Cooperative has grown from 30 to 300 farmers since 2009. With government support, the Cooperative delivers planting materials and provides training. As members, small holder farmers are able to market and even export their products through the Cooperative and demand fair prices. Since 2009, collective harvests have been steadily rising.

In 2009, the Cooperative set up a half million dollar, aromatic oil distillation plant with a grant from the federal government. The unit now gets enough flowers to operate through the May-December season. Marketing linkages have been established within India and in Britain, and the Cooperative is now marketing essential oils of lavender, rose and geranium under the brand name 'Pure Aroma'.

The switch to low-risk, high-value aromatic and medicinal crops that thrive in the soil and unpredictable climate of the Kashmir region has given farmers new market opportunities and provided a more reliable source of income.

Source: UNFCCC, 2013a

National and international agribusinesses

Agribusinesses with supply chains in developing countries are increasingly exploring the potential of buying climate-smart produce or engaging in climate-smart agricultural practices. They are well placed to promote market literacy among smallholder farmers. An advantage of corporate advisory services is that these are often highly specialized, focusing on the specific products being produced in the precise context of their production. The advisory personnel work exclusively with the contract farmers (Swanson and Rajalahti, 2010). Though strongly localized, this focused and in-depth attention cannot often be matched by public sector or civil society efforts, which usually have broader mandates.

Commercial consultancies

Governments or farmer organizations are increasingly choosing to contract commercial consulting firms to provide extension services. This is gaining popularity as private sector service is generally identified with greater efficiency, as the business ethos of providing value for money tends to lead to results-oriented delivery (Anderson and Feder, 2003).

Banks, credit and savings institutions

Implementing CSA requires a certain amount of capital to manage the transition to the new climate-smart practices. Liaising with credit-giving institutions to provide appropriate means (e.g. microfinance loans) to smallholder farmers can enable a wider uptake of CSA practices (see Box 12.7. and module 14 on financial instruments and investments). Reaching out to inform smallholder farmers about the available funding and insurance options is essential.

Purchasers of carbon credits

Private sector actors (e.g. multinational businesses) seeking to offset their carbon footprints by purchasing emissions reductions on the carbon markets represent a viable source of financing for agricultural climate change mitigation projects, including those that promote agroforestry.

Box 12.7
Micro-insurance reduces exposure to weather risk in Andra Pradesh, India

The changing climate threatens agricultural productivity in Asia. Higher temperatures and increased drought and flooding, which degrade the soil, can result in large-scale crop failure and decreased productivity over the long term. For most Indian farmers, traditional crop insurance has not been a viable option for managing such weather risks. Insurance providers faced high costs of measuring crop damage for large numbers of smallholder farmers, and as a result, coverage premiums were too expensive for small-scale rural producers.

In 2003, however, a partnership between ICICI Lombard General Insurance and BASIX, a Hyderabad-based microfinance institution, with technical support from the World Bank, piloted the sale of rainfall index insurance contracts to smallholder farmers in Andra Pradesh. This project represents the first farmer-level weather index-based insurance in the developing world.

Contrary to traditional weather insurance, index-based insurance uses the strong correlation between crop yields and rainfall to trigger insurance payments to policy holders when rainfall falls below a certain level. Indicators can vary according to the local climatic conditions relevant to the policy holder. The scheme does not require insurance companies to assess crop damages for individual farmers, and this greatly cuts transaction costs and allows for more affordable policies.

The scheme began on a small scale with 230 participants and focused only on crop-specific risks. By 2005, the scheme was considering the risk exposure to climate variations of an entire district. During the 2005 monsoon, BASIX sold over 7 600 policies to almost 7 000 customers across six states. Complementary partnerships with local organizations and effective and transparent communications with farmers were crucial to the scheme's success. Innovative features like doorstep delivery and quick payouts when index triggers are reached helped build trust and confidence. The partnership's communication strategy enabled farmers to understand insurance as a product. The strategy also channelled customer feedback to ICICI, which adapted its product designs to suit different local conditions and needs.

Source: UNFCCC, 2013b

Stakeholders

The local stakeholders (e.g. farmers and employees of local agriculture-related organizations) who are the main recipients of the extension training discussed in Section 12.1 are often linked to each other by institutional arrangements. These may be formal, such as cooperatives and farmer's unions and organizations1 or informal.

Producer cooperatives and farmers' unions and organizations

Farmer's unions, cooperatives and organizations are the most visible stakeholder institutions representing and supporting local interests at the regional and national levels.

Along with voicing farmers' interests on a political level, farmers' organizations also commonly provide or coordinate demand-driven extension services to their members. Their legitimacy as lobbyists for bottom-up action makes them important partners for promoting the adoption of CSA-related practices. In bringing about the transformation to CSA, unions and cooperatives are well-placed to take on key responsibilities, including:

- actively leading their members to embrace CSA principles and practices;
- becoming stronger information and service providers , serving as 'CSA knowledge platforms';
- catalyzing carbon fund mobilization and channelling payments for ecosystem services to smallholder farmers;
- serving as policy lobbying and advocacy groups to influence national CSA-related policies; and
- taking a role as value chain actors in promoting carbon footprint labelling in partnership with private companies.

Partnerships between farmers' unions and decentralized training institutes need to be strengthened to empower national farmers' federations to act as direct, CSA-specific service providers to farmers. Section 12.3 *'Building synergies'* discusses the support platforms or networks for CSA offered by individual institutions.

Box 12.8
Uganda National Farmers Federation: climate adaptive approaches to food security workshops

The Uganda National Farmers Federation (UNFFE) was established in 1992 as the Uganda National Farmers Association. Today, over 200 000 individual farmers and more than 70 organizations are members, paying a small annual fee in return for representation and support. This support comes in a variety of forms: policy advocacy, agricultural trade fairs, market and climate information or extension services and materials (e.g. the UNFFE's quarterly publication 'The Farmer's Voice', radio and cassette training sessions, farmer workshops and study tours).

The increasing hardships brought about by climate change, such as late rainfalls or droughts, that agricultural producers are facing have not gone unnoticed by the UNFFE. To meet the challenge, UNFFE organized, in collaboration with the Dutch Farmer's Organization Noord and the pan-African agricultural company Agriterra, a national workshop and two regional workshops on 'Climate Adaptive Approaches to Food Security' in 2012. The objectives of the workshops were to:

- clarify the link between agricultural development and climate change;
- analyse the potential impacts of climate variability and climate change on the livelihoods of farmers in the pilot-districts Nakasongola and Sironko;
- identify appropriate adaptation measures taking into account the differences between short, middle and long-term approaches; and
- optimize communication to members and farmers, by replicating best practices through demonstration farms and extension services and linking farmers through District Farmers Organizations networks and the UNFFE national network.

Following discussions of how climate change has been manifesting itself and affecting livelihoods in Uganda, priority solutions were formulated. These include differentiated directives for government, UNFFE and farm-level actions. They would also be tested in pilot projects in Nakasongola and Sironko. Once the pilot process has been completed, the UNFFE intends to mainstream the lessons learned on CSA into its wider support systems.

Source: UNFFE, 2012

[1] Private sector actors may be considered local stakeholders as well. However, as corporate willingness to train its producers and staff to maximize results has already been addressed in the previous section, it will not be repeated in this one.

Informal, social and cultural institutions

As mentioned earlier, institutions are not only formal organizations. Informal arrangements, common practices, habits and spoken or unspoken agreements all constitute 'institutions'. They also shape how things are done in a community and influence if and how new practices are adopted. The term 'culture', signifying 'the distinctive ideas, customs, social behaviour, products, or way of life of a particular nation, society, people, or period' (Oxford English Dictionary) is often used to broadly describe these informal institutions.

Initiatives, such as CSA, which demand changes in practices and habits, often have cultural implications (see Box 12.14) that create barriers to adoption. Implementing change is most successful if the informal, social and cultural arrangements in place are understood, and activities and actions are channelled through the appropriate institutions, including faith groups, women's groups, ethnic communities or traditional leadership hierarchies. These institutions can be powerful allies for development projects at the community level and can bring local knowledge, social legitimacy and established networks to CSA programmes. As many rural people prefer to undertake collective, rather than individual actions, the importance of local, typically small, groups for CSA activities should not be underestimated. These collective actions may include tree planting, tree nurseries, water storage and management (e.g. irrigation), and soil improvement (e.g. terracing) (Meinzen-Dick *et al.,* 2010; Place *et al.,* 2004).

Box 12.9
Informal seed systems

A key example of an informal institutional arrangement is 'informal seed systems' , which includes all non-certified seed sources (primarily farmers' own seed, saved from previous crops, but also seed obtained in exchanges through social networks or at rural markets). Most farmers in developing countries access the seeds they plant through the informal seed system. Seeds are cheap and easy to access in this way, which makes the informal seed system popular.

In traditional systems of seed exchange, the social principles of trust and reciprocity usually serve as an assurance of quality. In general, these networks are confined to a very local level, with little interchange with outside sources. This limited opportunity for exchange and a lack of scientific information about the quality and genetic content of the varieties being exchanged make it difficult for farmers to select appropriate seeds. Climate change is likely to affect the geographic suitability of crop varieties. For this reason local markets should be used to communicate and collect relevant information about changing conditions and feed climate-resilient varieties into the informal system, where seed exchange continues beyond the market between families and neighbours. Further initiatives to help spread CSA through informal networks include local seed and genetic diversity fairs, alternative labelling systems (e.g. quality declared seed or farmer-based labelling schemes) and training of traders.

Source: Lipper and Oosterveer, 2011

12.3 Building synergies

To facilitate interaction and communication between many individual institutional actors (e.g. agricultural producers, traders, community and agricultural producer groups, government agencies, and private food sector actors), a conducive environment needs to be created. Actors need a place where they can articulate demands, share lessons and promising solutions, and create the 'pull' that elicits innovation (Clark *et al.,* 2011). This 'institutional interplay' should not only be 'horizontal', taking place on the same organizational level, but also integrate institutions 'vertically', incorporating perspectives across traditional levels and hierarchies (Young, 2002; Lebel, 2005). The scale (national, regional, district, or village) of such efforts depends on the problem being addressed, its coordination requirements, and the structures of the value chains involved.

This section considers key requirements for setting up such 'safe spaces' or platforms for institutional learning and innovation. These include capable partnership brokers as well as careful consideration of equity issues and cultural institutions. On this basis, networks and CSA platforms are emerging as a kind of 'umbrella' institution, enabling a lively interaction among communities working on climate-smart agricultural activities all over the world. Box 12.10 illustrates an example of synergy at the international level in the coffee and tea industry.

Box 12.10
AdapCC: a climate-smart partnership for coffee and tea production

The 'Adaptation for Smallholders to Climate Change' (AdapCC) initiative supports coffee and tea farmers in developing strategies to cope with the risks and impacts of climate change. The initiative is a public-private partnership by the leading British Fairtrade company for hot beverages, Cafédirect, and the German Agency for International Cooperation (GIZ). Financing of the project is shared by Cafédirect (52 percent) and the German Federal Ministry for Economic Cooperation and Development (BMZ) Public-Private Partnership programme (48 percent).

Six pilot projects in Latin America (Mexico, Nicaragua and Peru) and in East Africa (Kenya, Uganda and the United Republic of Tanzania) were implemented between April 2007 and February 2010. In Nicaragua, the International Centre for Tropical Agriculture (CIAT) projected a 2.3°C average temperature increase in certain municipalities by 2050 and 100 to 130 mm decreases in annual rainfall. It was predicted that there would be an overall loss of the coffee farming areas, coffee production would need to move to higher altitudes, and coffee quality would decline.

Based on a detailed Risk and Opportunity Assessment (ROA), the Nicaraguan pilot group, PROODECOOP (a coffee-growers' organization), developed an action plan to manage the risks identified by adapting local production systems. Some of the outcomes of the action plan are listed below.

- A training process for 24 CAFENICA members on climate change and adaptation measures was conducted. (CAFENICA is an umbrella organization, grouping 12 coffee organizations including PRODECOOP. It represents over 6300 small-scale coffee growers.)
- A small meteorological station to monitor rainfall and temperature was established.
- Techniques and methodologies for the fabrication of agricultural organic inputs were validated.
- More efficient water use and management techniques (drainage, storage and micro irrigation) were tested and implemented.
- The experiences from the pilot were collected and systematized in order to be transferred to a wider range of coffee producers.

Following the successful implementation of its six pilot projects, the AdapCC partnership is now due to be scaled up in and beyond the original pilot countries.

Source: AdapCC, 2010

Brokering partnerships

Partnerships, such as joint public-private initiatives, needed to support and catalyse CSA involve diverse sets of actors with diverse goals, agendas and interests. Because of this, they entail high transaction costs and require a specific set of skills. Experience shows that brokerage functions are critical in facilitating such partnerships (Clark *et al.,* 2011). By definition, these brokers have to be good communicators, skilled at supporting interactive collaboration between different types of stakeholders. They must be proficient in helping people to acquire and share different kinds of knowledge. It is also critical that brokers be able to deal with large (and often hidden) asymmetries of power among actors. Successful cross-institutional interactions rely on clearly delineated and appropriately assigned responsibilities. This minimizes competition or duplication between individual entities in favour of harmonized efforts and shared outcomes (Young, 2002).

Depending on the local context and capacities, social capital and legitimacy, the brokering role can be played by local government, extension services, civil society organizations or national agricultural research systems (see Box 12.11).

Box 12.11
Participatory and negotiated territorial development in Mozambique

Mozambique has made significant advances in the last 20 years with legislation that can avoid a major social conflict over land and promote an equitable form of new investment. FAO facilitated the consensus-building process that led to the National Land Policy declaration (1995) and resulting Land Law (1997) using two complementary approaches: Participatory and Negotiated Territorial Development (PNTD) and a rights-based approach.

Local communities are not always able to use all the land resources which they legally have rights over. As growing environmental concerns such as climate change increase pressures on land and other natural resources, the need for sustainable economic growth and securing local rights is underlined, especially as surging investment in large-scale agriculture occupies the best and ever-larger areas. It is not enough to rely on legal protection alone: however, existing rights must be identified and made visible through registration, but, perhaps even more importantly, rights holders must be empowered to articulate and defend their rights, allowing for equitable participation in consultations. FAO has therefore provided civic education and legal support for communities, specialized training for district officers responsible for implementation on the ground, specific programmes for paralegal training over the years, as well as extensive media campaigns and the active pursuit of partnerships.

Brokering such partnerships between smallholders, local communities, private sector actors and the overall government institutions requires time, energy and tact. FAO (as an impartial entity with expertise on the subject) assumed this brokering role in Mozambique making use of PNTD: a people-centered and process-oriented approach whose purpose is to bring diverse stakeholder interests to a negotiation table in order to build a wide consensus on further steps, clearly defining specific stakeholder contributions against a timeline.

Source: Tanner, De Wit and Norfolk, 2009

When establishing or considering support to existing CSA initiatives, it is crucial to prepare key partners to play their different roles effectively. This is especially true as some of the skills required (e.g. facilitation, synthesis, stakeholder engagement, monitoring and evaluation, impact assessment) cannot be easily mastered in formal training alone. These skills require substantial coaching and mentoring on the job. Two vital questions for CSA project designers to answer are:

1) Who is best placed to play the role of broker?
2) Who should be responsible for individual aspects of the project?

Various tools and approaches have been developed to help with this. One such tool is 'Outcome mapping', which was developed at the Canadian International Development Research Centre to help principal project partners articulate what they want the project to achieve. Each partner chooses specific metrics to measure progress towards achieving those outcomes. Articulating the outcomes sought by the different individuals and organizations at the project outset helps bring the different actors towards a joint understanding of overall project goals and come up with innovative strategies to achieve them (Kristjanson *et al.,* 2009).

Many CSA initiatives, such as payments for environmental services, have to deal with conflicting viewpoints of different stakeholders (e.g. upstream versus downstream communities), which require pioneering modes of engagement. Negotiation support tools can be helpful to project and programme planners (Clark *et al.,* 2011), as are approaches that build and nurture public-private partnerships (e.g. Box 12.12).

Box 12.12
The Challenge Dialogue SystemTM

The Challenge Dialogue System (CDS)TM is a corporate methodology for engaging diverse stakeholders in dialogue to help tackle a complex issue collaboratively, overcome deadlock and facilitate exchanges of information. The system is built around eight steps including: participant engagement and input-gathering; face to face interactions and virtual exchanges; outcome synthesis and integration; and the continuous reflection on the strategies being acted upon and their results.

CDSTM has been applied to a wide range of users, including: private sector actors seeking performance improvement; public sector actors seeking to enhance their information systems and decision-making processes (e.g. the Forestry Ministry of British Columbia, Canada); and networks between non-profit, public and private sector actors working on a common theme (e.g. The Food Innovation Network).

Source: Innovation Expedition Inc., 2006

Equity issues

Diversity, inclusion, and participatory approaches are critical to building the quality of social capital needed for the lasting uptake of resilience-enhancing climate-smart agricultural practices. Long product value chains can only realize their full climate-smart potential by considering the individual well-being of the many stakeholders involved. Attention to equity issues throughout these chains is required (Box 12.12) to ensure that the institutions do not (knowingly or unknowingly) discriminate against certain groups. Different inequalities and asymmetries call for different kinds of support. Key options are listed below.

Developing capacity

Capacities should be developed so that all relevant stakeholders understand their own rights and can represent their own interests in the inclusive planning processes that should underpin CSA project design (more on capacity development in Module 17).

Involving mediators

Like partnership brokers, mediators must be strong communicators who can foster collaboration by helping to find common ground between disagreeing parties and helping to minimize obstructive hierarchies of influence. Bringing external mediators on board may be worthwhile, as they can be accepted as impartial facilitators by involved parties. Respected figures (e.g. traditional leaders or religious guides and prominent advocates for a relevant issue) with eminence and legitimate authority can also draw attention to the issue at hand and play a powerful mediatory role within a given community or context.

Providing support mechanisms

Evidence shows that the least food secure households are also those least likely to take up new CSA practices (Kristjanson *et al.,* 2012). Support mechanisms, such as social safety net programmes (e.g. cash transfers, distribution of food, seeds and tools), can assist particularly vulnerable minorities or social groups by ensuring their access to a minimum amount of food and other vital social services. Recent initiatives in this area include Ethiopia's Productive Safety Net Programme and Kenya's Hunger Safety Net Programme. Both of these programmes make it more likely that additional CSA efforts will benefit women, children and the poorest households (more detail on social safety nets in Module 16).

Box 12.13
Women in (climate-smart) agriculture

The 'Women's Empowerment in Agriculture Index' (WEAI), an approach for measuring the empowerment, agency, and inclusion of women in the agriculture sector, was launched by the International Food Policy Research Institute (IFPRI) and partners in 2012.

The Index measures women's empowerment relative to men within their households. The five domains of empowerment for women considered in the Index are:

- inclusion in decisions about agricultural production;
- access to and decision-making power over productive resources;
- control over use of income;
- leadership in the community; and
- use of time.

In 2011, pilot surveys, conducted in Bangladesh, Guatemala and Uganda, provided insights into the different gender dynamics in each country. The WEAI partners continue to validate the Index, testing whether the relationships between empowerment and its underlying determinants remain consistent in larger samples. These efforts will help to promote transparency and ensure that investments in women's empowerment are targeted for maximum impact.

Also seeking to further gender equity, CCAFS and FAO published a training guide for agricultural development professionals in 2012. The guide provides users with resources and participatory action research tools for collecting, analysing and sharing gender-sensitive information about agricultural communities, households and individuals who are facing a changing climate.

Sources: IFPRI, 2012; CCAFS and CGIAR, 2012b

Cultural considerations

While addressing questions of equity and representation, CSA projects need to take into account the cultural institutions that shape the lives and practices of the communities they seek to support. Negotiating a balance between the international principle of equity and the reality lived in local communities can be a delicate matter. In this regard, the issue of women's rights may be particularly sensitive. In addition, committees elected democratically for project support may ignore existing informal institutions and traditional leadership (Reid *et al.,* 2010). Because they may be seen as central to the local cultural identity, certain traditional agricultural practices may not be able to be replaced with climate-smart practices (Box 12.14). Taking local realities into account is vital if projects are to be successful over the long term.

A participatory planning process allowing stakeholders to articulate their convictions, preferences and concerns is of critical importance. This ensures that these issues can be taken into account in project design from the outset (see Box 12.14). Cultural considerations overlap with questions of equity. Again, participatory planning should include skilled mediators and capacity building to integrate cultural institutions into CSA project plans.

Box 12.14
Cultural barriers to climate change adaptation in Northern Burkina Faso

A 2009 study comparing the ethnic groups Rimaiibe and Fulbe in the village of Biidi 2 in Northern Burkina Faso shows that Rimaiibe are successfully embracing livelihood diversification to adapt to climate change, but the same adaptive approach is not considered viable by Fulbe. The Rimaiiibe's chief adaptive strategies (labour migration, working for development projects, growing gardens and including women in economic activity) contravene Fulbe's sense of personal integrity and freedom.

Fulbe identity is bound to the annual practice of transhumance (they herd livestock across Burkina Faso's central plateau between December and June). Among Fulbe men, transhumance is considered to be a proof of independence and self-worth. Transhumance continues to be pursued even though the plateau is becoming increasingly cultivated and inhabited, which makes the practice more and more difficult. Fulbe view sedentary crop cultivation less favourably than itinerant livestock rearing. In addition, hiring oneself out for work or migrating for labour is not considered an option. Until postcolonial legislation in the 1980s afforded Rimaiibe rights and land, they were effectively slaves to the Fulbe. This history makes Fulbe even more reluctant to be associated with activities that are proving successful for Rimaiibe. Highly prizing their self-sufficiency, Fulbe tend to live scattered in the bush at some distance from the village. The Rimaiibe live closer together in the village. When development practitioners hire workers for day labour, they do so in the village centre, which is easily accessible to Rimaiibe, but not Fulbe. Finally, strongly defined gender roles make Fulbe men reluctant to include women in income-generating activities. These cultural factors that have created barriers to adapting to changing conditions have led to a sharp rise in Fulbe poverty and food insecurity.

These insights offer an idea of how local cultural institutions may complicate the uptake of climate change initiatives that have succeeded in other contexts. Understanding the local culture is useful when formulating project strategies. In the case of Biidi 2, it became evident that development practitioners needed to meet with Fulbe in the bush and with Rimaiibe in the village. They could not assume that Fulbe would come to the village centre when in need of paid work. Dialogue about cultural practices and beliefs along with an exchange about securing physical and economic well-being is also advisable.

Source: Nielsen and Reenberg, 2010

Networks

Because of the many institutional interactions involved, CSA initiatives rely on networks to support information exchange and partnership-building. These networks link research institutes (e.g. National Agriculture Research Systems (NARS), universities and international agricultural research institutes), the providers of agricultural advisory and extension services, climate information services and farmers' organizations. Specifically formed CSA networks or 'platforms' are proliferating regionally and internationally (see Box 12.15).

In addition to sharing and managing knowledge across institutional silos and facilitating institutional cooperation in pursuit of shared objectives (Young, 2002), these networks can also fulfil a significant extension role. By centrally training trainers (e.g. professors, regional planning experts, and technology transfer specialists) to go on to train local practitioners in different regions (e.g. extension field agents, local and decentralized planning officers), the benefits of extension can be widely scaled up.

When creating, facilitating or joining a network, it is crucial to be clear about the added value the network intends to provide to its users. Networks can be vast repositories of data, expertise and contacts. However, due to the high rate of network proliferation, staying abreast of all developments and navigating the information offered can sometimes be overwhelming. Building up a forum for sharing knowledge and discussing new ideas can be time- and resource-intensive. In general, it is better to join already existing platforms and develop new conversations or collaborations within them and leave the creation of new fora for distinct issues.

The most successful networks are those in which users do not view their participation as an additional effort. Instead, they feel the benefits are concrete enough to merit a commitment to an ongoing engagement with the network. In such cases, following discussions and sharing information via networks becomes part of the normal working mode. It is not always easy for a network to motivate its members to move beyond passive or cursory participation. Building a sense of concrete 'achievement' can be done through initiatives such as periodic face-to-face meetings between network members, explicitly moderated discussion groups, virtual briefings and workshops.

At the same time, it is not necessary for a network to be constantly active with vibrant collaboration. A data repository, updated and accessed by members on an as-needed basis, is also valuable, as is a mostly passive group of affiliates, who mobilize themselves when required.

Box 12.15
Examples of CSA platforms

Each of the CSA platforms listed below fosters international interaction on different aspects of climate change activities using different means (e.g. face-to-face or virtual facilitation; discussion groups or document pools).

The Climate Change Adaptation and Mitigation Knowledge Network (AMKN)

AMKN is a map-based online platform created by CCAFS that brings together climate, agriculture, and socio-economic information and posts photos and videos of farmers living at research sites across the tropics. It is an information service and key tool for practitioners, donors, policy makers, and researchers interested in food security and climate change. The platform displays food security and climate data, such as crop adaptations to climate change, drought indexes and global climate models. Zooming into a region, you can also explore multimedia features, including dozens of video testimonials from farmers in CCAFS regions, which illustrate how farmers today are coping with climate variability.

Source: CCAFS and CGIAR, 2013b

The Community for Climate Change Mitigation in Agriculture

Launched in 2012 by FAO, the Community for Climate Change Mitigation in Agriculture has built a network specifically for practitioners who work on reducing greenhouse gas emissions in agriculture. It offers an online resource library and hosts discussions on relevant issues, both in a member-only online forum and in a public social networking group. The community has over 600 members. A three-week online learning programme on agroforestry was delivered to over 250 participants in February 2013.

Source: FAO, 2013

WeADAPT

WeADAPT is an online 'open space' on climate change adaptation issues with over 1 500 members from more than 200 organizations. Members share case studies, tools and advice online in different thematic 'hubs'. In doing so, they help build a professional community of practice on adaptation issues and develop policy-relevant tools and guidance for adaptation planning and decision-making. The forum provides a number of services. For example, fellow members working in related fields are automatically introduced to each other in order to foster an exchange of ideas, and materials relevant to members' stated research interests are listed automatically. Collaboration with the Climate Information Portal of the University of Cape Town makes international climate data accessible to all members.

Source: WeADAPT, 2013

Climate and Development Knowledge Network

The Climate and Development Knowledge Network supports decision-makers in designing and delivering climate-compatible development by combining research, advisory services and knowledge management in support of locally owned and managed policy processes. It works nationally, regionally and globally in partnership with decision-makers in the public, private and non-governmental sectors. Led by PricewaterhouseCoopers LLP, the network is managed by an alliance of organizations that include Fundación Futuro Latinoamericano, International NGO Training and Research Centre (INTRAC), LEAD International, the Overseas Development Institute and SouthSouthNorth.

Source: Climate and Development Knowledge Network, 2012

12.4 Quick institutional context assesment

Whether a new CSA initiative is being designed, or an existing project is being reviewed or expanded, the guidelines below are intended to help establish a clearer understanding of the institutional environment in hand. A context assessment itself is already a form of capacity building (European Commission, 2005), as an overview of relevant institutional capacities is crucial in advising decision-making. 'FAO has developed a detailed Capacity Assessment to facilitate situation analysis (FAO, 2012). Many additional, formalized methodologies for carrying out institutional and capacity assessments also exist (FAO, 2012). There are many detailed, formalized methodologies for carrying out institutional and capacity assessments (see reference list and additional resources for examples; see also Modules 13 on policies and programs, 17 on knowledge, learning and capacity development and 18 on assessment, monitoring and evaluation). The following key steps are simple and easy to follow. By identifying possibilities for successful project progress, they will help project developers and practitioners build a quick but useful picture of the institutional context. Table 12.2 summarizes these key steps in a simple matrix and provides an example of what such an assessment might look like using a fictional case scenario.

STEP 1. GENERAL OVERVIEW

List existing climate change plans in the project country (e.g. NAPs, NAPAs and NAMAs). Do they mention agriculture?

- Have CSA projects been implemented in the country or region so far? If yes, by whom and how? If not, why not?
- List all sectors the project involves and which should be involved (e.g. agriculture, forestry, fisheries).
- List the relevant individual institutions involved and to be involved, as thoroughly as possible. Note whether these are finance and/or service providing institutions, stakeholder groups, value systems, etc. Refer to the distinctions provided in this chapter.

STEP 2. INSTITUTIONAL INTERESTS AND MANDATE

Different kinds of institutions have different interests and functions.

- Against the general competencies identified for the institutions listed in step 1, sketch their interests, underlying principles and aims. (There may be overlap with competencies.)
- List how these institutions stand to benefit from the project in question.

STEP 3. INSTITUTIONAL STRENGTHS

Different kinds of institutions have different kinds of authority and areas of influence. Map out apparent strengths for the institutions listed in step 1.

- How can these be capitalized upon in the project design?

STEP 4. INSTITUTIONAL WEAKNESSES

Along with the strengths found in step 3, note down which areas the institutions require support for the project to flourish. Possible areas for attention highlighted by the World Bank Institute (2011) include: weak social and political commitment; minimal stakeholder participation in setting priorities and in transparency issues; poorly defined rights and responsibilities; complex and inflexible administrative and bureaucratic structures; corruption; and lack of means.

- Factor these institutional weaknesses into the planning to ensure the project's aims are feasible, given the institutional context.
- Use this part of the assessment to determine plans for capacity development within the project.

STEP 5. SCOPE FOR SYNERGIES

Based on the mappings produced in steps 1-4:

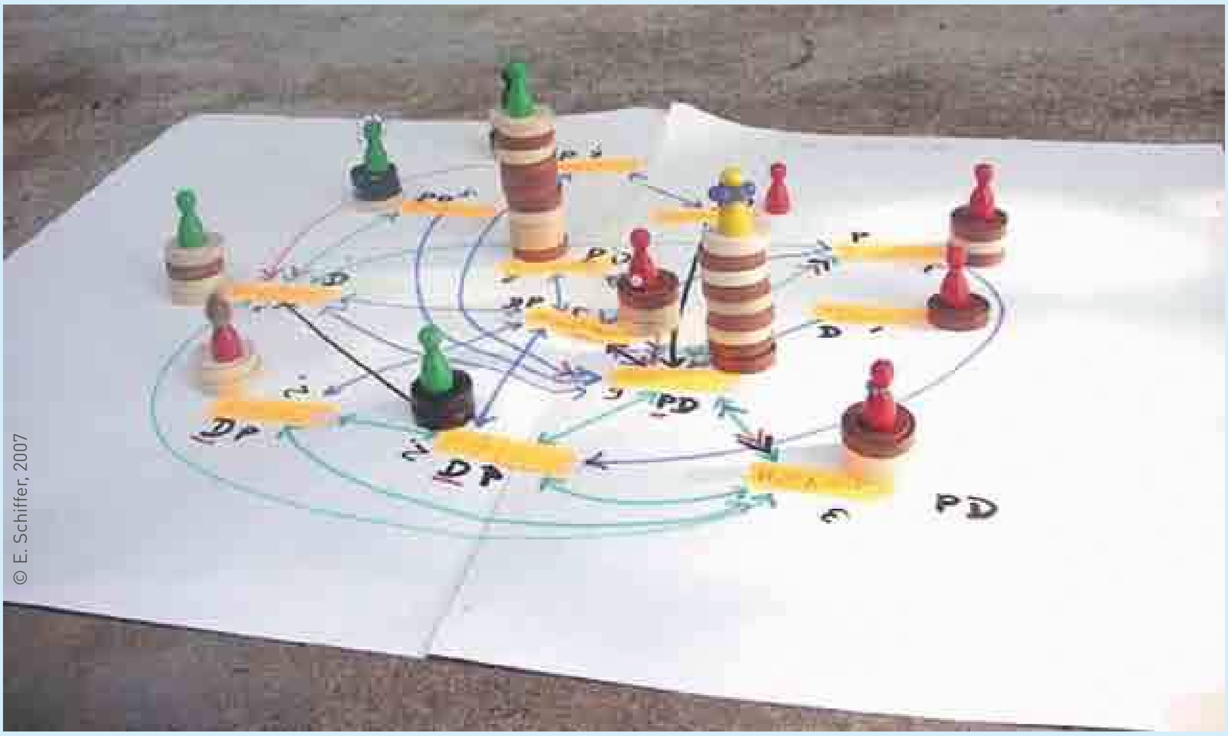
- Identify what kinds of synergies and collaborations could best bring out the institutional strengths and compensate for identified institutional weaknesses.
- Consider how such partnerships could be brokered and mediated.
- Bring partners together and jointly map out desired outcomes and strategies for achieving them (Box 12.15 features a tool that could further support such mapping).
- Let these synergies guide the project's progress.

Box 12.16
Net-Map: a hands-on social networking tool

'Net-Map', an empirical tool produced by the IFPRI, makes it easier to assess and improve complex governance systems. The tool can be used both as a means for conducting research and as an instrument for organizational development and strategic network planning.

Net-Map's approach is participatory. Interviewees and interviewers work together to sketch a network map of the actors and stakeholders involved in the situation in question, and map out the connections between them. The aims, motivations and power dynamics between all stakeholders are also assessed collaboratively. These different factors are translated onto the map in three dimensions by building up checkers pieces to demonstrate hierarchies between different actors (these 'influence towers' are depicted below). Simple to set up and visually straightforward, Net-Map has been used successfully when working with local communities and at national and international strategic levels.

The tool was originally developed in collaboration with the White Volta River Basin Board (inaugurated in 2006) in rural Ghana. It was designed to enhance the Board's capacity to realize its large-scale environmental goals by clarifying the interactions between individuals, organizations and networks around its 17 members, which include local leaders, district officials, NGOs and researchers. The tool has been used by a wide range of international organizations since, including the International Fund for Agricultural Development (IFAD), the World Bank and the World Health Organization (WHO).



Source: IFPRI, 2008; IFPRI, 2009

Table 12.2
Matrix for the quick institutional context assessment

Fictional sample case: an initiative on women's empowerment in CSA

1) General overview		2) Institutional interests/ mandate	3) Institutional strengths	4) Institutional weaknesses	5) Scope for synergies
Sector/Type of institution	Name of institution				
LEAD: International NGO specializing in environmentally sustainable development.	–	Climate-smart development Women's empowerment	Institutional experience implementing development projects Availability of funds	Outsider; little local knowledge or legitimacy	Can partner with all the below, capitalizing on their strengths and balancing out their weaknesses (see below).
Regional branch of ministry of agriculture	–	Rural economic development Sustainable resource management	Authority Access to relevant population data Experience delivering agricultural extension services Availability of some funds	Overstretched human resources Limited funds Limited experience with CSA or women's development initiatives	Can support its rural development and sustainable resource management by developing women's earning potential through CSA in partnership with NGOs. Can contribute its authority, technical and site-specific knowledge to the project.
Local women's rights NGO	–	Women's empowerment	Activism and campaigning experience, at national and local level Local knowledge and networks (stakeholder, government, etc)	Lacking funds No interaction with policymakers	Can bring skills and local socio-cultural expertise to project funded by public sector and international NGO.
Local radio station	–	Disseminating information to benefit the public Profit (i.e. producing popular broadcasts)	Wide-reaching dissemination of information at low cost	Only reaches households with radios Programmes listened to may be determined by the men of the household	Can be engaged for a 'women's hour' CSA show, gender equality awareness raising campaigns, etc. Radios could be distributed to women via women's faith group.
Women's faith group	–	Faith Mutual support amongst each other and to others Constituent well-being	Access to a large number of women, with pre-existing sense of solidarity	Authority within wider (mixed) society uncertain (e.g. if perceived to transcend traditional gender roles)	Can endorse CSA for women and proliferate messages within the community. Can serve as an access point for talks, or distribution of inputs (e.g. seeds, tools, radios).

1) General overview		2) Institutional interests/ mandate	3) Institutional strengths	4) Institutional weaknesses	5) Scope for synergies
Sector/Type of institution	Name of institution				
Local branch of national farmers' union	–	Support and profit for constituents Political representation	Detailed knowledge of local farming conditions Access to established farming community	Male-oriented (majority of constituents are male) Low capacity; not powerful enough to influence agricultural policy at national level	Can provide valuable technical knowledge and extension. Can be a forum for dialogue about women's inclusion in farming within the traditional farming community. Can provide insights on market conditions and private sector partners.
International retailer	–	Profit Positive public perception	Market access Funds available	Little experience working with smallholders Output rather than outcome/process oriented	Can provide a market for the emerging women smallholder farmers while augmenting public standing by engaging in socially and environmentally sustainable production. National farmers' cooperation and national/ international NGOs can act as interface with smallholders for the retailer.

12.5. Conclusions

This module has outlined the major kinds of institutions that can advance CSA and has described their most salient characteristics and roles. The case studies provided indicate how different institutions in distinct contexts can provide key support to CSA initiatives. This support includes: producing and sharing technical knowledge; providing financial services and access to markets; and brokering or fostering collective action between stakeholders and initiatives. The Quick Institutional Context Assessment provides a simple methodology to assist project planners and implementers in identifying helpful institutional partners for their own CSA projects. It highlights areas requiring particular attention in order to create a enabling environment for the project in hand. References to more detailed mapping, planning and capacity assessment metodologies methodologies are made throughout the chapter and are provided in the reference list.

Understanding the institutional context within which a CSA initiative is implemented is crucial to the project's success. Institutional endorsement is vital, as it is often pivotal in motivating individuals to support projects. Institutional opposition or apathy is highly obstructive. If smallholder producers are to adopt climate-smart agricultural practices and maintain them over the long-term, a strong network of institutional support needs to be in place to assist and encourage their efforts. Equally, local-level activities can and should help shape institutional actions. Institutional networks on CSA, open to bottom-up information flows as well as horizontal and top-down ones, should plan to engage in an ongoing learning process and be prepared to be adaptable in their approaches (Lebel, 2005).

CSA initiatives should ground their interventions in a sound understanding of the different opportunities, capacities and complexities that individual institutions bring to the table. Based on these insights, participatory processes can be used to formulate practical ways in which partnerships and collaborations between individual institutions can lead to mutually beneficial synergies that can increase food security, improve livelihoods and foster environmental integrity.

Notes

This Module was written by Patti Kristjanson (CCAFS, CGIAR), Alashiya Gordes (FAO) and Reuben Sessa (FAO) with contributions from Ademola Braimoh (WB) and Sonja Vermeulen (CCAFS, CGIAR).

Acronyms

AdapCC	Adaptation for Smallholders to Climate Change initiative
AMKN	Climate Change Adaptation and Mitigation Knowledge Network
BMZ	German Federal Ministry for Economic Cooperation and Development
CARE	Cooperative Assistance for Relief Everywhere
CCAFS	Programme on Climate Change, Agriculture and Food Security
CDSTM	Challenge Dialogue SystemTM
CGIAR	formerly Consultative Group on International Agricultural Research
CIAT	International Centre for Tropical Agriculture
CNFO	Caribbean Network of Fisherfolk Organisations
CSA	climate-smart agriculture
GHG	greenhouse gas
GIZ	German Agency for International Cooperation
ICRAF	International Centre for Research in Agroforestry
ICT	Information and Communications Technology
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
MICCA	Mitigation of Climate Change in Agriculture project
NAMA	Nationally Appropriate Mitigation Action
NAP	National Adaptation Plans
NAPA	National Adaptation Programme of Action
NARS	National Agricultural Research Systems
NGO	non-governmental organization
OED	Oxford English Dictionary
PRC	Participatory Radio Campaign
ROA	Risk and Opportunity Assessment
SACC	Sustainable Agriculture in a Changing Climate project
UNFCCC	United Nations Framework Convention on Climate Change
UNFFE	Uganda National Farmers Federation
VSLA	Village Savings and Loans Associations project
WEAI	Women's Empowerment in Agriculture Index
WHO	World Health Organization

References

AdapCC. 2010. *Adaptation to climate change for smallholders of coffee and tea.* (available at www.adapcc.org)

Anderson, J.R. & Feder, G. 2003. Rural extension services. World Bank Policy Research Working Paper No. 2976. (available at http://faculty.arec.umd.edu/jhanson/Extension-Hanson_Johnson/Extension_PDF/Rural%20Extension%20Services%20-%20Anderson.pdf)

Birner, R., Davis, K., Pender, J., Nkonkya, E., Anandajayasekeram, P., Ekboir, J., Mbabu, A., Spielman, D.J., Horna, D., Benin, S. & Cohen, M. 2009. From best practice to best fit: a framework for designing and analyzing pluralistic agricultural advisory services worldwide. Journal of Agricultural Education and Extension, 15(4): 341-355.

CCAFS & CGIAR. 2012a. *New study finds African carbon projects can help poor farmers.* (available at ccafs.cgiar.org/blog/new-study-finds-african-carbon-projects-can-help-poor-famers)

CCAFS & CGIAR. 2012b. *Gender, climate change, agriculture, & food security.* (available at http://www.ccafs.cgiar.org/gender)

CCAFS & CGIAR. 2013a. *Where we work: West Africa.* (available at http://ccafs.cgiar.org/where-we-work/west-africa)

CCAFS & CGIAR. 2013b. *Adaptation and mitigation knowledge network.* (available at http://www.amkn.org)

Clark, W. C., Tomich, T. P., van Noordwijk, M., Guston, D., Catacutan, D., Dickson, N.M. & McNie, E. 2011. *Boundary work for sustainable development: natural resource management at the consultative group on international agricultural research (CGIAR).* Proceedings of the National Academies of Science. (available at www.pnas.org/cgi/doi/10.1073/pnas.0900231108)

Climate and Development Knowledge Network. 2012. *(available at http://www.cdkn.org)*

European Commission. 2005. *Institutional assessment and capacity development: why, what and how?* Tools and Methods Series, Reference document No 1.
(available at http://ec.europa.eu/europeaid/multimedia/publications/documents/tools/europeaid_institutional_assessment_capacity_devlpmt_2006_en.pdf)

FAO. 1999. *FAO policy and strategy for cooperation with non-governmental and civil society organizations.* (available at http://www.fao.org/docrep/X2214E/X2214E00.htm)

FAO. 2010. *Climate-smart agriculture: policies, practices and financing for food security, adaptation, and mitigation.* Rome.

FAO. 2011. *From nationally appropriate mitigation actions (NAMAs) to low-carbon development in agriculture: NAMAs as a pathway at country level.* EASYPol module No. 103. (available at http://www.fao.org/docs/up/easypol/881/nationally_appropriate_mitigation_actions_namas_103en.pdf)

FAO. 2012. *Learning module 2: FAO approaches to capacity development in programming: processes and tools.* (available at http://www.fao.org/docs/eims/upload/299903/LM2_webready_interactive_final.pdf)

FAO. 2013. *Community for Climate Change Mitigation in Agriculture.* Mitigation of climate change in agriculture (MICCA) programme. (available at http://www.fao.org/climatechange/micca/75150/en/)

Farm Radio International. 2011. *Participatory radio campaigns and food security: how radio can help farmers make informed decisions.* African Farm Radio Research Initiative. (available at http://www.farmradio.org/pubs/farmradio-prcreport2011.pdf)

Hansen, J., Mason, *S.J.,* Sun, L. & Tall, A. 2011. *Review of seasonal climate forecasting for agriculture in sub-Saharan Africa.* Experimental Agriculture, 47(2): 204-205.

IFPRI. 2008. *Tracing power and influence in networks: net-map as a tool for research and strategic network planning.* (available at http://www.ifpri.org/sites/default/files/publications/ifpridp00772.pdf)

IFPRI. 2009. *A hands-on social networking tool: net-map.* (available at http://www.ifpri.org/publication/hands-social-networking-tool-net-map)

IFPRI. 2012. *Women's empowerment in agriculture index.* (available at www.ifpri.org/publication/womens-empowerment-agriculture-index)

Innovation Expedition Inc. 2006. *Introducing the challenge dialogues system™ (CDS™).* (available at http://www.innovationexpedition.com/Introducing%20the%20Challenge%20Dialogue%20System.pdf)

Kristjanson, P., Reid, *R.S.,* **Dickson, N., Clark, W.C., Romney, D. & Puskur, R.** 2009. *Linking international agricultural research knowledge with action for sustainable development.* Proceedings of the National Academies of Science 106(13): 5047–5052.

Kristjanson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F., Desta, S., Sayula, G., Thiede, B., Förch, W., Thornton, P.K. & Coe, R. 2012. *Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa.* Food Security. Published Online May 25, 2012. (available at http://www.springerlink.com/content/1876-4517/)

Lay, M., Nicholls, V., Geoghegan, T. & Sandy, K. 2013. *Getting a seat at the table: Fisherfolk empowerment for policy change in the Caribbean. A New Dialogue: Putting People at the Heart of Global Development*, pp.43-46. (available at http://irishaid.ie/media/irishaid/allwebsitemedia/30whatwedo/HNCJ-conference-papers_final_small.pdf#page=45)

Lebel, L. 2005. *Institutional dynamics and interplay: critical processes for forest governance and sustainability in the mountain regions of northern Thailand.* In *Global Change and Mountain Regions: Advances in Global Change Research,* 23: 531-540. (available at http://link.springer.com/chapter/10.1007%2F1-4020-3508-X_53?LI=true)

Lipper, L. & *Oosterveer, P.* 2011. *Institutions to support the adoption of climate-smart agricultural practices with a focus on smallholder agricultural systems in developing countries.* Background document, Global Conference on Climate-Smart Agriculture 2011. (available at http://www.gscsa2011.org/LinkClick.aspx?fileticket=L6fd42i6H-A%3d&tabid=3251)

McCarthy, N., Lipper, *L.* **& Branca, G.** 2011. *Climate-smart agriculture: smallholder adoption and implications for climate change adaptation and mitigation.* FAO, MICCA Series No. 4. Rome, FAO.

Meinzen-Dick, R., Markelova, *H.,* **& Moore, K.** 2010. *The role of collective action and property rights in climate change*. Collective Action and Property Rights (CAPRi) Policy Brief No. 7. Washington, DC, IFPRI. (available at http://www.capri.cgiar.org/wks_0912.asp)

Nielsen, J. Ø. *& Reenberg, A.* 2010. Cultural barriers to climate change adaptation: a case study from northern Burkina Faso. *Global Environmental Change*, 20 (1): 142 – 152. (available at http://www.sciencedirect.com/science/article/pii/S0959378009000879)

North, D.C. 1990. *Institutions, institutional change, and economic performance.* Cambridge, UK, Cambridge University Press.

Ostrom, E. 2005. *Understanding the diversity of structured human interactions.* In E. Ostrom, ed. *Understanding Institutional Diversity*. Princeton, USA, Princeton University Press.

Oxford English Dictionary Online. www.oed.com (accessed August 2012).

Place F., Kariuki *G.,* **Wangila J., Makauki A., Ndubi J. & Kristjanson P.** 2004. *Assessing the factors underlying differences in achievements of farmer groups: methodological issues and empirical findings from the highlands of central Kenya.* Agricultural Systems, 82(3): 197-353.

Reid, H., Huq, S. & Murray, L. 2010. *Community champions: adapting to climate challenges.* International Institute for Environment and Development. (available at http://pubs.iied.org/10028IIED.html)

Swanson, B.E. & *Rajalahti, R.* 2010. *Strengthening agricultural extension and advisory systems: procedures for assessing, transforming, and evaluating extension systems.* World Bank Agriculture and Rural Development Discussion Paper No. 45.(available at http://siteresources.worldbank.org/INTARD/Resources/Stren_combined_web.pdf)

Tanner, C., De Wit, P. & Norfolk, S. 2009. *Participatory land delimitation: an innovative development model based upon securing rights acquired through customary and other forms of occupation.* Land Tenure Working Paper No. 13. (available at ftp://ftp.fao.org/docrep/fao/012/ak546e/ak546e00.pdf)

Thorlakson, T. & Neufeldt, H. 2012. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. *Agriculture & Food Security,* 1: 1-15.

Uganda National Farmers' Federation (UNFFE). 2012. http://www.unffe.org/ (accessed August 2012).

Uphoff, N. & Krishna, A. 2004. Civil society and public sector institutions: more than a zero-sum relationship. Public Administration and Development, 24: 357-372. (available at http://onlinelibrary.wiley.com/doi/10.1002/pad.313/pdf)

UNFCCC. 2013a. *Adapting to climate change by growing medicinal and aromatic plants.* Private sector initiative actions on adaptation. (available at http://unfccc.int/files/adaptation/application/pdf/jammu_and_kashmir_cooperative.pdf)

UNFCCC. 2013b. *Microinsurance reducing farmers' exposure to weather risk.* Private sector initiative actions on adaptation. (available at http://unfccc.int/files/adaptation/application/pdf/basix.pdf)

WeADAPT. 2013. *Collaborating on climate change adaptation.* (available at http://weadapt.org/)

World Bank Institute. 2011. *Institutional assessment to inform capacity development program design: a case study in Bangladesh based on the capacity development and results framework.* (available at http://api.ning.com/files/Q26fAAvBl7sxLcBgY9qlcNqHkBqOjvcWpUn8NWbZPkP9GSPXRm4tn3bb3nGZTXO11HD*2qXTNhrFLZcYuABrrsWSl37lZ1oN/BangladeshCase6.15.pdf)

Young, O. 2002. *Institutional interplay: the environmental consequences of cross-scale interactions.* In The Drama of the Commons, pp.263-292. Washington D.C., The National Academies Press.

Additional Resources

Beck, T. 2005. *Learning lessons from disaster recovery: the case of Bangladesh.* World Bank Working Paper Series No. 11. (available at http://www.recoveryplatform.org/assets/publication/bangladesh.pdf)

Beddington, J., Asaduzzaman *M.,* **Clark M., Fernández A., Guillou M., Jahn M., Erda L., Mamo T., Van Bo N., Nobre C.A., Scholes R., Sharma R. & Wakhungu J.** 2012. *Achieving food security in the face of climate change: final report from the commission on sustainable agriculture and climate change.* Copenhagen, Denmark, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). (available at www.ccafs.cgiar.org/commission)

Brammer, H. 2010. *After the Bangladesh flood action plan: looking to the future.* Environmental Hazards, 9: 118-130. (available at http://www.southasia.ox.ac.uk/sites/sias/files/documents/Oxford%20University%20CSASP%20-%20Work%20in%20Progress%20Paper%2017%20Brammer%20Flood.pdf)

FAO. 2008. *Water and the rural poor: interventions for improving rural livelihoods in sub-Saharan Africa.* (available at http://www.fao.org/docrep/010/i0132e/i0132e00.htm)

IFAD. 2011. *Weather index-based insurance in agricultural development: A technical guide.* (available at http://www.ifad.org/ruralfinance/pub/WII_tech_guide.pdf)

Mundy, P. & *Sultan, J.* 2001. *Information revolutions*. Wageningen, The Netherlands, Technical Centre for Agricultural and Rural Cooperation (CTA) (available at http://www.mamud.com/Docs/InfoRev_English_full.pdf)

Outcome Mapping. 2012. www.outcomemapping.ca (accessed November 2012).

Reiquam, S. 2008. *The private sector and smallholder agriculture: best practices with relevance to Mali, Zambia, India and Sri Lanka.* (available at http://worldaginfo.org/files/Agpedia.pdf)

Shames, S., Wollenberg, *E.,* **Buck, L.E., Kristjanson, P., Masiga, M., & Biryahwaho B.** 2012. Institutional innovations in African smallholder carbon projects. CGIAR Program on CCAFS, Report No. 8. Copenhagen, Denmark, CCAFS. (available at http://ccafs.cgiar.org/resources/reports-and-policy-briefs)

Shaw, R. 2006. *Critical issues of community based flood mitigation: examples from Bangladesh and Vietnam.* Journal of Science & Culture, special issue on flood disaster risk reduction in Asia, January 2006, 72(1-2).

Shaw, L., Lubell, *M.* **& Ohmart, C.** 2011. *The evolution of local partnerships for sustainable agriculture.* Society & Natural Resources: An International Journal, 24(10): 1078-1095. (available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1450797)

Vamsidhar Reddy T.S., Hall *A.* **& Rasheed Sulaiman V.** 2011. *The when and where of research in agricultural innovation trajectories: evidence and implications from RIU's South Asia projects.* UNU-MERIT Working Paper Series 2011-024. Maastricht, The Netherlands, Maastricht Economic and Social Research Institute on Innovation and Technology (UNU‐MERIT).

Van Noordwijk M., Tomich *T.P.* **& Verbist B.** 2001. *Negotiation support models for integrated natural resource management in tropical forest margins.* Conservation Ecolology, 5:21.

Willekens, M. & Van Pouke, L. 2011. *Legal evaluation tool for analysing the institutional adaptation capacity framework of your country. Accessed 14th August 2012.* (available at http://www.coastaladaptation.eu/images/legal-evaluation-tool-institutional-adaptation-capacity-framework_QA.pdf)

World Bank. 2012. *Agricultural innovation systems: an investment sourcebook.* (available at http://issuu.com/world.bank.publications/docs/9780821386842/1)

MODULE 13:

MAINSTREAMING CSA INTO NATIONAL POLICIES AND PROGRAMMES

Overview

Greater coherence, coordination and integration between various sectors dealing with climate change, agricultural development and food security is a key requirement for creating an enabling policy environment to promote the transformation to climate-smart agriculture (CSA). CSA policies and support measures need to be mainstreamed into broader public policy, expenditure and planning frameworks at the national, subnational and local level. Coordination is also necessary between concerned agencies across sectors at the national and local level. Policy priority needs to be given to CSA practices that bring productivity gains, enhance resilience and reduce emissions.

The first part of this module describes CSA within larger economic and policy frameworks and stresses its key role as a major driver of green economy. The second part examines ways to improve market accessibility through appropriate policy and financial instruments. It then looks at cross-sectoral coordination and the integration of CSA with disaster risk management and social safety net programmes. The last section highlights the role of implementing actors and how to improve their access to knowledge and monitoring.

Key messages

- CSA needs to be mainstreamed into core government policies and programmes, including policy, expenditure and planning frameworks. Priority needs to be given to CSA practices that bring productivity gains, enhance resilience and reduce emissions.
- CSA and CSA policies must contribute to broader economic growth, poverty reduction and sustainable development goals. They should also provide an enabling environment for the adoption of CSA by the private and public sectors.
- CSA requires coordination, between concerned agencies across different sectors at central and local levels. Partnerships with non-state stakeholders play a key role in CSA. A wider landscape approach is needed for the better management of agricultural production and ecosystem services.
- An integrated approach to providing incentives for CSA, such as payments for environmental services, is needed. Public support that focus on research, the development of human capital, the sustainable management of soil and land, social protection and safety nets, and the development of technology and value chains are conducive to CSA adoption.
- Secure land rights provide the enabling environment for investments in sustainable land and water management, which are key elements of CSA.
- The successful design and implementation of CSA approaches require integration with disaster risk management strategies and actions, and social safety net programmes.

Contents

List of Tables

List of Boxes

13.1 Climate-smart agriculture within larger economic and policy frameworks

Agriculture is an essential driver of economic growth, particularly in rural areas and least developed countries. At the national level, boosting agricultural production stimulates overall economic growth and development, particularly in countries with high economic dependence on agriculture (FAO, 2012a). At the same time, agriculture is a major user of natural capital and has a considerable impact on the environment. The 2012 United Nation's Conference on Sustainable Development in Rio considered the green economy[1] as one of the essential tools for achieving sustainable development. It called for economically viable sustainable agriculture (crops, livestock, forestry, fisheries and aquaculture) to eradicate hunger. At the same time, the move to more sustainable agriculture must also help conserve land, water, plant and animal genetic resources, biodiversity and ecosystems, and enhance resilience to climate change and natural disasters (UN, 2012).

CSA meets these expectations by improving productivity, enhancing resilience and reducing greenhouse gas (GHG) emissions. CSA and green economy are thus complementary concepts, and greening the economy with CSA is a concrete way to operationalize sustainable development (FAO, 2012a).

CSA policies must facilitate "using natural capital without using it up". Agriculture is crucial to climate-smart development and overall green growth because of the key contribution it makes to food security and human welfare and because of its role as a principle 'user' of natural capital. Agriculture accounts for 70 percent of water extracted; covers 40 percent of land area; and, together with land use change, forest degradation and deforestation, produces 30 percent of global GHG emissions. CSA is about meeting the needs of people for food, fuel, timber and fibre. It also contributes to economic development and poverty reduction; maintains and enhances the resilience of the natural ecosystem functions on which green economic growth depends; and addresses the new challenge of climate change. CSA is resource-efficient, resilient, and low-carbon emitting.

Identification of supporting policies and programs

The key to developing appropriate policies, strategies and actions to enhance CSA adoption is to understand the barriers to adoption of CSA practices, including the trade-offs between short-term costs and longer-term benefits, the mix of private and public benefits, institutional and financial barriers and lack of access to inputs or markets (FAO,2012b). The main requirements for an policy environment capable of promoting CSA are greater coherence, coordination and integration between climate change, agricultural development and food security policy processes (FAO, 2010).

CSA needs to be mainstreamed into core government programmes with appropriate priority given to public support of CSA. This process should be developed consistently with ongoing national climate-resilient long-term visions, such as the National Adaptation Programmes of Action (NAPAs), National Appropriate Mitigation Actions (NAMAs) and United Nations Framework Convention on Climate Change (UNFCCC) National Communications. It should include vulnerable economic sectors and ecosystems.

A gender-sensitive approach is also crucial to achieving CSA. The roles, responsibilities and capabilities of men and women need to be well understood to ensure that both men and women have access to and benefit from CSA practices and policies.

[1] Agencies have similar definitions for green economy and inclusive green growth. UNEP defines a green economy as "one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UNEP, 2011). OECD (2011) defines green growth as "fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies." The World Bank (2012) defines green growth as economic growth that is environmentally sustainable: green in that it is efficient in use of natural resources; clean, in that it minimizes pollution and environmental impacts; and resilient in accounting for natural hazards and the role of environmental management and natural capital in preventing physical disasters. For FAO the green economy embraces a vision that tries to steer economic development in the direction of sustainability, of which there are five key pillars: renewable energy and energy efficiency, waste management and minimization, sustainable use of natural resources, and green job creation.

National CSA policies are affected by developments at the international level, particularly in terms global agreements and mechanisms to support climate change adaptation and mitigation. Despite the current limited recognition of agriculture in the major global climate financing mechanisms, the interest in agriculture in the international climate change policy forums has been increasing (FAO, 2012b).

The lack of progress on agriculture within the UNFCCC context contrasts with the growing concern and interest many developing countries have shown for the implementation of agriculture adaptation and mitigation actions. Their interest is focused on how these actions might best be taken within subnational contexts and through nationally-owned policies and strategies. The national interest to pursue CSA provides an opportunity for shaping both domestic policies and international instruments for meeting the challenges of ensuring global food security and addressing climate change (FAO, 2012b).

CSA's public good element

CSA provides public goods (e.g. erosion control measures in an upper watershed may help to control flooding in a lower watershed; or control of field nutrient run-off will help maintain adequate water downstream), and for this reason public support is justified.[2] CSA may also have negative consequences (e.g. when an individual, firm, or country takes an action but does not receive all its benefits or bear all costs) or deliver benefits in other areas. CSA may also generate private goods. Most CSA options either bring both environmental and economic benefits (e.g. improved water use efficiency, enhanced fertility, enhanced resilience to drought) or reduce negative externalities (e.g floods, pollution, GHG emissions, soil erosion, deforestation) and generate non-market public goods (e.g. climate resilience, enriched soil with carbon).

At a general level, the key challenge is to alter policies and remove public subsidies that act as disincentives for adopting CSA, and reallocate resources to programmes that provide incentives for the adoption of CSA practices. Policymakers have a set of tools and instruments (e.g. rural credit programmes, input and output pricing policies, including subsidies, support for investments with public good benefits, property rights, research and extension services as well as safety net programs) that they can apply to change the incentives and build the capacity of farmers to modify their production systems (FAO, 2012b).

Box 13.1
Brazil: four decades of focusing support on public goods

In Brazil, the overall level of public support to agriculture is less than 6 percent of agricultural gross domestic product (GDP), compared with 25 percent in OECD countries and 18 percent in India. However, public support has focused on public goods, including funding research in crops, livestock breeds and farm systems that adapted to Brazil's tropical ecosystems, and investments in enriching soil fertility. Over half of Brazil's soybean crop is now farmed using conservation tillage. There has also been support for mixed crop and livestock systems, and rotating pastures with crops to supplying additional nutrients. In its lending conditions, the Brazilian National Development Bank (BDNES) now includes criteria for sustainable land, water and forest management. Brazil has also launched programmes on agricultural water management and rural development that are targeted to the specific conditions in each region of the country. In the north east, for example, sustainable land, water and nutrient management is a priority of the regional programme; in the south, the focus is on livelihoods; and in the western Amazon, forest management is emphasized. It has been a leader in piloting the use of renewable resources for fuel, including ethanol from sugar, and the sustainable cultivation of charcoal for iron production. In the last decade, Brazil has made impressive progress in reducing deforestation.

Source: World Bank, 2011a

A guiding FAO principle with respect to CSA is the 'no-regrets' approach. It emphasizes measures that should be taken even in the absence of climate change because they improve the efficiency of agricultural, forestry and fishery practices. At the same time, these measures put farmers, foresters or fishers in a better position

[2] A good with benefits for the broader economy and society, or which generate benefits in a different location from where the activity takes place

to adapt to or mitigate the effects of climate change. A CSA practice will often contribute to both adaptation and mitigation. For example, minimum tillage stores moisture and organic matter in the soil, which increases adaptive capacity, and supports climate change mitigation by sequestering carbon. By following an integrated approach, these practices increase long-term productivity, create synergies between adaptation and mitigation initiatives and reduce tradeoffs.

Sustainable intensification and productivity enhancement policies

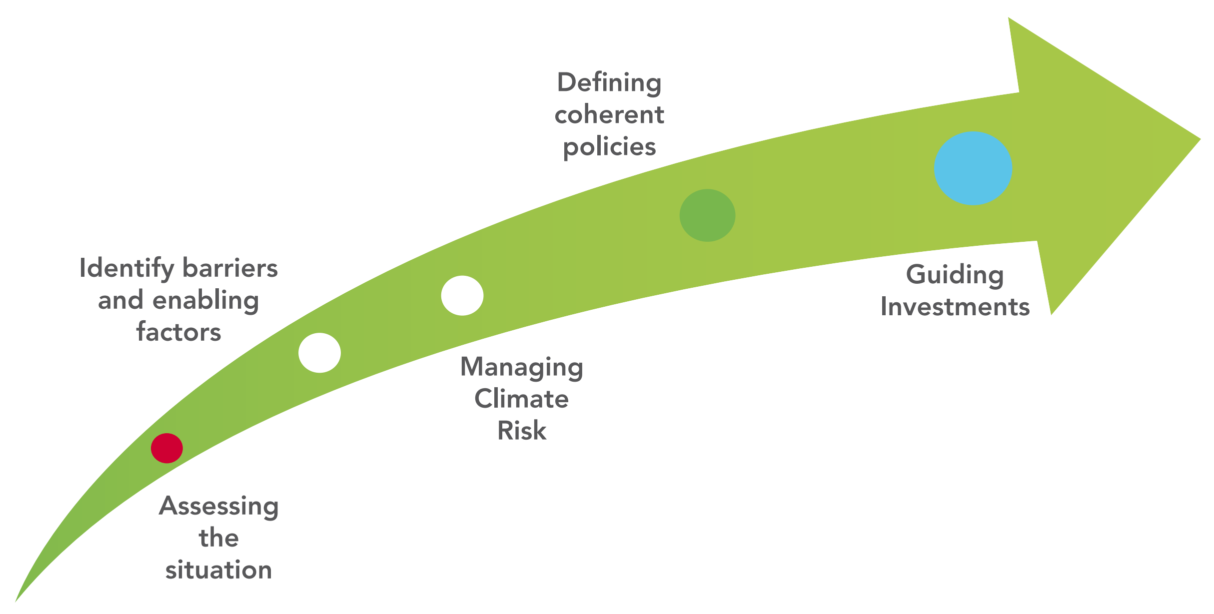
Policies for intensifying sustainable production and enhancing productivity are vital for the development of CSA. However, these policies need to be combined with broader landscape restoration measures. Included in these measures are: improved technologies and innovations; the efficient use of land, water, energy and other inputs; improved access to information and infrastructure; and efficient markets and risk management tools (see also Module 2 on the landscape approach). Programmes that support reduced food loss and waste, enhance value chains (see Module 11 on sustainable and inclusive food value chains), improve rural infrastructure and increase access to improved weather and climate services are also climate-smart. The challenge is to tailor these policies to the national political situation and climatic context in a way that builds on existing environmental strategies and ad-hoc programmes.

Box 13.2
Economic and Policy Innovations for Climate Smart Agriculture (EPIC) Programme

The EPIC programme, housed in the Agricultural Development Economics Division of FAO, was initiated in 2011, shortly after the CSA concept was introduced in preparation for the 2010 Hague Conference on agriculture, food security and climate change. The programme is supported by the European Community to work with three partner countries (Malawi, Zambia and Viet Nam), in developing CSA policies, strategies and investment proposals. The programme supports work in five main areas:

- identifying and prioritizing locally viable CSA practices through the development of an evidence base on the food security, adaptation and mitigation benefits of a range of feasible changes in agricultural technologies and practices;
- assessing barriers to adoption of CSA practices and identifying institutional and policy strategies to overcome them;
- analysing the impacts of climate risks on policy and investment priorities;
- strengthening country efforts to build a coherent and enabling policy environment for CSA implementation at the country level and;
- building with country partners investment proposals for scaled up CSA activities that link to both agricultural and climate financing sources.

Figure 1 gives an indication of the sequencing of these five building blocks of CSA implementation in country level.



The CSA project explicitly assesses how climate change may alter the effectiveness of existing agricultural policy and investment frameworks in supporting food security and economic growth in partner countries; and policy options to overcome barriers to adoption of CSA practices. The experience from the project indicates that operationalizing CSA at the country level requires greater coordination between agriculture, climate change and food security policies, as well as better links between research and policy. Partnering with the CGIAR Research Program on Climate Change, Agriculture and Food Security to launch participatory scenario building is an approach the programme is employing to facilitate the needed dialogue and coordination. With this tool, stakeholders from government, the private sector, researchers and civil society explore key socio-economic uncertainties for future food security, environments and livelihoods. Multiple socio-economic scenarios are developed by stakeholders, which can be used for 'back-casting' from future desired outcomes to current policy and investment needs across a range of possible conditions. By linking to quantitative models, the process can explicitly explore the potential costs and benefits of alternative development paths. Since policy-makers and researchers from agricultural, food security and climate change are all involved in the scenario development process, the process inherently generates greater coordination and dialogue across these different groups.

Interlinkages with existing strategies

The most effective way of supporting resilient agricultural systems and rural communities is to incorporate adaptation into other policies (IISD, 2006). This has been the principle behind the Pilot Programme for Climate Resilience (PPCR), one of the programmes supported through the Climate Investment Funds (CIF). PPCR has approved US$ 1 billion of grant and concessional finance for mainstreaming resilience into core programmes. Agriculture and water management feature strongly in all participating countries. The PPCR may provide a useful model that countries can follow to access climate finance for adaptation in a development context under a future Green Climate Fund. Countries can building on the lessons from ongoing PPCR's programmes and follow their implementation arrangements.

Providing an enabling legal and policy environment

To secure an enabling environment for the development and mainstreaming of CSA in overarching national plans, appropriate institutions with effective and transparent governance structures are needed to coordinate the division of sectoral responsibilities and the work done by national and local institutions (more on institutions in Module 12). An enabling environment also requires capacity development of for all relevant stakeholders (more on capacity development in Module 17).

Landscape approaches and incentives are needed for a coordinated management of various land-based ecosystem services. These approaches may require trade-offs, which would need to be explicitly quantified and addressed through negotiated solutions among various stakeholders. The scaling up of landscape approaches requires knowledge management and institutional capacity and must be backed up by an enabling policy and market environment. Coordinating sectoral policies is key to aligning the different goals (see also Module 2 on landscape approach).

CSA expenditure and planning

There is a strong need for coordination for expenditure and planning between concerned agencies at the national and local levels. In addition, cross-sectoral CSA strategies need to take account of current legislation and regulations and be incorporated into legal and regulatory frameworks if they are to be implemented. There a many areas where synergies can be created with CSA, including social safety nets (see Module 16 on safety nets); energy (see Module 5 on energy); land-use regulations; and disaster risk management (see Module 15 on disaster risk reduction).

Annual budget laws in which public expenditure planning is transposed into the budget allocation for the responsible line agencies, are a core legal and regulatory instrument for implementing CSA policies. In this regard, aligning capacity and financing with responsibility is critical. Operations and maintenance, as well as investment budgets, need to be considered. Raising new sources of revenue for implementing CSA strategies may also be possible by establishing an integrated investment framework to attract national and international climate funds from different public and private sources (see also Module 14 on financing).

Where decentralized government organizations have responsibility for certain elements of strategy implementation, it is important that financial flows from the central government or local revenue-raising capacity are sufficient to allow decentralized authorities to carry out their responsibilities in ways that are consistent with the law. In countries where prices are regulated, price support regimes and options for sharing public support between price support and other supporting mechanisms should be reviewed.

Land tenure regimes

Secure land rights are part of the enabling environment for investments in sustainable land and water management, which are crucial elements of CSA. Many CSA strategies have a strong land tenure dimension because tenure security promotes and generates incentives for long-term investment. Unclear land tenure may lead to difficulties in establishing benefit distribution mechanisms for payments for ecosystem services (Runsten and Tapio-Bistrom, 2011).

Land tenure is a complex issue. It covers a mix of rights, rules and institutions that vary from highly individualistic to communal systems. CSA systems need to be adapted to a country's particular tenure systems. Those working to implement CSA need to work together with land tenure specialists to understand tenure systems and work within them. Some examples include: simple land registrations systems in Ethiopia that facilitated investment in sustainable land management; the provision of land-users rights to trees that promoted 're-greening' in Niger; and the transference of long-term land use rights to users in China, which played a key role in broader watershed restoration and CSA. Since land rights are a key part of the enabling environment for investing in sustainable intensification, landscape restoration and sustainable woodland and forest management, land tenure regimes create the link between sound agricultural and forest land-use planning.

Land management regulations also play a role in CSA. For example, protecting stream beds or erosion control mechanisms can be done by requiring controlled grazing of animals. However, such measures only work where they can be implemented and enforced and where there is public acceptance of them and an understanding of why they are needed. Voluntary mechanisms and incentives are equally important.

Private Sector Investments

Regulations governing private sector investment must also play a part in creating an enabling environment for CSA. By taking into account the importance of improving the overall business environment through simple, transparent regulations and tax structures, finance regulations can incorporate climate-smart requirements into lending conditions. The example of the BNDES is illustrative. Using screening guidelines to determine whether loans are consistent with the Equator Principles (a credit risk management framework for determining, assessing and managing environmental and social risk in project finance transactions), the BDNES has improved its environmental and social screening process, developed specific guidelines for sustainable agriculture, livestock and forest management, heightened the attractiveness of green lines of business, increased the focus on social inclusion and decreased its carbon footprint (see also Box 13.1).

13.2 Improve market accessibility: policy and financial instruments

Market failures in rural areas often are the result of asymmetric information, high transaction costs and imperfectly specified property rights. Addressing these constraints requires innovative institutional arrangements and partnerships that improve effective market linkages and offer more stable and better prices to producers. Realizing the potential of CSA depends on the ability to convey market information, coordinate production and marketing, define and enforce property rights, and mobilize farmers to participate in markets and enhance the competitiveness of agro-enterprises (FAO, 2012b).

Role of prices and subsidies

Most governments intervene actively in the operation of their agricultural markets. Governments intervene to support farm prices because these prices are often volatile. Climatic conditions, over which farmers have no control, determine to a large degree how much a farmer produces in a given year. The most common approach to supporting the price of an exportable agricultural product is to create a government agency to buy a quantity of a product offered by the country's farmers at the guaranteed 'support price'. Price support certainly has a role to play in countries affected by climate change. However, often there are other forms of support (e.g. regulations, incentives, investments in technology, infrastructure, connectivity or the broader enabling environment, social marketing and use of social capital) that are more effective in addressing market failures.

Price support is most often channelled through subsidies for inputs (e.g. fertilizer, energy, water, and seeds).[3] With the exception of countries where input use is currently low, price support and energy subsidies should be redirected towards policies that recognize and reward CSA practices, and provide an enabling environment for value addition, commercialisation and trade. For example, input subsidy programmes designed to support a more efficient and timely use of fertilizers, rather than simply to increase their use, are important policy measures for implementing CSA (FAO, 2012b).

In countries with low-input and low-output systems, a fertilizer subsidy may initially be justified to increase yields and enhance plant growth and soil carbon. Analysis suggests that the fertilizer subsidy (up to 50 kilograms per hectare) adopted in the United Republic of Tanzania as part of its agricultural productivity project is climate-smart in that it has increased productivity and helped increase biomass. This has enhanced resilience and carbon sequestration. However, to ensure correct and timely fertilizer application, the price support needs to be accompanied by advice delivered through extension services and improved access to reasonable information on rainfall.

In countries where fertilizer use is already high, price support may not be climate-smart. In land-scarce, intensely farmed agricultural systems with high levels of inputs, the subsidization of inorganic fertilizer encourages overuse, which limits long-term productivity and harms the environment. In densely populated, land-scarce countries with high rates of intensification, different policies may be needed, such as the above-mentioned policies promoting more precise and timely use of inputs. For example Viet Nam has adopted the "five reductions, one must" policy. Farmers are encouraged to use rice varieties with clear origin, pure breed and guaranteed quality ("one must"). The "five reductions" are the reduction of the number of seeds planted, the reduction of the amount of water used (at certain times), the reduction of amount of the amount of fertilizer applied, the reduction of the amount of pesticides applied, and the reduction of post-harvest losses. Under this policy, the amount of rice seeds planted has declined by nearly 50 percent and the use of chemical fertilizers, pesticides and water declined by 20 to 30 percent from earlier levels, while productivity has increased from 15 to 20 percent.

Subsidizing energy may lead to unsustainable practices. For example, energy subsidies have contributed to aquifer depletion in water-scarce countries, such as Yemen. Inadequate water regulation and pricing regimes, which leads to a lack of incentive to conserve water, have contributed to widespread drainage and salinity problems in a number of irrigation-dependent economies (e.g. India, Pakistan and Uzbekistan). Addressing these problems demands a range of both price and non-price interventions to ensure reliable water delivery that farmers will be willing to pay for, as well as proper drainage.

With the demand for energy growing, oil prices increasing and the urgency to reduce GHG emissions becoming more acute, bioenergy has become an important energy source. Bioenergy is part of a mix of options for addressing energy concerns and climate change, which includes increased energy efficiency, more renewable energy,

[3] This section will not discuss price volatility in detail; but it recognizes its importance. Volatility is shaped by a mix of short-term and long-term factors, including weather variations and export restrictions that are sometimes imposed as a result of drought or flood, rising demand for food, and for some commodities (especially maize and soybean) the growing role of biofuels.

Box 13.3
Increasing output, damaging the ecosystem: the use and misuse of input subsidies in India

In India, fertilizer and other input subsidies contributed to the rapid development of irrigation and more intensive farming methods. This led to increases in yields and food security. By 2010, irrigated wheat yields in some provinces averaged 4.5 tonnes per hectare. Subsidized energy is now contributing to excess groundwater withdrawals. About 75 percent of groundwater used in Punjab and Harayana is withdrawn from overexploited aquifers. As a result, water must be to be pumped up from ever-deeper aquifers, and aquifers in some areas are becoming saline. The fertilizer subsidy, which cost the government US$ 30 billion (2 percent of GDP) in 2008, is contributing to excessive use of nitrogen, which is contributing to nitrate pollution in rivers and aquifers. There are, however, difficult and well recognized political economic challenges in reforming the pattern of subsidies.

Source: Barley *et al.*, 2011

and new patterns of energy production and consumption (see also Module 5 on energy). In some cases, governments have subsidized production of agricultural commodities for bioenergy, for example maize in the United States (although the support measures were recently phased out) and rapeseed in Northern Europe. These subsidies are part of broader energy policies. However, life cycle analyses suggest these measures, in temperate ecosystems, cannot be considered climate-smart. On the other hand, life cycle analyses for bio-ethanol from sugar cane in tropical humid countries (e.g. Brazil) are likely to be climate-smart. The sustainable production and use of bioenergy presents a major opportunity to address climate change by reducing carbon dioxide emissions. Whether or not these are climate-smart depends on the ecosystem, the underlying enabling environment and alternative land use options. In the implementation of CSA, there is a role for sustainable bioenergy production from woody biomass, crop residues and newer sources that are currently under development.

In many countries there is poor access to long-term finance, which is often a requirement for CSA. For instance, in Ghana, where the business environment is among the best in Africa, long-term finance for smallholder agriculture is not readily available. A range of non-price interventions (e.g. incentives, regulations, extension, and market access) are likely to provide better investment incentives than subsidized interest rates. Improved access to long-term finance is important in tree crop cultivation where replacing older trees with newer, higher yielding varieties may lead to short-term revenue losses.

Regulations for adoption of CSA

If they are successful in changing behaviour and providing incentives for adoption of CSA, national regulations need to be tailored to the country's particular environmental conditions and accompanied by other supporting incentives.

Where broader institutional capacity and governance is weak, regulations alone are unlikely to be effective. For example, in the United Republic of Tanzania, a ban on charcoal trading proved to be unenforceable since charcoal is the main source for cooking energy for urban Tanzanians. However, a system of forest and woodland management administered by local districts in line with the national decentralization law has proven to locally acceptable and environmentally sustainable. This locally managed system has been combined with measures that promote the planting of trees.

For CSA to take hold, a mix of regulations and incentives is often needed. In the Loess Plateau watershed restoration programme in China, key elements for success included: the regulation of free grazing of small ruminants; technical support for improved fodder production for stall feeding; secure land rights for the farming population that participated in the watershed restoration programme; and technical support for restoring landscapes rand enhancing agricultural productivity. For decades, in the highly populated, densely farmed areas of Central and Western Kenya, where land rights are clear, there has been a requirement to plant trees and tree crops on 10 percent of the land. Many of the farmers exceed this percentage because of the income earned from the trees and the ecosystem services they provide. However, in Ghana, the current regulatory system for revenue allocation from timber harvesting outside forest reserves, in which revenues are divided between the Forestry Department and traditional leaders, does not provide an incentive for local communities to manage forests sustainably.

The impact of regulations on production incentives needs to be considered. For instance, the Ukraine, an upper middle-income country, is a major global wheat producer. However, during the 2010 drought, as global wheat prices rose, there was concern that there would not be enough of this key staple available at reasonable prices to meet local demands, especially those of lower income people. In response to these concerns, Ukraine imposed an export ban (a regulatory measure). The ban damaged Ukraine's reputation as a reliable supplier of good quality wheat and reduced incentives for farmers to make the investments needed to increase productivity. Since then, the Ukrainian government has reconsidered its policy and has initiated a social protection system targeted at low-income and vulnerable people, so that they have the means to buy food in times of high prices, while Ukrainian farmers still have incentives to increase productivity and output.

Regulations also need to be adapted to changing circumstances. Viet Nam, once a food-deficit country concerned with food security, still regulates rice production, requiring that rice be grown on certain areas, even though it now produces a large surplus and is a major rice exporter.

Incentives for CSA investments

Incentive measures need to focus on overcoming barriers to the adoption of CSA practices. There are two main barriers to adoption. First, implementing CSA often involves upfront investments that take time to bring about gains in productivity. Second, present markets cannot accurately account for the value of the environmental benefits that CSA delivers. To reap the long-term benefits that CSA brings with regard to productivity, resilience and climate change mitigation, farmers and governments need to take advantage of a range of available financing sources (see also Module 14 on financing). The most successful programmes often blend different sources of funding and include a mix of policy support measures.

The Plan Vert (Green Plan) of Morocco follows an integrated approach to providing incentives for CSA. In its river basin management activities, the Plan takes account of the increasing challenges posed by water scarcity. It has a dual approach. In irrigated areas, Plan Vert provides incentives for improving water management and conservation, and integrating national value chains with international markets. In rain-fed areas, Plan Vert increases access to social services, and supports participatory natural resource management initiatives. It also supports a programme for replacing arable crops with more drought tolerant olive trees and other tree crops. Plan Vert is implemented through a range of measures that are incorporated into policy instruments. It also receives targeted support for specific technical innovations. Box 13.4 provides an example of a targeted support programme in Colombia and Zambia.

The valuation of ecosystem services (see Module 2 for more on ecosystem services), which measures the degree to which activities carried out in one part of an ecosystem or economic sector benefit other sectors, remains a challenge. Payment for ecosystem services is one policy instrument for providing incentives to adopt CSA. Carbon finance, which focuses on mitigation, is an important example of this approach. However, as the previous sections have highlighted, CSA also provides many other environmental services. Broadly conceived, incentives can include indirect mechanisms, such as laws and regulations, and direct incentives, such as cash subsidies and grants or non-cash subsidies, including technical assistance and other forms of support.

13.3 Improving access to knowledge and monitoring: the role of implementing actors

Role of local institutions and participatory approaches

CSA policies and programmes, as with any cross-sectoral development programme, need to be aligned across various levels of government. Another requirement is the widespread building of capacities because in many countries decentralization processes have not been accompanied by adequate strengthening of local level

Box 13.4
CSA incentives in Colombia and Zambia

In Colombia, there is a new focus on integrated landscape planning within a broader strategy for sustainable agriculture, forest intensification and reduced deforestation. One key theme is "to be a good cattle farmer it is necessary to be a good agricultural farmer." A mix of policies and incentives has brought about sustainable increases in productivity for livestock by encouraging landscape-based mixed agrosilvopastoral systems. The objective has been to introduce trees and improved pasture in grazing lands. This provides improved fodder and shade, lowers heat stress for animals and reduces soil degradation. Results have included: increased meat and milk yields; improved water infiltration; increased bird populations; reduced methane emissions; and greater carbon capture. These approaches have helped achieve a 'triple win': increased productivity, enhanced resilience to climate variability, and reduced carbon emissions (Lopez, 2012).

In Zambia, support has focused on technological advice to producers. In addition, modest support has been provided to producers to help them overcome the upfront costs of moving to sustainable land management in cropping and livestock systems, such as the incorporation of trees into the agricultural system. Five basic conservation farming techniques are being used: retaining crop residues; concentrating tillage and fertilizer application in a permanent grid of planting basins or series of planting rows; completing land preparation in the dry season; weeding aggressively to reduce plant competition; and intercropping or rotating nitrogen-fixing legumes on up to 30 percent of cultivated area. Many farmers also incorporate nitrogen-fixing trees, which provide fodder and fuelwood. Findings show that these practices bring significant benefits (Scherr *et al.*, 2011). However, there is also evidence that considerable barriers exist when it comes to the adoption and maintenance of these practices (Arslan *et al.*, 2013). This evidence attests to the need for institutions and policy alignment to support the adoption of CSA practices.

capacities (see also Module 12 on local institutions and Module 17 on capacity development). Developing CSA policies and programmes demands an understanding of the structure and functioning of different levels of government. This principle cuts across sectors. Participatory approaches, which are more likely to build lasting results than top-down approaches, need to be adapted to local circumstances.

Policies to mobilize non-state actors

It is important that civil society, the private sector and financial institutions are all involved in the development of CSA (more on institutions in Module 12). Civil society organizations can play a role in the development of new, adapted technologies and in the provision of extension services. An example of civil society engagement is the Kenyan agricultural soil carbon project, which is supported by World Vision, a non-governmental agency. Civil society organizations have played a strong role in testing and scaling up the 'system of rice intensification' (SRI). Paddy rice production system that poses special challenges for climate change mitigation. For example, the majority of GHG emissions in the agricultural sector in Viet Nam are linked to paddy rice production. SRI

Box 13.5
Linking productivity, adaptation and mitigation through incentive measures: the case of Karnataka, India

In India, the US$ 120 million Karnataka Watershed Project addressed dryland and hill-farming practices covering an area of 0.5 million hectares and benefiting about 1.8 million people. Using participatory approaches it introduced improved technologies and farming practices, which led to the recovery of groundwater levels (up to 50-90 feet in 3 agro-ecological zones) and improved groundwater discharges (from 250 to 326 gallons per hour). As a result, average crop yield increased by 24-26 percent; and household incomes by about 53 percent. A related follow-up operation, the Mid-Himalayan watershed project supports social mobilization; soil and water conservation treatments that follow a micro-watershed approach; farm system intensification, including improved horticultural practices and animal health; forest institution capacity building; income-generating activities; and institutional strengthening. Watershed management operations in some areas of India (e.g. the Mid-Himalayas in Umal Pradesh) are now gaining leverage with the International Development Association (IDA) and local funders through carbon finance in reforestation programmes.

Source: World Bank *et al.*, 2013

Box 13.6
Improving climate resilience through participatory pastoral development in Ethiopia

Ethiopian pastoralists are one of the most vulnerable groups to climate shocks. Livestock products, including hides and skins, are a key source of livelihoods in Ethiopia, and, after coffee, the second largest source of foreign exchange earnings. Well managed rangelands and pastoral systems are climate-resilient, bring economic benefits and conserve the natural environment.

A community pastoral development programme in Ethiopia (US$ 80 million) is working to increase the resilience of Ethiopian pastoralists to external shocks and improve the livelihoods of beneficiary communities, and in doing so, contribute to overall poverty alleviation in the country. The objectives of the programme's first component of is to enhance sustainable livelihoods and strengthen decentralized and participatory planning at the community/*kebele* (sub-district) and *woreda* level, while operating within the regional government structure. Women and men in pastoral and agropastoral communities design and implement community action plans that reflect their development priorities. The programme's second component addresses pastoral risk management. The goal of this component is to improve the existing pastoral early warning system through a participatory approach; establish an early response fund; and support disaster preparedness and mitigation investment planning and financing of associated subprojects. The third component involves improving community-level participatory learning and knowledge management and supporting knowledge management and information exchange at the federal and regional levels. The fourth component deals with project management and supports project management units at the regional and federal levels in their efforts to coordinate, supervise and implement project activities under the direction of the ministry of federal affairs and the pastoral commissions and bureaus of each region.

Source: World Bank, 2008a

is an approach to rice cultivation that increases rice yields significantly and at the same time reduces requirements for seeds, water and chemical inputs. The system originated in Madagascar, and has been successfully tested in 30 countries in West Africa, Latin America and Asia often with the support of civil society organizations.

Improving the broad enabling environment for responsible investment has a key role to play in CSA. Many private sector companies are committed to reducing the environmental footprint of their operations. They are also the principal players in building value chains and connecting farmers with markets. Box 13.7 provides an example of a technical innovation by an Indian private-sector organization in India that has developed a production system adapted to local conditions.

Monitoring and assessment framework

As assessments, monitoring and evaluation are covered in Module 18, this section only provides a brief overview on monitoring and evaluation issues from a policy perspective.

In general, monitoring and assessment for CSA should be integrated into existing measurement and assessment systems for agriculture and climate-responsible development. Simple results-based systems should be used. Also, the present capacity for monitoring and evaluation of the transition of existing agriculture and food systems to CSA needs strengthening in many countries (also see Module 17 on capacity development).

Measuring climate change adaptation is a highly debated topic. Using a single approach to measure adaptation, adaptive capacity and vulnerability presents challenges. In general, the measurement of adaptation (or vulnerability) is hampered by difficulties in defining the concept to be measured and the interaction of multiple factors, which vary depending on location, time and scale.

One way of overcoming these difficulties is to build monitoring and learning networks across food systems and across different levels of governance. The household-level decisions concerning agricultural production are often influenced by higher-level institutions and policies. A comprehensive food system monitoring and learning network enhances the understanding of an intervention's impact on the food system and on other interven-

Box 13.7
Producing a climate resilient backyard chicken in India

Kegg Farms in India has bred a robust and improved dual-purpose backyard chicken. The 'Kuroiler' lays 100-150 eggs a year. Native chicken breeds (Desi) lay around 40 eggs a year. In addition, Kuroiler birds grow to 2.5 kilograms in about half the time a native breed needs to reaches 1 kilo. Because the meat is darker and more flavourful, the Kuroiler chickens typically command a premium of about 60 Rupees per kilo over other broiler chickens.

Kegg Farms produces about 16 million day-old chicks a year, which it sells to 1 500 small enterprises. The chicks are then raised for about two weeks before they are inoculated and sold to about 6 500 bicycle salespeople, who in turn sell them to approximately 800 000 farmers. Most of these farmers are women living in some of the remotest parts of the country. The turnover in sales of chicks is about US$ 5 million a year. There is another US$ 5 million turnover from the thousands of small rurally-based businesses that raise and sell the chicks. An independent assessment indicates that the average gross revenue generated per Kuroiler chick (as eggs and meat) is US$ 3.10. With some 16 million chicks distributed annually, the total output is about US$ 50 million, with a net profit of about US$ 10 million. Profits from the Kuroiler are significantly higher than profits from the native breed. The Kuroiler birds contribute significantly to household cash flow. Women have maintained control over their chicken-growing enterprises as the business has become more commercial.

The success of Kegg Farms is due to several factors. Its chickens are more robust than other chickens; they can scavenge for food and have higher food conversion ratios. They are thus adapted to long periods of drought and can survive with limited nutrition. The company's business model features a devolved, rural-based distribution system with built-in incentives.

Source: Isenberg, 2006

tions. To track adaptation in food systems, it is often necessary to monitor process and outcomes, as well as impacts. For example, policy-level processes (e.g. the implementation of price and tenure policies) may lead to different outcomes, such as modifications in fertilizer use and more secure land tenure, and have a range of impacts, such as less fertilizer waste and more efficient land use. Finally, monitoring and learning networks contribute to the achievement of the key food system-level objective of more efficient use of scarce resources (Thornton and Lipper, 2013).

A number of countries and programmes have developed Indicators for monitoring the changes in food and agricultural systems the systems. One example is the Climate Investment Funds, which have designed generic result frameworks that are being used for the Strategic Programmes for Climate Resilience developed under the Pilot Programme for Climate Resilience (CIF, 2010). These result frameworks use key indicators for monitoring enhanced resilience, including: the presence of adequate early warning systems; changes in land degradation; social protection systems; access to long-term finance; income diversification; and budget allocations to climate-resilient activities. Process indicators include: the existence of sector policies addressing climate variability and change; the quality of planning processes and the availability of information to the public, including science-based information that incorporates local knowledge.

Within programmes, specific indicators can also be designed for particular project areas. For example, the Colombian programme of support to agrosilvopastoral systems (see Box 13.4) has led to reduced temperatures in the project area, lower heat stress for animals and greater productivity. The Ethiopian productive social safety nets programme (see Box 13.9) seeks to address the link between drought and the number of people requiring food aid.

In the United Kingdom the goal is to integrate national adaptation plans and other supported adaptation actions with departmental and 'whole-government' development approaches. While this benefits implementation, it makes it difficult to measure the impact of specific actions as opposed to the performance of the whole system. The United Kingdom has responded to these multiple challenges by devising a flexible, multidimensional and less costly approach to measuring climate change adaptation (DEFRA, 2010). The Organisation for Economic Cooperation and Development (OECD) countries has also argued for this approach.

There are a variety of approaches that are suited to monitoring mitigation and the carbon footprint of CSA interventions including: Reduced Emissions from Deforestation and Forest Degradation (REDD +) strategies; carbon footprint tools, such as the Ex Ante Carbon Balance Tool (EX-ACT) (Bockel *et al.,* 2010); value chain and farm level tools (e.g. FAO, United States Department of Agriculture, Unilever); and pilot project carbon finance operations.

Table 13.1 illustrates a framework to compare the impact of investment or policy options on the areas analysed (adaptation, resilience, food security, vulnerability and mitigation) in assessments of CAADP investment plans (Branca *et al.,* 2011). As many countries already have agricultural development plans and national climate change policies that support the development of CSA, efforts are needed to pinpoint common elements and ensure a coordinated vision. This will further enable the identification of priority actions, the institutions and policies that support CSA activities, and overall investment strategies (FAO, 2012b). Marginal abatement cost curves have also been developed to compare the cost effectiveness of different activities within low-carbon development strategies (Favor *et al.,* 2011).

Table 13.1
Multicriteria assessment of planned investments' climate-smartness

Multicriteria Assessment of the degree to which planned investments are climate-smart						
Adaptation: Reducing vulnerability related to slow onset climate change (increasing system resilience)				Mitigation: comparison against a business-as-usual”’ growth baseline		
Dimensions of system resilience			Reduce vulnerability to extreme weather events	Carbon sequestration	GHG emission reductions	GHG emission efficiency
Increase physical resiliencecrease physical resilience	Increase economic resilience	Increase social resilience		Carbonsequestered (tCO_2/ha) (net balance)	GHG reduced (tCO_2/ha) (net balance)	GHG reduced from increased efficiency of production (tCO_2/unit of product) (net balance)
Water quantity and quality	Income diversification	Extension and research				
Soil resource and soil fertility	Equity, risk management and off-farm	Technical know-how				
Seed resources		Connection to social networks				
Livestock	Diversity of employment opportunities	Education and training				
	Health and social services	Information management				
	Markets					

Source: modified from Branca *et al.*, 2011

Improving general information, data collection and data availability is a priority in many developing countries. To formulate CSA strategies and interventions reliable information, including good quality data, documented vulnerabilities and accurate evidence is required. Frequently, these data are lacking or are only available for some sub-sectors. In Africa, for example, while estimates of food produced for subsistence are generally monetized and reflected in GDP estimates, this is often not the case for timber and non-timber forest products. For The FAO Global Forest Resource Assessment records the value of non-timber forest products in Europe as US$ 7 billion (where they are of minor economic importance) compared with US$ 0.5 billion in Africa, where they are of much greater importance. This gap has relevance in prioritizing climate-smart approaches, whose benefits often include elements that are not easily monetized. A programme is underway to pilot valuing natural capital in national accounts through the WAVES (Wealth and Valuation of Ecosystems Services) initiative using country-led approaches. At present, Botswana, Madagascar, Colombia, Costa Rica and the Philippines are participating, together with a number of OECD countries including Norway and Spain.

13.4 Conclusions

While principles for CSA and related sustainable development and food security policies may be similar, there are likely to be specific policy differences between agriculture-dependent economies, urban economies and economies in transition. There will also be differences between countries that are land or water-scarce and countries that have abundant land and water resources. To formulate CSA strategies and interventions reliable information, including good quality data, documented vulnerabilities and accurate evidence is required. In addition, national capacities to implement CSA interventions and current barriers to adoption need to be systematically assessed.

CSA contributes to a cross-cutting range of development goals. It needs to be implemented using an integrated, cross-sectoral approach to agriculture and food security that links it to other aspects of sustainable development, poverty reduction and economic growth. CSA policies and programmes, as with all cross-sectoral development programmes, need to be developed so that they are aligned among all levels of government. This requires an understanding of the structure and functioning of each level of government. Comprehensive capacities need to be developed because in many countries, local-level capacity development has not been included as part of the decentralization processes.

To create an enabling environment for the development and mainstreaming of CSA in the overarching national plan, appropriate institutions with effective and transparent governance structures are needed. These institutions would coordinate the division of sectoral responsibilities and the work done by national local institutions that will incorporate CSA strategies into legal and regulatory frameworks. Regulations need to be adapted to country environments and accompanied by other supporting incentives if CSA interventions are to be successful in changing behaviour and providing additional incentives for advancing CSA.

Investment in CSA brings long-term gains in productivity, builds resilience, reduces GHG emissions and increases carbon sequestration. The most successful programmes often blend sources of funding. Incentive measures need to focus on overcoming barriers to adoption of CSA practices. Price and non-price measures are needed to support transition to CSA. Behavioural change is also an important element. Price support certainly has a role to play in countries affected by climate change, but often other forms of support (regulations, incentives, capacity development, investments in technology, innovation, efficiency gains and infrastructure, connectivity or the broader enabling environment, social protection and safety nets, and use of social capital) are more effective in paving the way for CSA.

Civil society, the private sector and financial institutions all play vital roles in implementing CSA. These groups should work jointly with key national line ministries and development agencies and donors through an efficient stakeholder consultation process.

Notes

This module was written by Majory-Anne Bromhead (World Bank) and Reuben Sessa (FAO) with contributions from Savis Joze Sadeghian (FAO) and reviewed by Leslie Lipper (FAO).

Acronyms

BDNES	Brazilian National Development Bank
CAADP	Comprehensive Africa Agriculture Development Programme
CAP	Community Action Plan
CCAFS	Climate Change, Agriculture and Food Security
CIF	Climate Investment Fund
CSA	climate-smart agriculture
DEFRA	Department for Environment, Food and Rural Affairs
DRM	disaster risk management
EX-ACT	Ex Ante Carbon Balance Tool
GAFSP	Global Agriculture and Food Security Program
GDP	gross domestic product
GHG	greenhouse gas
IDA	International Development Association
IFAD	International Fund for Agricultural Development
IISD	International Institute for Sustainable Development
NAMA	National Appropriate Mitigation Action
NAPA	National Adaptation Programme of Action
OECD	Organisation for Economic Cooperation and Development
PPCR	Pilot Program for Climate Resilience
PSNP	Productive Safety Net Programme
REDD	Reduced emissions from deforestation and forest degradation
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WAVES	Wealth and Valuation of Ecosystem Services

References

Arslan, A., McCarthy, N., Lipper, N., Asfaw, S. & Cattaneo, A. 2013. *Adoption and intensity of adoption of conservation farming practices in Zambia.* ESA Working paper No. 13-01. (available at http://www.fao.org/docrep/017/aq288e/aq288e.pdf)

Barley, D., Holmes, L. & McMahon, P. 2011. *What price resilience? toward sustainable and secure food systems.* Prince's Charities' International Sustainability Unit. London.

Bockel, L., Smith, G., Bromhead, M., Bernoux, M., Tinlot, M., Matieu, H. & Branca, G. 2010. *Mainstreaming carbon balance appraisal of agriculture projects and policies? a tool for measuring carbon-balance in Ex-ante Project-programme impact appraisal.*

Branca, G., Tennigkeit, T., Mann, W. & Lipper, L. 2011. *Identifying opportunities for climate-smart agriculture investments in Africa.* FAO. Rome. (available at http://www.fao.org/docrep/015/an112e/an112e00.pdf)

Climate Investment Fund (CIF). 2010. *Pilot program for climate resilience: results framework.* Climate Investment Funds. See also specific country programs for Bolivia, Tajikistan, Niger, Mozambique, Zambia, Nepal, Bangladesh, Pakistan. (available at http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/PPCR%204%20Results%20Framework%20nov2010_1.pdf)

Department for Environment, Food and Rural Affairs (DEFRA). 2010. *Measuring adaptation to climate change: a proposed approach.* United Kingdom.

FAO. 2010. *Climate-smart agriculture: policies, practices and financing for food security, adaptation and mitigation.* Technical Input for the First Conference on Agriculture, Food Security and Climate Change in the Netherlands.

FAO. 2012a. *Greening the economy with climate-smart agriculture.* Technical Input for the Second Conference on Agriculture, Food Security and Climate Change in Vietnam.

FAO. 2012b. *Developing a climate-smart agriculture strategy at the country level: lesson's from the recent experience.* Technical Input for the Second Conference on Agriculture, Food Security and Climate Change in Vietnam.

Favor, J., Behrends, B. & Nelissen, D. 2011. *Analysis of GHG marginal abatement cost curves.* Delft. CE Delft.

International Institute for Sustainable Development (IISD). 2006. *Designing policies in a world of uncertainty, change, and surprise: adaptive policy-making for agriculture and water resources in the face of climate change.*

Isenberg, D. 2006. *Keggfarms (India): which came first, the Kuroiler(TM) or the KEGG(TM)?.* Harvard Business Review Case Study.

Lopez, R. 2012. *Sustainable agriculture and animal production in Colombia.* Paper presented to the Ministry of Agriculture and Rural Development of Colombia during Sustainable Development Week, Bogota.

OECD. 2011. *Towards green growth.* (available at http://www.oecd.org/greengrowth/48224539.pdf)

Runsten, L. & Tapio-Bistrom, M.L. 2011. *Land tenure, climate change mitigation and agriculture. Mitigation of Climate Change in Agriculture (MICCA) project.* (available at http://www.fao.org/climatechange/30353-0c11859e8b0cac7aabe39520498b2df22.pdf)

Scherr, S. J., Buck, L.E., Majanen, T., Milder, J.C. & Shames, S. 2011. *Scaling-up landscape investment approaches in Africa: where do private market incentives converge with landscape restoration goals?* Background paper for the Investment Forum on Mobilizing Investment in Trees and Landscape Restoration. Washington D.C., EcoAgriculture Partners and Program on Forests (PROFOR).

Thornton, P. & Lipper, L. 2013. *How does climate change alter agriculture strategies to support food security?* Background paper for the Food Security Futures: Research Priorities for the 21st Century conference.

United Nations. 2012. *The future we want: outcome document adopted at Rio+20.*

United Nations Environment Programme (UNEP). 2011. *Towards the green economy pathways to sustainable development and poverty eradication.* (available at http://www.unep.org/greeneconomy/Portals/88/documents/ger/ger_final_dec_2011/Green%20EconomyReport_Final_Dec2011.pdf)

World Bank. 2008. *Ethiopia second pastoral community development project.* Project Appraisal Document.

World Bank. 2011a. *Increased productivity and food security, enhanced resilience and reduced carbon emissions for sustainable development opportunities and challenges for a converging agenda: country examples.* Agricultural and Rural Development Department.

World Bank, the African Union, CCAFS, Department of Agriculture, Forestry and Fisheries of South Africa, IFAD, PROFOR (Program on Forests), UNEP, WBI (World Bank Institute), FAO & WFP. 2011. *Climate-smart agriculture: a call to action.* Washington D.C. (available at http://climatechange.worldbank.org/sites/default/files/documents/CSA_Brochure_web_WB.pdf)

World Bank. 2012. *Mexico: strengthening social resilience to climate change.* Project Appraisal Document.

World Bank, International Finance Corporation & Multilateral Investment Guarantee Agency. 2013. *The Karnataka Watershed (Sujala) Project.*(available at http://ieg.worldbankgroup.org/content/ieg/en/home/reports/climate_change3/karnataka_watershed_project.html)

Additional Resources

Beddington, J., Asaduzzaman, M., Clark, M.E., Fernández Bremauntz, A., Guillou, M.D, Howlett, D.J.B., Jahn, M.M., Lin, E., Mamo, T., Negra, C., Nobre, C.A., Scholes, R.J., Van Bo, N. & Wakhungu, J. 2012. *Agriculture: what next after durban?*, Science, 335 (6066): 289—290.

Bockel, L., Thoreux, M. & Sayagh S. 2009. *Resilience of rural communities to climatic accidents: a need to scale up socio-environmental safety nets.* FAO Easypol Policy Brief. Madagascar & Haiti.

Brown., D., Dettman, P., Rennado, T., Teferu, H. & Tofu, A. 2011. *Poverty alleviation and environmental restoration using the CDM (Clean Development Mechanism): a case study from Humbo, Ethiopia.* Dakar, Africa Adapt World Vision.

CIF. 2011. *Forest investment plan results framework.* Climate Investment Funds. (available at https://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/FIP_Results_Framework_final.pdf)

Pagiola, S. 2008. *Payments for environmental services in Costa Rica, Ecological Economics, 65 (4): 712–772.*

World Bank. 2008. *World development report 2008: agriculture for development.* Washington D.C.

World Bank. 2008. *China biogas.* Project Appraisal Document. Washington D.C.

World Bank. 2010. *Turpan water conservation program.* Project Appraisal Document. Washington D.C.

World Bank. 2010. *World development report 2010: development and climate change.* Washington D.C.

World Bank. 2010. *China forest policy: deepening the transition, broadening the relationship.* East Asia and Pacific Region. Washington, DC.

World Bank. 2011b. *Ethiopia pastoral development project.* Project Appraisal Document.

MODULE 14:

FINANCING CLIMATE-SMART AGRICULTURE

Overview

Investments made in the agricultural sector are intended to achieve multiple objectives, such as agricultural growth for food security, poverty reduction and economic development. Climate change, already evident in the increased frequency of extreme weather events, is projected to have profound effects on the agricultural sector in the future. It has become necessary to explicitly incorporate projections of future impacts of climate change into today's investment planning. Integrating adaptation to existing and future threats posed by climate change into current agricultural planning and investment is essential for reducing vulnerability to the impact of climate change and the costs of dealing with these impacts. It is also essential to identify and account for mitigation potential. Reducing projected emissions growth from agricultural development can slow the progression of climate change and reduce the costs of adaptation. Many mitigation actions are synergistic with activities that promote agricultural growth and have the potential to attract new sources of finance for sustainable agriculture.

This module gives an overview of how climate change alters agricultural investment needs. It focuses on agricultural growth to support food security and poverty reduction objectives in developing countries. The first part of the module summarizes the current state of agricultural investment in developing countries, including major sources, levels and composition, and looks at how climate change adaptation and mitigation affect investment needs. It also provides insights as to how climate change affects farmers' investment behaviour and the implications that this has for public sector investments to support the adoption by farmers of climate-smart agriculture (CSA).

The second part of the module describes the current and future potential of climate finance to support CSA. Six sources of climate finance are analysed in terms of their potential for CSA investment financing: financing mechanisms directly under the UNFCCC; UN organizations or programmes; Multilateral Development Banks (MDBs); bilateral public financing channels; compliance and voluntary carbon markets; and private sector investors and philanthropy. The module concludes with a look at emerging opportunities for CSA financing and the need for national actions that ensure readiness to access this financing.

Key messages

- Current agricultural investment flows are insufficient to adequately finance sustainable agricultural development. This financing deficit is due not only to a lack of overall funds, but also to the fact that the activities that are currently allocated resources do not generate the highest returns for sustainable agricultural growth. The main sources of agricultural investment finance are the farmers, herders, fishers and foresters themselves. For this reason, public investment that enables agricultural producers to make investments in CSA is a priority.
- The changes in agricultural systems needed to achieve agricultural growth for food security under climate change are largely built upon sustainable agricultural intensification activities. Building an evidence base to identify the most suitable activities (e.g. explicitly accounting for adaptation and mitigation impacts) is an essential part of developing CSA strategies, investments and financing plans.

- Climate finance can play an important role in meeting the CSA investment gap, but there are some challenges that must be addressed. To date, most public sector climate finance, as well as almost all private sector climate financing, flows into mitigation activities in the industrial and energy sectors. While the newly established Green Climate Fund (GFC) may shift the balance between mitigation and adaptation funding in the mid-term, currently adaptation financing, a significant part of which is targeted to agriculture activities, is small in comparison to mitigation financing. Consequently, the financing gap for CSA remains large. In addition, the traditional separation of mitigation and adaptation in funding sources has hindered investments in activities that generate synergies between the two; a key facet of CSA.
- A recent positive developments related to CSA financing is the Global Environment Facility's (GEF) movement towards combining adaptation and mitigation activities in the draft GEF-6 CCM strategy. The substantive upgrading of CSA in the GEF-6 Strategy might be reflected to some degree in the priority setting of the GCF. This means that, regardless of the ultimate structure of financing channels, the GCF has the potential to be a clear and direct financing option for CSA activities, presumably with a significantly higher volume than current multilateral funding instruments.
- While interest in agricultural GHG emission reductions has been increasing in voluntary carbon markets, the share of actual activities in any carbon market remains small. There are some promising niche markets for agricultural carbon credits, such as methane avoidance from manure management, fertilizer use efficiency and REDD+ forest certificates. However, because of high transactions costs and a lack of methodologies, together with the challenges that carbon markets are facing in general, carbon finance is unlikely to develop into a significant source of CSA finance in the near future.
- For developing countries, changing patterns of climate finance represents an opportunity as well as a challenge. To successfully access, but more importantly, to effectively use increasing volumes of international CSA financing, developing countries will have to ensure that they have fulfilled the necessary prerequisites. Building the CSA evidence base and institutional capacities will be needed to secure a foundation for larger-scale CSA investments.

Contents

List of Figures

List of Tables

List of Boxes

14.1 Introduction

This module addresses the issue of financing climate-smart agriculture (CSA). The first part of the module looks at how climate change affects investment needs for agricultural development to support food security, poverty reduction and economic growth. The focus of the module is on the near term – particularly the next 20 years, as this is the critical window of opportunity to transform agricultural systems to reduce the vulnerability of rural populations to climate change by improving rural livelihoods, income and welfare. Some 70 percent of the food insecure people in the world are rural and directly or indirectly dependent on agriculture for income as well as food (IFAD, 2011). People who are poor and food insecure, and who rely on agricultural production for their livelihoods are amongst the most vulnerable to climate change (HLPE, 2012). In the next 20 years, rural populations in the two areas of the world with the highest incidence of food insecurity and poverty, sub-Saharan Africa and South Asia, are expected to peak (IFAD, 2011). Investment to support sustainable agricultural growth in these areas is essential, as experiences have shown that the most effective means of reducing poverty and food insecurity amongst rural populations in agricultural-based economies is economic growth in the agricultural sector (World Bank, 2008; De Janvry and Sadoulet, 2010). Agricultural growth for food security and poverty reduction is also a key adaptation strategy by reducing vulnerability and increasing the resilience of affected people. Investment is the engine for such growth, but until now the levels and composition of investment have not been adequate to stimulate needed growth, particularly in those regions where it is most important.

Climate change multiplies and alters the challenges of achieving sustainable agricultural growth for food security, and this has important implications for investment strategies. The necessity of adapting to and mitigating climate change mandates reconsideration of growth strategies and investment priorities. Most of the models assessing climate change impacts on agriculture indicate that major impacts on temperature and rainfall patterns and thus agricultural production will occur after 2050. In the intervening years, however, increased frequency and intensity of climate shocks such as drought, flooding and extreme temperatures are expected and are already occurring (IPCC, 2012). The critical importance of achieving mitigation in the near term to avoid future and larger costs of climate change compels planners to incorporate low emission considerations into large capital investment plans that have the potential to generate significant new emissions, as is the case with widespread agricultural growth strategies in developing countries.

However it is also important to consider the effects of climate change on agricultural growth and investment strategies within the larger context and challenges of sustainable agricultural development. Major drivers of change — such as rapidly evolving food systems and food markets, increasing population land ratios in rural areas and increasing resource scarcity and costs in some areas— mandate the need for different agricultural development models. Strategies have been articulated in the sustainable agricultural development and intensification literature, which forms an important basis for building CSA strategies and investments for specific contexts.

14.2 How does climate change affect investment needs for agriculture?

In order to understand how climate change affects agricultural investment needs in developing countries, it is necessary to first obtain an understanding of investment needs to support development and the current deficit in meeting these needs (this is referred to as the "development deficit"). This then must be complimented with an analysis of how climate change alters what is needed to achieve development – e.g. to "keep development on track" (Brooks *et al.*, 2011). Accounting for the costs of failing to adequately adapt to climate risks is defined as the "adaptation deficit" which essentially adds to the development deficit. A final, but equally important issue to consider is how mitigation may affect agricultural investment requirements, and the implications for financing – e.g. a "mitigation deficit". In this section we present information on the current state of understanding on these three dimensions of investment requirements for agriculture, concluding with a discussion of the overall implications for financing flows and instruments to support CSA.

The development deficit

In 2009, FAO estimated that average annual investment flows amounting to US$ 209 billion would be needed to meet the projected growth in demand for agricultural products in 2050 in 93 developing countries (Schmidhuber *et al.,* 2009). This estimate was derived under a set of assumptions about population and consumption growth and focussed on investment to meet global food demand which implies some reduction in food insecurity but not total eradication of hunger. In a separate study analysing the additional incremental public expenditures needed to eradicate hunger by 2025, Schmidhuber and Bruinsma (2011) estimated that an additional annual investment expenditure of US$ 50.2 billion/year would be needed. The categories where the largest additional investment needs for hunger eradication were rural infrastructure (roads and water) and safety nets, but additional investments for improved management of natural resources, research and development and rural institutional development were also identified (Schmidhuber and Bruinsma, 2011).

Farmers (as well as herders, fishers and foresters) are by far the largest source of agricultural investment finance (FAO, 2012a). However, they face significant barriers and disincentives to invest in activities that support sustainable agricultural growth, particularly smallholders. One key barrier is gender; on average, women comprise 43 percent of the agricultural labour force in developing countries, ranging from just over 20 percent in Latin America to almost 50 percent in Eastern Asia and sub-Saharan Africa, yet they have considerably less access to the land, financing, inputs and knowledge needed to support investments (FAO, 2011a). Other important barriers include poorly functioning systems of rights to land and water, thin or non-existent credit and insurance markets, lack of effective extension services and the technical packages for agricultural productivity growth adapted to specific contexts, as well as poor agricultural value chains (McCarthy *et al.*, 2011). Thus, a key role of public sector finance is to create the conditions and incentives for farmers to make needed investments. However, recent research indicates that public sector investments in agriculture are lagging in areas where growth is essential for poverty reduction (e.g. South Asia and sub-Saharan Africa). Furthermore, the composition of public sector spending on agriculture does not favour investments with the highest returns to long-term agricultural growth.

Table 14.1, reproduced from the 2012 State of Food and Agriculture report, illustrates the problem. The table summarizes public sector spending per agricultural worker in low- and middle-income countries by region. It indicates that the absolute levels of spending per agricultural worker in South Asia and sub-Saharan Africa are the lowest amongst the regions, and the growth rate over past decades has been very low (South Asia) or negative (sub-Saharan Africa).

Table 14.1
Public spending on agriculture per worker in low- and middle-income countries by region

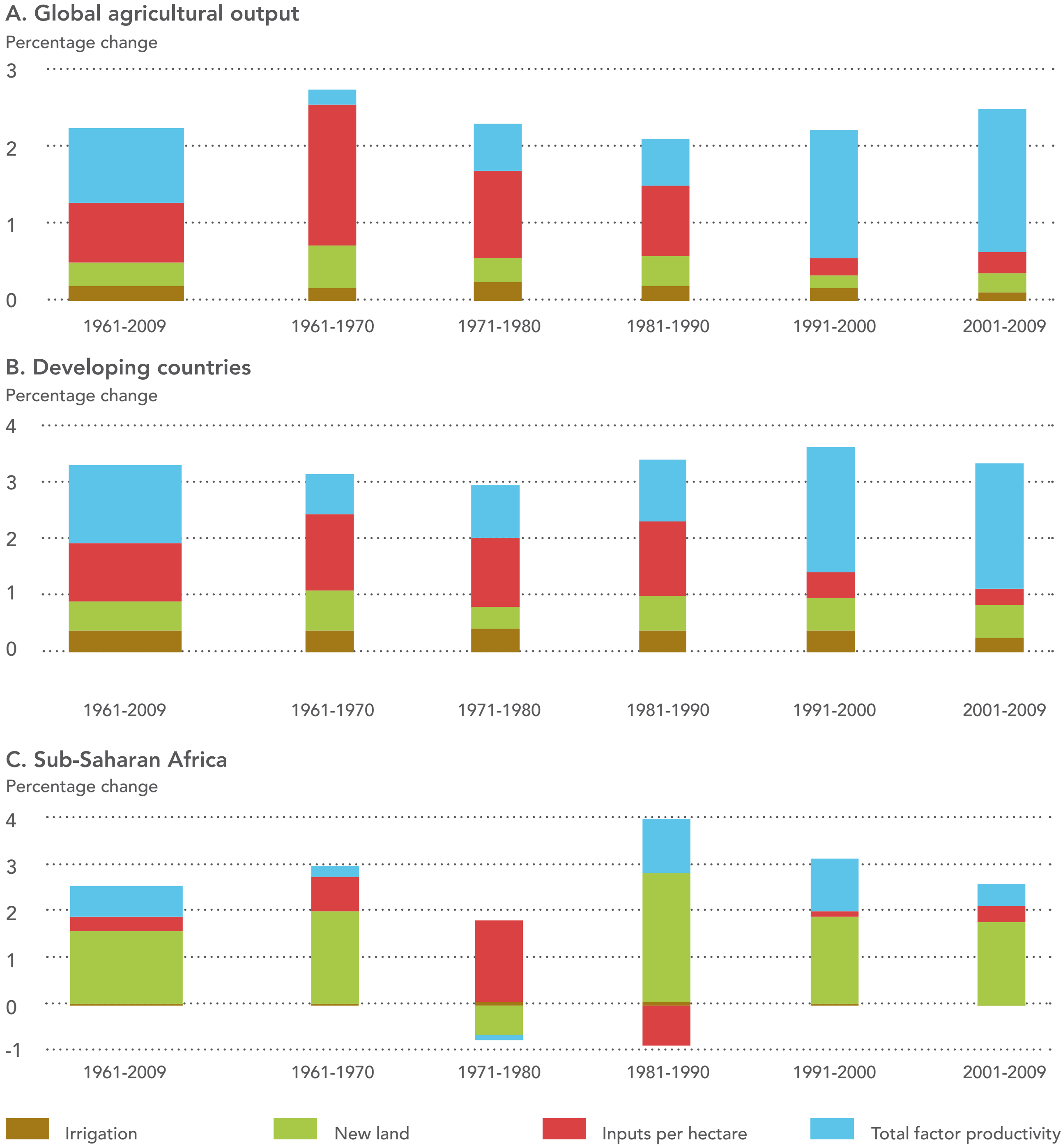
Region	1980–89	1990–99	2000–04	2005–07
(Constant 2005 PPP dollars)				
East Asia and the Pacific (8)	48	69	108	156
Europe and Central Asia (9)		413	559	719
Latin America and the Caribbean (10)	337	316	309	341
Middle East and North Africa (7)	458	534	640	677
South Asia (7)	46	50	53	79
sub-Saharan Africa (10)	152	50	51	45
total (51 countries)	68	82	114	152

Notes: calculations include 51 low- and middle-income countries. The number of countries included in each group is shown in parentheses. For countries in Europe and Central Asia estimates are from 1995 to 2007.

Source: FAO, 2012a

The 2012 SOFA report also gives evidence that the deficit in overall levels of spending is compounded by poorly targeted expenditures that generate relatively low returns to agricultural growth and poverty reduction. In an analysis comparing the sources of growth in agricultural output over time, the report found that in most areas of the world recent growth has been attributable to growth in Total Factor Productivity (TFP), a measure of resource-use efficiency, which is a fundamental building block of CSA. This is in contrast to past decades where growth was driven by area expansions and increases in input use. However, one exception is sub-Saharan Africa, where TFP as a source of growth has actually decreased since 2001, with input use increasing as a source of output growth. Altering investment patterns to augment the role of TFP in driving agricultural growth, and reducing the importance of area expansion and increased input use is needed to support climate-smart agricultural growth.

Figure 14.1
Sources of growth in agricultural output by investment category



Source: FAO, 2012a

Focussing public sector spending on essential public goods such as agricultural research and development, rural transport and human capital development will allow countries to shift to more sustainable and climate-smart sources of agricultural growth. Analysis has shown that expenditures in these categories have consistently shown higher returns than expenditures on semi-private goods such as input subsidies (FAO, 2012a). Yet public expenditures for such goods are still a high proportion of total public investments in agriculture for many countries (FAO, 2012a).

Thus, meeting the development deficit will require not only an increase in overall spending, but also a significant shift in composition of spending for many countries.

Investments for adaptation

The need to adapt to climate change in the near, medium and long term implies changes in agricultural investment needs ranging from the farm scale up to the national and international levels. There is more than one way of categorizing adaptation actions in agriculture. For example, in the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), the nature of the changes required for adaptation was divided into two main categories: spontaneous and planned.

A more recent publication divides adaptation actions into three categories: adapting to the current adaptation deficit, adapting to incremental changes and adapting to qualitative changes (Brooks *et al.*, 2011). The table below is reproduced from the report and gives examples of what is included in each category.

Table14.2
Adaptation categories, types and examples

Category of Type of adaptation action		Examples
Addressing the adaptation deficit	Resilience building	• Livelihood diversification to reduce poverty in context of climate variability • Crop insurance, seasonal forecasting and other agricultural innovations including irrigation • Early warning systems for disaster risk reduction
Adapting to incremental changes	Climate proofing	• Upgrading of drainage systems to accommodate greater runoff due to more intense precipitation • Adapting cropping systems to shorter growing seasons, greater water stress and heat extremes (e.g. through crop substitution, irrigation and new strains) • Improving disaster risk reduction systems to cope with more frequent and severe extremes
Adapting to qualitative changes	Transformational change	• Phased relocation of settlements away from areas at existential risk from sea-level rise • Shifts in emphasis in large-scale economic activity away from areas/ resources threatened by climate change (e.g. away from water-intensive agriculture, climate-sensitive tourism, high-risk marine resources, to less sensitive activities) • Transformation of agricultural systems from unsustainable (under climate change) intensive rainfed or irrigated agriculture to lower input e.g. pastoral or agropastoral systems.

Source: Brooks *et al.*, 2011

It is useful to categorize adaptation in terms of how it alters the projection of agricultural investment needs for development – in terms of amount, timing and type of investment required. This entails estimating the additional costs adaptation imposes on agricultural investments. Some studies have been done on this issue at global, national and local levels with various methods employed. For example, the United Nations Framework Convention on Climate Change (UNFCCC) estimated an additional US$ 14 billion would be required annually for adaptation in agriculture globally, divided equally between developing and developed countries (Parry *et al.*, 2009).

Nelson *et al.* (2009) estimate the negative impacts of climate change on crop productivity and then on child malnutrition. Their model's results indicate that approximately US$ 7.1 billion is needed annually in additional productivity enhancing investments to counteract the negative impacts of climate change and maintain a baseline level of welfare, of which US$ 3 billion would be for sub-Saharan Africa, and US$ 1.5 billion for South Asia.

It is important to recognize that these studies are generally based on calculating the additional resources climate change adaptation necessitates – assuming that the base investment requirements for development are in place (Parry *et al.*, 2009). As the discussion in the previous section has indicated, this is generally not the case, and particularly in the case of the two most vulnerable agricultural areas in the world – sub-Saharan African and South Asia— there is a large deficit in investment resources. This is the adaptation deficit and it is the main reason these countries are considered so highly vulnerable to climate change.

Another important issue to consider is the potential costs of maladaptation (e.g. agricultural investments that increase vulnerability to climate change or increase risks of economic losses associated with unsustainable and unprofitable investments). Investments, particularly large fixed capital investments with significant lifetimes, are particularly vulnerable to being maladaptive if climate risks are not considered. An example that is likely to be maladaptive and essentially add to the adaptation deficit is a case where major capital expenditures on irrigation systems use outdated estimates of water demand and supply in areas where climate change is predicted to have major impacts.

Screening agricultural investment plans for their degree of "climate smartness" is a simple first step that can be taken to identify the potential overlap between adaptation and development investments, as well as potential maladaptive agricultural investments. FAO (2012b) presents a simple screening methodology and applies it to a set of agricultural investment plans developed under the Comprehensive African Agricultural Development plans (FAO, 2012b). The screening methodology considers the potential contribution of planned activities to various aspects of adaptation as well as mitigation.

The conclusion of the screening was that there potentially is a high degree of "climate smartness" in existing agricultural investment planning, although more detailed analysis for specific locations and climate change effects would be needed.

A more detailed analysis of the potential investment costs likely to be associated with CSA activities was conducted for Malawi, using the screening methodology applied to the national agricultural strategy and investment plan as a starting point (Branca *et al.*, 2012). The Agriculture Sector Wide Approach (ASWAp) is the national agricultural plan for Malawi, and it includes prioritization and target scales for major agricultural investment activities. Using information from the ASWAp, as well as indicative investment costs from a range of sources, Branca *et al.* (2012) developed the estimates shown in Table 14.3 below. This table shows the unit and total capital investment costs associated with priority agricultural investments that have high potential CSA characteristics (e.g. the potential to generate agricultural growth while incorporating the need for adaptation and mitigation).

Table 14.3
Indicative investment costs for top ranking CSA investments in Malawi's ASWAp

Practice	Details of the practice	Target area	Total capital cost	Unitary capital cost
		ha	(000$)	($/ha)
Agronomy	Develop improved crop varieties, multiply breeder seed, increase distribution of improved maize seed, train staff and farmers in seed multiplication	3 200 000	230 976	72
Integrated nutrient management	Promote good agricultural practices (GAP), develop and promote technologies taht maintain soil fertility (increased efficiency of fertilizers and organic fertilization), fertilizers subisdy programme	3 200 000	390 976	122
Tillage/residue management	Conservation agriculture	150 000	21 100	141
Agroforestry	Live barriers, promote coomunity-based dambo management, prevent river banks degradation	70 000	35 920	513
Water management	Rehabilitate existing irrigation schemes and develop new ones with appropriate systems, establish rainwater harvesting systems (dams, box ridges), strengthen technical capacity for irrigation management, promote water users associations	228 000	167 670	735

Note: Values are from 2009-2013 in the cereals sub-sector

Including mitigation in investment analysis

Unlike adaptation, mitigation is a political choice rather than a biophysical necessity, despite its critical importance in ensuring human well-being. The role of developing countries in contributing to global mitigation has been the subject of much debate in the UNFCCC process and the issue is still not resolved. Yet the case for including mitigation considerations into agricultural planning is strong. Not only is the agricultural sector a projected significant source of emission growth, it is also one where a considerable number of new capital investments are required in order to achieve needed growth. Thus, there is the opportunity to build low emission capacity directly into the sector, rather than replacing existing inefficient capital infrastructure. Delaying emissions reductions (from any source) will result in higher global costs of climate change, and the developing countries and their agricultural sectors stand to bear much of these costs.

The cost of generating mitigation from agricultural sources is generally estimated by looking at the impact on the returns to agricultural activities. The opportunity cost – or the amount of income that a farmer would have to forego in making a climate-smart investment is calculated to give an estimation of mitigation costs. This involves estimating the net returns to a baseline or "without mitigation" agricultural investment compared with the returns to alternative options that include mitigation. Since many of the activities associated with agricultural mitigation also have the potential to generate positive net returns to the agricultural system itself (e.g. there are synergies between mitigation and agricultural returns) the opportunity costs are negative or very low (FAO, 2009). For example, restoring degraded grazing lands can generate a net positive return to grazing activities – as well as generate mitigation. In this sense the mitigation cost would be considered zero, or even negative (e.g. the positive return to grazing could be considered a negative cost to mitigation). Two key features of sustainable agricultural intensification strategies that increase agricultural returns offer the potential to capture significant mitigation co-benefits: increasing resource use efficiency and increasing carbon stocks in soils and above-ground biomass (e.g. trees and perennials).

However it is important to recognize the shortcomings in adopting this approach. First of all, the returns to agricultural activities that also generate positive mitigation benefits vary considerably across agro-ecological and socio-economic conditions, so broad estimates of positive returns need to be carefully scrutinized in more specific contexts. Soil type, rainfall patterns, farming systems and input and output market conditions are all key determinants of the returns. Secondly, the costs of transitioning to the agricultural activity with mitigation benefits can be quite significant, involving the need for institutional and infrastructural investments that are generally not fully included in the opportunity cost assessment. The costs of having an effective extension service, road transport and input supply that would be essential to achieve higher returns under an improved practice are generally not included in opportunity cost analysis of mitigation activities which would look only at farm level returns. The importance of having such an enabling environment and the implications for agricultural investments can be seen from the experience in recent decades of promoting sustainable agriculture. Often, these efforts have not resulted in the scale of adoption and transformation envisioned, because the necessary enabling environment was not in place (FAO, 2011c).

A final and important cost issue to consider when looking at the potential response of agricultural producers to mitigation payments, is that the transaction costs of participating in such a programme are not included and they can be a significant barrier, particularly where fairly stringent measurement, reporting and verification (MRV) requirements are needed to access financing (FAO, 2009 and 2011b). This issue is particularly important when looking at the potential of carbon market finance for smallholder agriculture (FAO, 2011b). It is also one of the reasons that public sector mitigation finance integrated into agricultural financing channels is considered a more viable option for scaling up mitigation financing in many developing country contexts.

The table below, Table 14.4, summarizes some of the potential synergies and trade-offs that may arise in implementing agricultural activities that have high mitigation potential. The left hand column in the table (changes in agricultural systems) refers to activities identified by the IPCC fourth assessment report as major potential sources of mitigation potential. The columns to the right then summarize potential impacts on crop/agricultural returns, as well as potential effects on the variability of returns, which is a key element of adaptation. The table gives illustrative examples only, but indicates that while there is considerable potential to capture synergies between productivity, stability and mitigation from changes in agricultural systems, there is also considerable potential for trade-offs to arise in specific contexts.

Table 14.4
Food production and resilience impacts of changes in agricultural production systems

Changes in agricultural systems	Impacts on Food Production		Impacts on Yield Variability and Exposure to Extreme Weather Events	
	Positive	Negative	Positive	Negative
Cropland Management				
Improved Crop Varieties	Increased crop yield		Reduced variability at plot level; greater diversity of seed varieties should reduce variability at the local/sub-national level	
Improved crop/ fallow rotations	Higher yields during crop rotation, due to increased soil fertility	Reduced cropping intensity may compromise household food security in short-run	Reduced variability due to increased soil fertility, water holding capacity	
Use of legumes in the crop rotation	Higher yields due to increased nitrogen in soil	Reduced cropping intensity may compromise household food security in short-run		
Use of Cover Crops	Higher yields due to reduced on-farm erosion and reduced nutrient leaching	May conflict with using cropland for grazing in mixed crop-livestock system	Reduced variability due to increased soil fertility, water holding capacity	
Increased efficiency of nitrogen Fertilizer/Manure Use	Higher yields through more efficient use of nitrogen fertilizer and/or manure		Lower variability more likely where good drainage and infrequent drought ; experience can reduce farm-level variability over time	Potentially greater variability frequent droughts and inexperienced users
Incorporation of Residues	Higher yields through increased soil fertility, increased water holding capacity	Potential trade-off with use as animal feed	Reduced variability due to increased soil fertility, water holding capacity	
Reduced/Zero Tillage*	Higher yields over long run, particularly where increased soil moisture is valuable	May have limited impact on yields in short-term; weed management becomes very important, potential waterlogging problems	Reduced variability due to reduced erosion and improved soil structure, increased soil fertility	
Live Barriers/ Fences	Higher yields	Reduces arable land to some extent	Reduced variability	
Perennials/Agro-Forestry	Greater yields on adjacent croplands from reduced erosion in medium-long term, better rainwater management; and where tree cash crops improves food accessibility	Potentially less food, at least in short-term, if displaces intensive cropping patterns	Reduced variability of agro-forestry and adjacent crops	

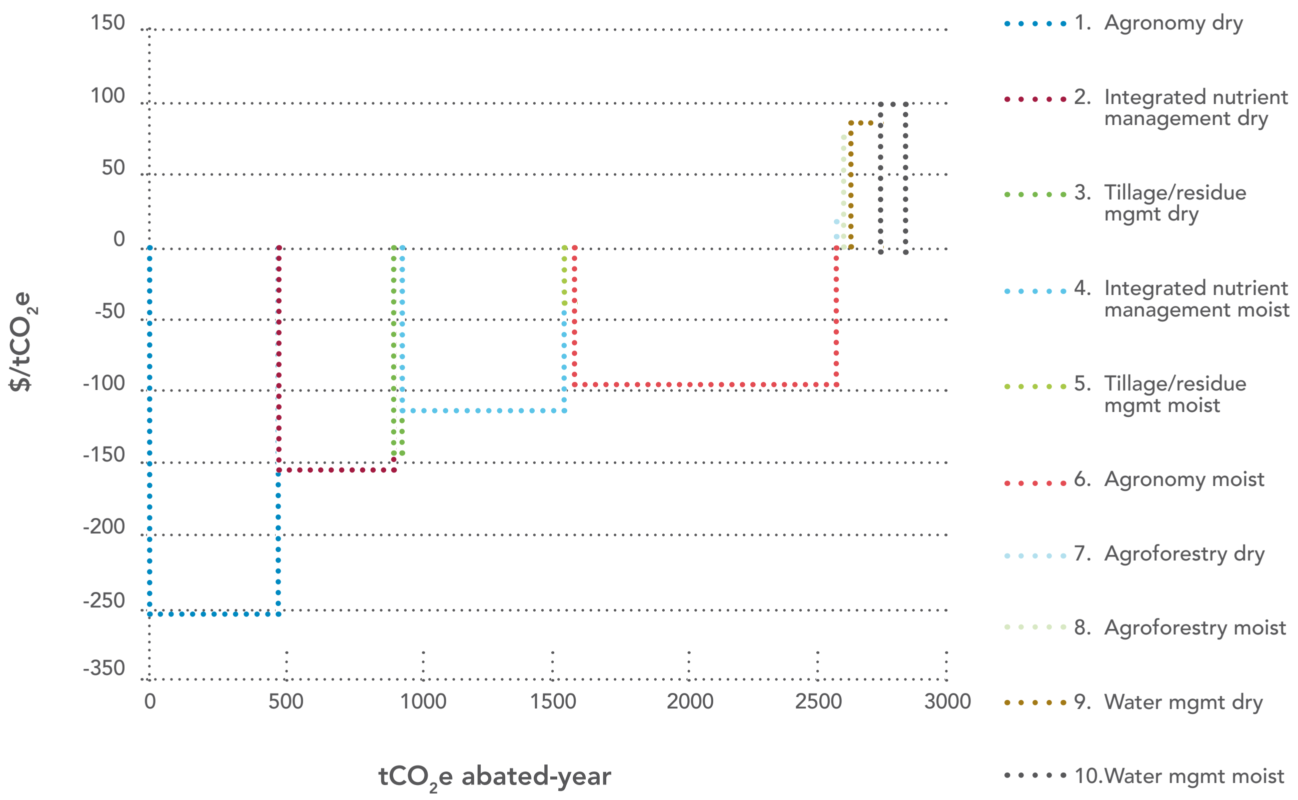
Changes in agricultural systems	Impacts on Food Production		Impacts on Yield Variability and Exposure to Extreme Weather Events	
	Positive	Negative	Positive	Negative
Water Management				
Irrigation	Higher yields, greater intensity of land use		Reduced variability in well-functioning systems	
Bunds/Zai	Higher yields, particularly where increased soil moisture is key constraint	Potentially lower yields when extremely high rainfall	Reduced variability in dry areas with low likelihood of floods and/or good soil drainage	May increase damage due to heavy rains, when constructed primarily to increase soil moisture
Terraces	Higher yields due to reduced soil and water erosion, increased soil quality	May displace at least some cropland	Reduced variability due to improved soil quality and rainwater management	
Pasture and Grazing Management				
Improving forage quality and quantity	Higher livestock yields due to more and higher quality forage		Reduced variability where improved forage is adapted to local condition	Potentially increased variability where improved forage more sensitive to climate conditions than natural pasture
Seeding fodder grasses	Higher livestock yields due to greater forage availability		Reduced variability where seeded fodder is adapted to local condition	Potentially increased variability where improved seeded fodder more sensitive to climate conditions than natural pasture
Improving vegetation community structure	Greater forage/fodder in medium-long term	May reduce forage/ fodder in short-term	Reduced variability due to improved soil structure, reduced erosion	
Stocking rate management	Potential increased returns per unit of livestock	Returns at the herd level may decline, at least in the short term	Potentially lower variability in long term, where forage availability is key factor in livestock output variability	
Rotational Grazing	Higher livestock yields due to greater forage availability and potentially greater forage quality	Short-term losses likely if rotational system supports fewer head of livestock	Potentially lower variability in long term, where forage availability is key factor in livestock output variability	
Restoring Degraded Lands				
Re-vegetation	Improved yields when crops sown in the medium-long run; improved yields on adjacent crop or grassland due to reduced wind, soil and/or water erosion		Reduced variability in local landscape due to reduced wind, soil and/or water erosion	
Applying nutrient amendments (manures, bio-solids, compost)	Improved yields when crops sown in the medium-long run			

Source: FAO, 2009

This suggests that climate-smart agricultural investments with mitigation co-benefits should be identified within the context of existing agricultural investment strategies developed for the purposes of agricultural growth for a specific context. One fairly simple (albeit crude) way of doing that is using the CSA screening methodology described in the previous section. Such a process can identify the potential for agricultural transitions planned for agricultural growth and development to generate mitigation co-benefits. Once these have been identified further analysis to develop a marginal abatement cost curve for agricultural mitigation can be conducted to identify where synergies are most likely to be present.

Figure 14.2 below illustrates an example of such a marginal abatement cost curve developed from screening the Malawi ASWAp described in the preceding section (Branca *et al.*, 2012). The analysis is built upon estimates of the potential mitigation that can be generated from agricultural activities prioritized in the ASWAp and the CSA screening process[1]. The analysis indicates that several of the planned activities will generate mitigation benefits at no additional cost at the farm level (e.g. activities whose costs are less than zero in the figure). The two activities with high up-front investment costs — agroforestry and water management in drylands— are the ones showing a positive marginal abatement cost, implying the need for external finance (e.g. for the associated mitigation benefits) to support the investment. The width of each step in the marginal abatement cost curve is derived from the magnitude of the targeted activity articulated in the ASWAp. This type of analysis can be useful in obtaining a rough estimate of potential mitigation benefits agricultural investment activities could generate, which can be used both for ranking investments as well as setting targets. This type of analysis can ultimately develop linkages to climate finance with a mitigation focus; however, as noted above, it is essential that it be accompanied by an analysis of the barriers to adoption and investment implications to overcome them, in order to obtain a full understanding of the costs and benefits of the activities.

Figure 14.2
Marginal abatement cost curve for selected CSA practices in Malawi



Source: Branca *et al.*, 2012

[1] The analysis was conducted using the Ex-Act tool (this tool is also discussed in Module 18). A more complete description of the analysis can be found in Branca *et al.*, 2012.

Farmers' investment behaviour

Given the importance of farmers as a source of agricultural investment, the potential impacts of climate change on farm investment decision-making is a critical issue to consider, and explicitly account for, in agricultural investment planning. Since the changes in agricultural systems needed to achieve agricultural growth for food security under climate change are largely built upon sustainable agricultural intensification activities, it is useful to also look at the lessons learned on farmers' investment patterns across different farming systems and socio-economic conditions. There are generally a range of possible options for sustainable agricultural intensification. Therefore, building an evidence base to identify which are most suitable to meet agricultural development goals under climate change (e.g. explicitly accounting for adaptation and mitigation impacts as well as food security and economic growth) is an important step in developing climate-smart agricultural strategies and investment plans.

In this section we highlight two important areas where climate change affects the incentives and constraints agricultural producers face in making investment decisions: increasing risk and uncertainty and augmenting the benefits of resource use efficiency (as well as the costs of inefficiency). Both of these factors are well recognized as important issues in agricultural investment behaviour in the context of sustainable agricultural intensification, and this module recommends building on this knowledge in assessing the potential impacts of climate change and potential public investments needed to address associated barriers to farm level investment. The responses to these two challenges as well as the implications for agricultural investments are often interlinked.

Coping with increased risk and uncertainty

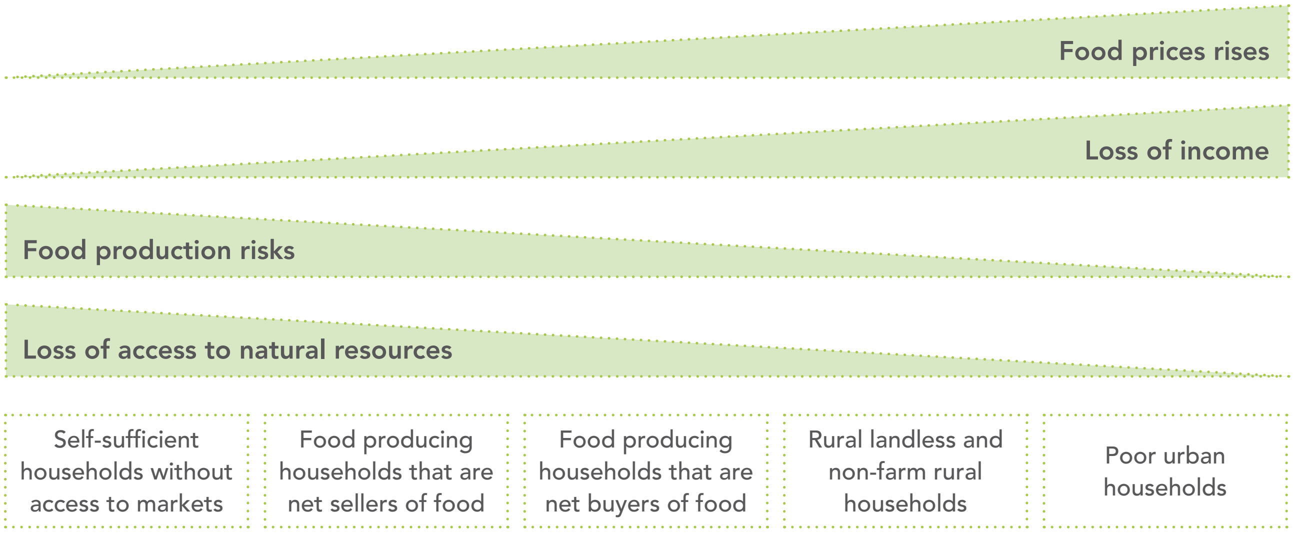
Climate change is already having effects on the risks and uncertainty that farmers face, and this has important implications for their decisions on agricultural investment. A large body of research on the effects of risk and uncertainty on farm decision-making indicates that they significantly change investment patterns in a number of possible ways: the selection of low-re urn but low-risk subsistence crops for investment (Heltberg and Tarp, 2002; Sadoulet and de Janvry, 1995; Fafchamps, 1992; Roe and Graham-Tomasi, 1986), lower likelihood of applying purchased inputs such as fertilizer (Dercon and Christiaensen, 2011; Kassie *et al.,* 2008), lower likelihood of adopting new technologies (Feder *et al.,* 1985; Antle and Crissman, 1990) and lower overall levels of investment (Skees *et al.,* 1999). All of these responses generally lead to both lower current and future farm profits (Hurley, 2010; Rosenzweig and Binswanger, 1993).

Managing risk and uncertainty at the farm level is thus essential in creating an enabling environment for farmers to invest in CSA practices. This in turn has implications for the development of public sector investment strategies: what does the public sector need to invest in to provide the enabling environment for managing risk and uncertainty under climate change? Gitz and Meybeck (2012) argue that there are three ways to increase resilience[2] in agricultural systems to address climate change risks: 1) reduce exposure; 2) reduce the sensitivity of systems to shocks; and 3) increase adaptive capacity. Measures can be taken ex-ante, ex-poste or during shocks and they comprise actions aimed at increasing resilience in ecosystems as well as in social and economic systems. The measure that will be most effective in increasing resilience in any specific context will depend on the main sources of vulnerability.

Figure 14.3 below, illustrates different sources of vulnerability across a range of household types, differentiated according to their entitlements to food (e.g. through own production and purchased with wage, agricultural income or transfers) (Sen, 1981). The figure illustrates that the main source of vulnerability to food insecurity can range from a production loss to market disruptions and volatile food prices. In analysing the public investment requirements to mitigate climate change induced vulnerability in the agricultural sector it is important to identify the nature of the vulnerability in order to develop an effective response. Planning and investments to increase resilience must also take into account the effects of increased uncertainty on developing "no regrets" strategies and avoiding maladaption (Gitz and Meybeck, 2012).

[2] Resilience is defined as "increasing the capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk and recover from shocks." Gitz and Meybeck, 2012. p.29.

Figure 14.3
Sources of vulnerability across different groups



Source: FAO, 2012c

The following section highlights important strategies for increasing resilience in agricultural systems under climate change and their implications for investment planning.

Information generation and dissemination. Generating, disseminating and translating information into a useful form is the key response to uncertainty generated by climate change. Much effort has been invested in helping farmers to make more effective climate-sensitive decisions (e.g. planting times and livestock shelter) via improved access to timely, meaningful and trustworthy climate information and knowledge. The investments need to support the development of a technical component developing agro-climate tools (Hansen and Coffey, 2011) — with institutions improving channels both for uptake of information and for demand for that information— supported by new information technology (e.g. information communication technology applications) (Thornton and Lipper, 2013). Investments to generate needed information as well as to support institutions/programmes for its dissemination are thus important in CSA.

Insurance. Agricultural insurance has expanded rapidly in recent years, with global agricultural premium value expanding from US$ 8 billion in 2004 to over US$ 20 billion in 2008 (Mahul and Stutley, 2010). However in low-income countries the penetration rates (measured by ratio between agricultural insurance premium value and agricultural gross domestic product) are still very low. Both the private and public sector could have a role in expanding insurance coverage in low-income countries vulnerable to climate risk. The ultimate costs depend on the nature of the support provided. Subsidizing premiums is the most common form of support in high-income countries, which require high levels of public investment. However, concerns have been raised about the effectiveness of such programmes, and their potential to lead to maladaptation by providing incentives to maintain production patterns that are no longer economically viable (Mahul and Stutley, 2010; FAO, 2012e).

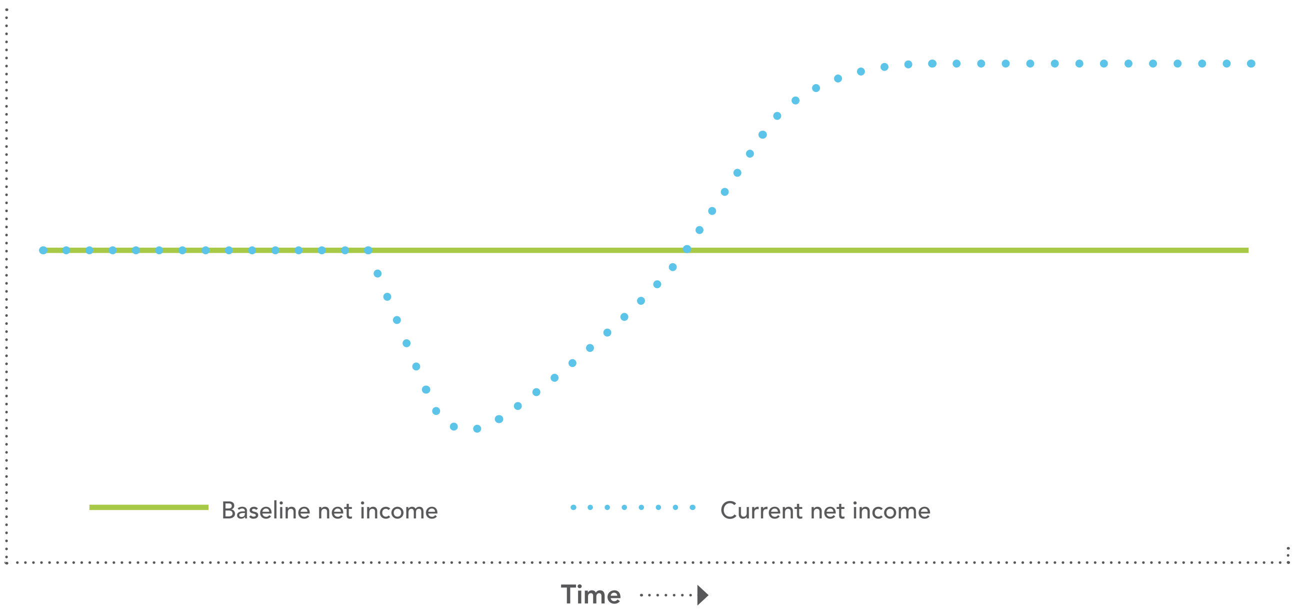
Safety nets are a form of social protection comprised of programmes supported by the public sector or non-governmental organizations that provide transfers to the poor to address risks, vulnerability and social exclusion. There is a broad range of activities that can fall into this category: conditional and non-conditional cash transfers, food vouchers and subsidies, seed and tool distribution, input subsidies and employment-based programmes such as food-for-work. Over recent years there has been a major expansion in social protection programmes, particularly cash transfers (HLPE, 2012a). Cash transfers have been found to stimulate investments in agriculture and livelihood activities (HLPE, 2012b). Investment costs for such programmes can be quite substantial, but they may not be included in investment plans for the agricultural sector, but rather under social protection investment plans. Regardless of where they are budgeted, their potential effects on risk management and farmers' investment behaviour are important factors to consider in designing CSA investment plans.

Diversification within and external to agricultural sources of income is widely regarded as a potential adaptation strategy under climate change. However, the ultimate impacts of diversification on farm level returns, food security and adaptation depend very much on the options selected for diversification. Diversifying into low-risk, but low-returning activities can lead farmers into a "poverty trap" characterized by decreasing farm incomes and increasing food insecurity (Barrett, 2007). Thus climate-smart agricultural diversification strategies rely on public sector investments to create options for diversification that contribute to increased farm incomes. Essentially this involves investments in developing alternative agricultural value chains and market linkages. It also involves changing public investment patterns that encourage mono-cropping, such as price supports and input subsidies for single crops.

Enhancing/restoring ecosystem services within agricultural production systems. Increasing the resilience of agricultural production systems to withstand and maintain productivity under extreme events such as drought and climate change is an important feature of CSA. To a large extent, this involves restoring and protecting ecosystem services related to soils and watersheds through the introduction of improved management systems and better management of biomass (including crop residues, perennials and trees) (FAO, 2010; Meybeck and Place, 2013).

The public sector can play a key supporting role in building resilient agricultural systems by developing financing schemes to support farmers in making investments whose returns are realized only after significant periods of time. Many sustainable land management practices require three to five years before a positive return is achieved, with even longer lags for restoration activities (McCarthy *et al.*, 2011). The extended lag time for realizing positive returns to sustainable agriculture investments was a key point made in FAO, 2007. Figure 14.4 illustrates the problem; sustainable agricultural investments can result in a short-term loss of income to the investors while ecosystems are being restored, and this represents an important barrier to adopting such changes.

Figure 14.4
Investment barrier to adoption



Source: FAO, 2007

Even where credit for agricultural investments is available, they generally do not support such long-term investments. Restoration of degraded ecosystems can involve even longer periods before positive returns are gained, and involve very significant opportunity costs in the form of foregone income from the ecosystem during restoration. A classic example is restoration of degraded grazing lands which involves reduction (or even elimination) of grazing for extended periods. The table below, Table 14.5, is reproduced from and shows the number of years before a positive return to restoring grazing lands can be obtained for a pilot project in Qinghai, China.

Table 14.5
An example of opportunity costs of implementing improved grazing management practices

Size of herd	Baselinenet income	NPV-HA over 20 years	N° of years to positive cash flow	N° of years to positive incremental net income compared to baseline net income
	($/ha/yr)	($/ha)	(number of years)	(number of years)
Small	14.42	118	5	10
Medium	25.21	191	1	4
Large	25.45	215	1	1

Source: McCarthy *et al.*, 2011

The smallest producers face the longest wait for positive returns – implying the importance of long-term financing to food security and poverty reduction. The implications for public sector finance are to support credit/safety net programmes that can maintain farm income levels over periods required for restoration.

Improving markets to reduce volatility is another key strategy to increase the resilience of agricultural producers to extreme events (FAO, 2012c). Recent experiences with food price spikes revealed the vulnerability of current food marketing systems to extreme events. Implications for national level agricultural investments are for improvements of both physical infrastructure (roads, storage, etc.) as well as regulations to support greater integration and stability of market processes (FAO, 2012c).

Increasing resource use efficiency

Increasing resource use efficiency is a key component of sustainable agricultural intensification strategies (FAO, 2011c, also see Module 1). For example, the environmental strategies underlying sustainable crop intensification include maintaining healthy soil to enhance crop nutrition, using well-adapted, high-yielding varieties and good quality seeds, integrating management of insects, pests and diseases and efficiently carrying out water management (FAO, 2011c). These strategies are all means of increasing resource use efficiency. They also have considerable potential to contribute to both adaptation and mitigation.

Resource use efficiency refers to a ratio between inputs and outputs (e.g. the amount of water or fertilizer utilized in producing a unit of agricultural output). TFP is a measure of resource use efficiency, and as argued in the first section of this module, increasing its importance as a source of agricultural growth is a fundamental principle for CSA. For example, increasing water use efficiency is a key adaptation strategy in areas where climate change is expected to reduce availability of water supplies (FAO, 2011b). Increased resource use efficiency is also highly correlated with reduced emissions per unit produced (Thornton and Lipper, 2013).

What kinds of investments are needed to support farmers in increasing resource use efficiency? One key category of investment required is information. For example increasing water use efficiency requires mapping water demand and use over time and space and calculating where and when inputs are necessary. Similar information is needed to increase fertilizer and pesticide efficiencies. This implies a need for investments in research as well as extension. While this need has been well recognized (FAO, 2011c) public sector investments have not been adequate, as discussed in the first section. Investments into development of technologies and practices that increase efficiency, such as drip irrigation or improved livestock feeding are another important investment category (Global Agenda of Action, 2012). Investing in efficient input supply chains that ensure the availability of inputs when they are needed in the quantities and packaging required is another important type of public sector investment needed to enhance farmers' willingness and capacity to increase resource use efficiency. For example, timely delivery of fertilizer in small packs was found to be key in determining efficient fertilizer management on farms in Kenya (Duflo and Kramer, 2011). This all would imply much greater attention to the design of input supply systems to support efficiency.

Building the evidence base to support CSA

One of the most important aspects of effectively implementing CSA is the use of evidence-based information to identify best options for changes in agricultural systems and the investments at farm, local institutional and national level to support scaling up implementation. Essentially this requires the development of a set of proposed changes in agricultural systems (e.g. from national agricultural planning) and screening them for their potential adaptation and mitigation benefits as well as agricultural benefits related to food security. A second important component of the evidence base is an analysis of the barriers to adoption of the practices or changes and their implications for achieving permanent adoption of improved practices. Consideration of investments in an enabling environment that supports sustained adoption of improved practices, avoids problems of dis-adoption after short-term project interventions. As discussed in the above section, another important component of the evidence base is assessing the need for risk management policy instruments as well as the potential for coordinating and capturing synergies between them. Finally, financial and economic analysis of scaled up CSA interventions is needed.

The costs associated with building an evidence base arise from data collection and analysis. These can range from large-scale quantitative survey data collection and analysis, to participatory approaches using simple tools such as the CSA screening methodology discussed above, with very different cost implications. It is clear that participatory approaches that involve key stakeholders from farmers to policy-makers in the discussion and development of the evidence base are needed to realize the effective potential of implementing CSA. In many cases data and analysis, as well as possible participatory processes already in place that CSA processes could build upon, could reduce overall costs. It also highlights the need for more simplified tools to help planners with CSA investment analysis. One recent publication (FAO, 2012d) gives good guidance on best practices that are very useful for CSA investment planning. Likewise the CSA screening methodology described above is another tool that can be used for building a very simple and low-cost evidence base. However these tools need to be improved, refined and extended before they can provide the needed level of detail and accuracy that CSA investment planning at the country level requires.

14.3 Global climate finance: catalysing the transition towards CSA

The reform of agricultural sectors to incorporate climate change considerations ultimately relies on the restructuring of agricultural investments, public as well as private, at the national level. Nevertheless, international financing plays a crucial role in this transition. International climate finance can act as a catalyst for the broader adoption of CSA practices by demonstrating the feasibility of CSA approaches, facilitating climate change mainstreaming into national policy and legal frameworks, and promoting the creation and transfer of skills, knowledge and technologies. If used correctly, the leverage of relatively small amounts of international climate finance can help to transform public agriculture budgets and private investments into sources of CSA financing. For many countries, learning how to access and effectively use international financing options represents the first step in the long-term transition towards CSA.

The challenging landscape of international climate finance for CSA

In the past, accessing international climate financing for CSA activities has been a particularly challenging endeavour for mainly three reasons:

1. Total funding falls well short of developing countries' needs. This overall resource constraint presents a problem for climate finance as a whole, but it is especially pronounced for CSA activities. Thus far, the lion's share of climate financing from public sources as well as almost all private sector climate financing flows into mitigation activities in the industrial and energy sectors. Adaptation financing, with a significant part targeting agriculture activities, is small in comparison to mitigation financing. Consequently, the financing need-supply gap is especially large for CSA.
2. The disjointing of mitigation and adaptation in UNFCCC negotiations has traditionally been reflected in a separation of corresponding funding sources. CSA draws its strength from the utilization of synergies between mitigation and adaptation, but few of the existing financing options provide clear funding channels for integrated activities.
3. While adaptation financing is strongly connected to agricultural investments, greenhouse gas (GHG) reductions from agricultural practices have no equally prominent role in the international financing of mitigation activities.

(Buchner, 2011)

Fortunately, all of these obstacles are already in the process of being removed or will potentially be lowered in the mid-term future. Existing funding mechanisms have started to move towards a more integrated view of adaptation and mitigation. Accordingly, funding eligibility criteria are changing to more readily accommodate combinations of adaptation and mitigation financing. The increasingly cross-cutting perspective also extends to the combination of climate change with other related areas such as forest management, biodiversity or land degradation. This shift bodes well for integrative approaches like CSA. Regarding the overall availability of resources, all eyes are on the Green Climate Fund (GCF), which was created with the expectation to disburse US$ 100 billion annually by the year 2020. Furthermore, in the UNFCCC the "Terms of reference for the design of the Green Climate Fund" in paragraph 1(c) states the "objective of achieving a balanced allocation between adaptation and mitigation" (UNFCCC, 2010) pointing towards an adjustment in the distribution at least of public climate financing in favour of adaptation. Even if these ambitious goals are not met, the GCF has the potential to ease at least some of the constraints on climate finance availability in general and adaptation financing in particular. Until then, developing countries can consider two interlinked paths of action: first, to access existing climate financing for agriculture, thereby facilitating CSA advances while creating a basis for accessing future funding and second, to prepare for accessing future GCF funds by building a tailored project pipeline, improving policy and legal foundations, and creating necessary implementation capacity. Both require a good understanding of existing finance options for CSA as well as current developments.

The existing climate finance options for CSA

The landscape of CSA financing options is complex, featuring a multitude of funding channels with different objectives and eligibility criteria. Financing options specifically targeting CSA are still limited, necessitating a strategic use and combination of existing funding sources. The basis for any CSA activity should be the identification of a country's opportunities and vulnerabilities, corresponding needs and preferred options for CSA activities. After national priorities have been defined, a strategic approach to sources of international finance based on an understanding of available channels will not only increase the chances for approval, but also enhance the fit between the finance option and the country's overall approach to climate change in agriculture. Without making the futile attempt to cover all available sources of international climate finance, this section will provide an overview of six categories of important climate finance options provided by:

1. Financing mechanisms directly under the UNFCCC;
2. United Nations (UN) organizations or programmes;
3. Multilateral Development Banks (MDBs);
4. Bilateral public financing channels;
5. Compliance and voluntary carbon markets; and
6. Private sector actors and philanthropy.

UNFCCC

The first category entails climate finance options for CSA directly connected to the UNFCCC (see Figure 14.5). The Global Environment Facility (GEF) serves as one of the "entities operating the financial mechanism" of the UNFCCC. Through the GEF Trust Fund, donor countries provide financing to cover the incremental cost developing countries incur when undertaking activities that create global environmental benefits. Climate change mitigation, as a particularly clear-cut case of global environmental benefits, represents one of the GEF's largest focal areas. Climate change adaptation activities are not funded under the GEF Trust Fund, but receive financing through separate funds, the Least Developed Countries Fund (LDCF) and the Special Climate Change Fund (SCCF) described in detail below.

The GEF Focal Area Strategies[3] provide the basis for GEF funding priorities. In line with the small role agriculture traditionally holds within international mitigation financing, activities reducing GHG emissions from agriculture are not particularly highlighted under the current GEF Strategy (GEF, 2007). Nevertheless, the GEF Trust Fund provides funding opportunities for agricultural GHG reductions, most importantly under Focal Area Objective Climate Change Mitigation (CCM)-5 on the promotion of the conservation and enhancement of carbon stocks through sustainable management of land use, land-use change and forestry. The current GEF strategy puts an emphasis on sustainable forest management, which connects to CSA practices under the broader landscape approach. In addition, the objective includes the enhancement of carbon stocks in non-forest lands, making CSA mitigation activities in a narrow sense eligible for GEF Trust Fund financing. Another niche for agricultural activities within the current GEF Strategy is the financing of biomass applications under the renewable energy objective (CCM-3). Overall, agriculture does not play a prominent role in the current GEF CCM Strategy. However, this situation is likely to change with the new upcoming GEF Strategy on CCM, which is likely to put an explicit focus on CSA (see section below on "Prospective development in climate finance for CSA").

In addition to the financing provided through the GEF Trust Fund, the UNFCCC has established several additional funds. The LDCF and the SCCF, both established in 2001, are managed by the GEF and have developed into one of the central global financing options for climate change adaptation activities. The LDCF's original mandate was to provide full cost financing to least developed countries[4] for the formulation of National Adaptation Programmes of Action (NAPAs). By now, practically all eligible countries have accessed their funds for NAPA preparation. Therefore the LDCF has shifted its focus towards the implementation of projects that respond to NAPA priorities. As agriculture is arguably the sector most vulnerable to climate change impacts, it is a priority for NAPA implementation in most countries. Consequently, agriculture is the main sector receiving LDCF funding. Following the GEF's own classification, 28 percent of the US$ 537 million LDCF resources dispersed to date were allocated to agricultural adaptation activities. A closer examination of LDCF and other NAPA related projects suggests that this percentage is actually much higher, as most LDCF projects across all categories are in fact "mainly related to agriculture" (Meybeck, 2013). Accordingly, the LDCF represents one of the most important sources for the adaptation aspects of CSA activities in least developed countries.

Only least developed countries are eligible to access LDCF funding. Other developing countries have to rely on funding from the SCCF. The SCCF formally features a broad mandate covering practically all aspects of climate change adaptation and mitigation. De facto, the SCCF has developed into a funding source for climate change adaptation activities accessible to non-least developed countries[5]. As in the LDCF, agriculture is one of the main target sectors for SCCF funding. More than half of total SCCF resources (US$ 189 million mobilized by June 2012) were dispersed to projects in agriculture, land management, and water management. The adaptation aspects of CSA activities thus connect directly to SCCF priorities. However, the SCCF particularly suffers from the limitation of overall financial resources and the unpredictability of finance availability. Other than

[3] GEF Focal Area Strategies are effective for the respective four-year long GEF replenishment period. The current replenishment period, GEF-5, extends from July 1st 2010 through June 30th 2014. On July 1st 2014, the new GEF Focal Area Strategies for the GEF-6 replenishment period are expected to come into effect.

[4] For a list of eligible least developed countries see GEF, 2011, p. 8.

[5] Least developed countries are also eligible for SCCF funding, but in most cases choose to use the often more readily available resources provided by the LDCF.

the GEF Trust Fund, which is replenished for four year periods, the LDCF and SCCF rely on voluntary ad hoc contributions from donor countries, making the planning of resource allocation difficult. While the situation is less problematic for the LDCF as it receives an overall higher volume of resources, it makes the availability of resources for SCCF activities highly uncertain, increasing the risk for countries and implementing agencies of conducting the laborious process of project preparation in vain.

One aspect that makes GEF managed funding channels especially suitable for the financing of CSA activities is their combinability in form of Multi Focal Area and Multi Trust Fund activities. The GEF hosts resource channels for climate change mitigation and adaptation under one roof. In addition, the GEF also serves as a financial mechanism for other international environmental conventions like the Convention on Biological Diversity or the United Nations Convention to Combat Desertification and in this function provides funds for biodiversity conservation, sustainable land management and other environmental concerns. All of these GEF funding channels are combinable, meaning that one project can access funding from different GEF channels for the respective aspects of the activity. As an integrated approach to agricultural development, CSA emphasizes the utilization of synergies. The combinability of GEF financing options provides opportunities to translate the integrative nature of CSA into additional financing. The combination of mitigation and adaptation funding in Multi-Trust Fund initiatives, merging GEF Trust Fund with LDCF/SCCF resources, corresponds most directly with CSA activities (see Box 14.1). For some CSA initiatives a combination of funding from different GEF focal areas like biodiversity or land degradation might also be an option. The combination of funding from different focal areas is especially incentivized for activities on Sustainable Forest Management (SFM) through the SFM/Reducing Emissions from Deforestation and Forest Degradation (REDD+) Incentive Mechanism (GEF, 2010).

Box 14.1
GEF/SCCF Multi-Trust Fund projects

The FAO/GEF Multi-Trust Fund project on Promotion of Climate-smart Livestock Management Integrating Reversion of Land Degradation and Reduction of Desertification in Vulnerable Provinces combines GEF Trust Fund and SCCF funds for an integrated approach to increase multiple benefits needed in the livestock sector in Ecuador. The proposed project is particularly innovative because it seeks to harness the synergies between sustainable land management, climate change mitigation, and climate change adaptation. Climate-smart livestock management (CSLM) integrates both climate change adaptation and mitigation practices in the agro-livestock sector, while enhancing the achievement of national food security and development goals. The overall GEF financing of US$ 3.86 million, which includes US$ 1.46 million from the SCCF, will support interventions to reduce soil degradation, increase adaptive capacity to climate change, and mitigate GHG emissions by implementing cross-sectorial policies and climate-smart livestock management, with emphasis on vulnerable provinces.

Source: GEF, 2013b

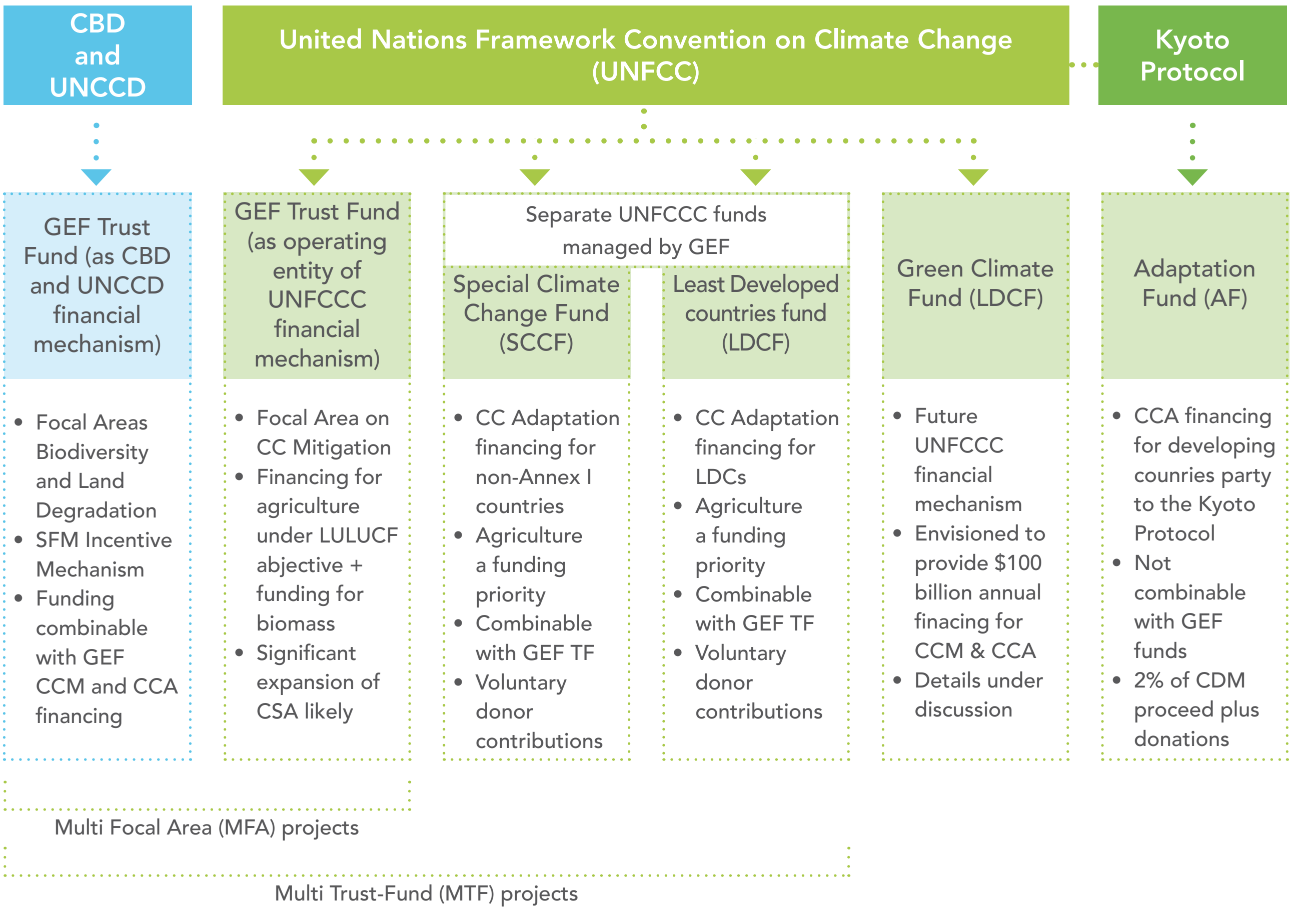
In addition to LDCF and SCCF, the UNFCCC created another fund to address adaptation needs of non-Annex I countries: the Adaptation Fund (AF), established in 2001 under the Kyoto Protocol. The AF began operations in 2007. Since then 28 projects with a total volume of US$ 184 million have been approved. The GEF provides secretariat services to the AF, but its governing body, the Adaptation Fund Board, is separate from the GEF governance structure and hence, the AF follows distinct policies. The most significant difference is the principle of direct access. For most GEF Trust Fund or LDCF/SCCF financed activities, developing countries have to partner with one of the ten GEF Agencies[6], which are accredited to apply for GEF funding and implement the respective project. The AF instead emphasizes the direct access to resources by National Implementing Entities in the recipient countries. At present, 15 National Implementing Entities are accredited to apply for AF funding. In addition, the AF has accredited ten Multilateral Implementing Entities as well as one Regional Implementing Entity. The most significant challenge the AF currently faces is the future inflow of financial

[6] The ten GEF Agencies are: World Bank Group, Inter-American Development Bank, Asian Development Bank, African Development Bank, European Bank for Reconstruction and Development, UN Development Program, UN Environment Program, UN Food and Agriculture Organization, UN Industrial Development Organization, and the International Fund for Agricultural Development.

resources. The primary source of AF resources is the sale of Certified Emission Reductions under the Kyoto Protocol's Clean Development Mechanism with two percent of its proceeds going to the AF. However, with the deflation of carbon markets and the corresponding collapse of Certified Emission Reduction prices in combination with the uncertain shape of the Post-Kyoto emission trading architecture, the financial basis of the AF is being threatened. One response of the AF has been to intensify efforts to increase the share of resources from donor contributions. With this shift, the competition over donor contributions between AF, LDCF and SCCF has increased, while the total resource availability remains tightly constrained.

The continuous lack of total available resources for climate change action in developing countries prompted efforts to overhaul the architecture of climate financing under the UNFCCC. The most visible result of these negotiations is the establishment of the GCF formally created at the Conference of the Parties (COP) 16 in Cancun. In distinction from other special funds, the GCF is envisioned to become an operating entity of the UNFCCC comparable to the GEF. The creation of the GCF Board as the fund's governing body as well as the selection of Incheon (South Korea) as host to the GCF represent first steps towards making the GCF operational. The details of the GCF's operation, its business model, resource mobilization, channels of disbursement as well as funding areas and priorities remain under discussion. The GCF is envisioned to provide US$ 100 billion of climate finance per year by 2020, which would represent a dramatic increase of multilateral funding relative to current resource levels. Potential sources to reach this funding goal are donor contributions, revenues from carbon markets, and private sector funding mobilized through a Private Sector Facility still to be designed. Even if these ambitious funding goals are not realized, the GCF can be expected to fundamentally change the overall architecture of global climate finance. The way in which the GCF will relate to the existing funding mechanism under the UNFCCC will influence the shape of international climate financing structures probably for decades to come.

Figure 14.5
Climate finance options under the UNFCCC



UN Agencies and Programmes

UN Agencies and Programmes play a central role as implementing agencies for the activities financed through the funding channels under the UNFCCC described in the previous section. In addition, UN Agencies also provide climate financing directly, primarily through multi-donor trust funds financed by member states. The UN REDD programme and the Rural Energy Enterprise Development (REED) Programme are two prominent examples for this category of international climate finance.

The landscape approach places CSA activities in the context of the broader ecosystem highlighting interdependencies with surrounding land uses. In many cases, this creates a direct link between CSA and sustainable forest management. Therefore, this module includes financing options aimed at the reduction of GHG emission from deforestation and forest degradation and the enhancement of carbon stocks through forest conservation and sustainable forest management, commonly summarized as REDD+. In addition to GEF funding for SFM, the main source of financial support for corresponding activities is the UN REDD programme. The programme, a collaborative initiative of the United Nations Development Programme, the United Nations Environment Programme (UNEP) and FAO, is currently financed by Denmark, Japan, Norway and Spain with funds amounting to approximately US$ 120 million. UN REDD primarily prepares countries for REDD+ activities, creating prerequisites like MRV and monitoring systems, enhanced policy and legal frameworks, stakeholder awareness and management accountability. The UN REDD programme coordinates its activities with the Forest Carbon Partnership Facility of the World Bank (see below).

Another example for CSA relevant funding options administered directly through UN Agencies and Programmes is the REED Programme implemented by UNEP. The programme makes investments in small and mid-size enterprises dealing in clean energy solutions in rural areas, thereby following a seed capital approach instead of the more conventional grant approach. The areas covered by the recipient enterprises include clean technology applications that play an integral role in CSA activities (e.g. solar crop drying and wind water pumping).

MDBs

The primary function of MDBs is to provide loans under conditions and objectives based on their overall principles as well as the specific agreements between a specific country and the respective development bank. The agricultural sector remains one of the primary target sectors of MDB loans, representing a share of the agricultural official development assistance discussed in Part 14.2 of this module. As MDBs are increasingly incorporating environmental sustainability criteria into their agricultural lending practices, their loans play an increasing role as a financing option for CSA activities.[7] Among the MDBs, the European Investment Bank plays a particular role with respect to climate finance, being one of the world's largest lenders for climate action. In 2011, European Investment Bank climate change related loans amounted to € 18 billion, approximately one third of its yearly total lending. More than € 2 billion was invested outside the European Union.[8]

In many cases, climate related MDB loans are coupled with grants from different funds described in this module. At the core of grant-based climate, finance provided through the MDBs are the Climate Investment Funds, a joint initiative of the World Bank and the Regional Development Banks envisioned to provide climate finance in line with the UNFCCC framework but without prejudicing outcomes of UNFCCC negotiations. With pledges of US$ 7.6 billion and currently 67 approved projects for a total of US$ 2.7 billion, the Climate Investment Funds carry significant weight within the climate finance architecture. However, only a very small part of Climate Investment Funds' resources can be accessed for CSA activities. The Climate Investment Funds consist of two separate funds: The Clean Technology Fund and the Strategic Climate Fund. The Clean Technology

[7] A prominent example for the increasing emphasis on environmental issues, including climate change, in MDB lending practices is the recent World Bank Group Environment Strategy 2012 – 2022 "Toward a Green, Clean, and Resilient World for All" released in May 2012. At the operational and procedural level, climate change criteria for World Bank lending are stipulated in the World Bank Group Safeguard Policy on Environmental Assessment, which links to Operational Policy and Bank Procedure 4.01. In this context, climate change criteria are laid out in the Environmental Assessment Sourcebook under Chapter 2: Global and Cross Sectoral Issues in Environmental Assessment.

[8] European Commission, 2013.

Fund currently has 41 projects and US$ 2.3 billion of resources approved (US$ 5.2 billion pledged), providing financing for renewable energy, sustainable transport, and energy efficiency. The Clean Technology Fund does not provide a clear channel for GHG reduction from the agricultural sector. Again, the comparably small role of the agricultural sector in mitigation financing is reflected in the priority setting of the Climate Investment Funds. The Strategic Climate Fund comprises three targeted programmes. The Programme for Scaling-Up Renewable Energy in Low Income Countries targets the realization of low carbon pathways in six pilot countries' energy sectors and has received US$ 505 million in pledges. No Scaling-Up Renewable Energy in Low Income Countries project has been approved yet and they would not provide clear financing options for CSA. The Forest Investment Programme thus far has received US$ 639 million in pledges for reducing emissions from deforestation and forest degradation in eight pilot countries. It is more closely connected to CSA activities from a landscape perspective, but no projects have been approved at this point. The Pilot Program for Climate Resilience (PPCR) is the part of the Climate Investment Funds that represents the most direct financing option for CSA activities. Financing under the PPCR is, however, earmarked for climate adaptation activities. In addition, PPCR funding is concentrated on nine pilot countries and two pilot regional initiatives[9] and only these countries are eligible for PPCR funding. Given the small pool of eligible countries, the available PPCR resources per country are much larger than through other funding channels, opening extraordinary opportunities for the pilot countries. With the approach of resource concentration, the PPCR aims to provide significant investments necessary to achieve comprehensive sector-wide transitions towards increased climate resilience. Naturally, the agricultural sector is of high priority under the PPCR. Eligible countries thus have a unique chance to receive significant funding for deploying a CSA approach at a large scale. For PPCR pilot countries, this represents an opportunity that is not to be missed. In addition, the PPCR supported transformations of agricultural sectors will be among the first examples at this scale and will potentially serve as crucial examples for the future of climate finance under the GCF.

Box 14.2
Strengthening climate resilience in the Kafue River Basin in Zambia under the PPCR

The Kafue River Basin is a sub-basin of the Zambezi River Basin and a headwater catchment located entirely within Zambia. The impacts of climate change are projected to increase the variability of precipitation in the area, exacerbating problems caused by drought and flooding. One of the PPCR project sub-components focuses on fostering sustainable water and land management, agricultural and pastoral practices that help local communities to better address the current and future impacts of climate change and variability. It would finance climate resilient Integrated Development Plans and Local Area Plans. The PPCR will assist communities to implement such plans in partnership with non-governmental organizations and other development agencies.

Source: PPCR, 2011

In addition to the jointly implemented CIFs, the MDBs also administer their own specific climate change financing mechanisms. Among these, the Forest Carbon Partnership Facility of the World Bank has already been mentioned as complementary to the UN REDD programme, leading in the area of economic analysis for REDD strategies including pilots on performance-based incentive payment systems. Examples for climate finance mechanisms managed by Regional Development Banks include the African Development Bank's Congo Basin Forest Fund addressing deforestation in the Congo basin, as well as the Asian Development Bank's Clean Energy Financing Partnership Facility targeting policy, regulatory and institutional reform promoting clean energy development.

Bilateral public financing channels

Bilateral instruments remain one of the primary sources of climate finance. Analysis provided by the Climate Policy Initiative estimates that total annual climate finance to developing countries through bilateral sources

[9] PPCR Pilot Countries and Regions: Bangladesh, Bolivia, Cambodia, Mozambique, Nepal, Niger, Tajikistan, Yemen, Zambia; Caribbean Region (Dominica, Grenada, Haiti, Jamaica, St. Lucia, St. Vincent and the Grenadines) and the Pacific Region (Papua New Guinea, Samoa, Tonga).

(ca. US$ 23 billion) is in fact higher than the amount channelled through multilateral instruments (ca. US$ 17 billion). This gap becomes even wider when looking at climate change adaptation activities separately with bilateral sources amounting to US $3.6 billion and multilateral channels disbursing less than US $0.5 billion. Bilateral Financial Institutions play a central role as intermediaries disbursing climate funding to developing countries. Spending on climate change by the French Development Agency, the German Development Bank and the Japan International Cooperation Agency amounted to US$ 11.4 billion in 2009, including both official development assistance and non- official development assistance finance (UNEP, 2010). In addition, levels of South-South bilateral climate finance are increasing. The Brazilian Development Bank, China Development Bank, the Indian Renewable Energy Development Agency and the Overseas Private Investment Corporation have provided approximately US$ 4 billion of climate finance in 2010 (Buchner, 2011). As with other funding channels, most of the bilateral climate financing is concentrated in the industrial and energy sectors and therefore not available for CSA activities.

The member states of the European Union have traditionally been the main source of climate change financing assisting developing countries, both through national level initiatives as well as climate finance activities coordinated at the European Union level. Recently, the Global Financial Crisis and the European Debt Crisis have had devastating effects on the European Union's funding levels for climate change. The official development assistance numbers released by the Organisation for Economic Co-operation and Development (OECD) show that European Union contributions for climate change adaptation in developing countries has dropped by 55 percent from € 1.4 billion in 2010 to € 619 million in 2011[10]. Nevertheless, the European Union continues to finance a number of major initiatives providing international climate finance. One important programme from a CSA perspective is the Global Climate Change Alliance (GCCA), launched in 2007 as a European Union initiative coordinated by the European Commission (EC). GCCA has already disbursed € 243 million from 2008-2012 with € 47 million pledged for 2013.[11] The GCCA currently supports 30 country level initiatives and 8 regional programmes in the priority areas of mainstreaming climate change into poverty reduction, adaptation, REDD, participation in carbon markets, and disaster risk reduction. Most GCCA priorities link directly to the agricultural sector and indeed a large share of GCCA funding has targeted agricultural activities, making it a promising CSA financing option. Another major programme funded by the European Union with potential links to CSA activities include the ACP-EC Energy Facility promoting access to sustainable energy services for poor rural populations in sub-Sahara Africa, the Caribbean and the Pacific. In addition to these umbrella initiatives, the European Union, through the EC budget, provides support for a large number of individual climate change projects including agricultural activities. One recent example is a joint EC-FAO project that will provide € 5.3 million for assisting Malawi, Vietnam and Zambia transition towards a CSA approach.

Most of the individual European Union member states also have national level programmes, partially linked with the bilateral finance institutions listed above, providing climate financing to developing countries. Examples for important initiatives in the CSA context are Germany's International Climate Initiative which receives funding of € 120 million per year for the promotion of climate-friendly economic development, measures for climate change adaptation and for the preservation or sustainable use of carbon reservoirs (REDD+), as well as the United Kingdom's International Climate Fund, which handles the United Kingdom's contributions to many of the multilateral funds described above, but also provides direct climate financing for initiatives in developing countries on adaptation to climate change, low-carbon growth and REDD+. Total International Climate Fund pledges amount to £ 2.9 billion of climate finance from within existing aid commitments from 2011 to 2015. Outside the European Union, significant national sources of climate finance include the USAID Development Grants Program, which includes a priority area on climate change adaptation, as well as Japan's Hatoyama Initiative[12], which pledged US$ 15 billion in public and private climate financing covering all areas of mitigation and adaptation. Among national initiatives, Australia's International Forest Carbon Initiative stands out due to

[10] Global climate change adaptation funding fell from US$ 3.1 billion to US$ 1.8 billion during the same period (OECD, 2013).

[11] GCCA resources come from the EC budget, the 10th European Development Fund, and contributions from individual European Union member states. GCCA funding includes parts of the fast start finance pledged at the UNFCCC COP 15 in Copenhagen in 2009.

[12] Often referred to as the Japan Fast-Start Financing

its specific focus and purpose. The International Forest Carbon Initiative strives to demonstrate feasibility and create a solid basis for the inclusion of REDD+ in a Post-Kyoto global climate change agreement. Accordingly, the International Forest Carbon Initiative provides financing for pilot REDD+ activities, enhancement of forest carbon monitoring and accounting systems, and the development of market-based REDD+ approaches. In addition, Australia's Aid Program also provides CSA relevant financing through its Adaptation to Climate Change Initiative.

Carbon markets

Despite all the difficulties with its implementation, the concept of putting a price on GHG emissions and installing a market-based price-setting mechanism through certificate trading provides a powerful instrument of climate finance. Carbon markets could possibly be a large source of international funding for CSA activities. However, the inclusion of carbon credits from agricultural GHG reductions in compliance with carbon markets has been a matter of continuous controversy for at least two decades. The scope of this module does not allow for a full presentation of the complex debate on agricultural carbon credits. However, this is a list of some of the central concerns: a) challenge of MRV and related difficulties to ensure environmental integrity with respect to possible leakage, uncertain permanence and additionality of GHG reductions; b) high transaction costs, especially through the coordination of large numbers of smallholder farmers that would be required to make soil carbon Certified Emission Reductions profitable; c) high opportunity costs through the diversion from conventional climate change efforts towards the complex process of achieving carbon market readiness; d) concerns about the potentially adverse effect on food security through increases in food price volatility and displacement of food production in favour of more effective carbon sinks; e) questions about the use of untested technologies to create easily calculated GHG reduction. These issues are usually embedded in a more general rejection of carbon markets as a tool for agricultural mitigation, highlighting the unstable situation of carbon markets overall and concerns about shifting the burden of emission reductions to developing countries.

The combination of these and other concerns led to the exclusion of carbon reductions from soil carbon management in croplands and grassland from the Clean Development Mechanism. Consequently, the existing compliance carbon markets have ruled most agricultural carbon credits as ineligible for trading. Most importantly, the European Union's Emissions Trading System, being the world's dominant source of demand for Certified Emission Reductions, does not accept carbon credits from soil management activities. The exclusion of large parts of agricultural mitigation potential from the Clean Development Mechanism and compliance markets also prevent the development of a comprehensive set of approved baseline and monitoring methodology to determine the amount of generated Certified Emission Reductions. One notable exception is methane avoidance through manure management, which has witnessed an exceptional level of activity after the Clean Development Mechanism introduced a manure methodology in 2006. The amount and proportion of Clean Development Mechanism manure projects dropped sharply after 2006, but continue to provide niche financing. Overall, however, the agricultural sector lags years behind the industrial and energy sectors with large Certified Emission Reductions markets and a corresponding wealth of approved methodologies, experiences and knowledge. However, for the time being, compliance carbon markets do offer limited opportunities for CSA financing (World Bank, 2011).

Voluntary carbon markets have been somewhat more inclined to include carbon credits from land use, land-use change and forestry activities (PwC and Rockefeller Foundation, 2011). The majority of credits derives, however, from REDD activities, with carbon reductions from CSA still playing a very limited role. Some of the major voluntary carbon market standards like Verified Carbon Standard or the American Carbon Registry allow for carbon credits from CSA activities. Also, in the emerging voluntary carbon market in China, based on its first domestic carbon standard, the Panda Standard, GHG reductions from agriculture, forestry and other land use are explicitly promoted (UNEP Riso Centre, 2011). In consequence, a broader spectrum of certification methodologies for CSA credits has been developed under these standards including for agro-forestry, integrated farm energy systems, nutrient management, rice system management, tillage and residue management and watershed restoration.

Most prominently, the Verified Carbon Standard recently approved a carbon accounting methodology for sustainable agricultural land management developed in the context of the controversially discussed Agricultural Carbon Project in Kenya. The project, implemented by the Swedish non-governmental organization Vi-Agroforestry, produces carbon credits from CSA activities that will be bought by the World Bank's BioCarbon Fund. The BioCarbon Fund is set up as a public-private trust fund and is part of a larger set of different carbon funds managed and administered by the World Bank's Carbon Finance Unit.[13] The BioCarbon Fund specifically provides carbon finance for projects that create GHG reduction in forest, agro and other ecosystems. Active exploration of opportunities to create carbon credits from carbon sinks makes the BioCarbon Fund an unusual player in the climate finance universe. The Emission Reduction Purchase Agreement signed between the BioCarbon Fund and Vi-Agroforestry in 2010, was the first for soil carbon credits, garnering significant international attention. Through the Verified Carbon Standard approval, these carbon credits will be tradable on the voluntary carbon market. The BioCarbon Fund thereby advances the inclusion of CSA activities in carbon trading schemes. At the same time, opponents of agricultural carbon credits have criticized the Agricultural Carbon Project in Kenya as affirming some of the concerns listed above, especially the lack of accurate measurability of soil carbon sequestration (see Box 14.3).

Box 14.3
BioCarbon Fund: the Agricultural Carbon Project in Kenya

The Kenya Agricultural Carbon Project has received much international attention and praise as a ground-breaking pilot initiative with the goal to illustrate the potential and feasibility of agricultural soil carbon sequestration in the context of carbon markets:

"The Kenya Agricultural Carbon Project is breaking new ground in designing and implementing climate finance projects in the agricultural sector. The project is regarded as an innovative example for climate-smart agriculture within and outside the World Bank. For the first time, while increasing productivity and enhancing resilience to climate change, smallholder farmers in Africa will receive payments for greenhouse gas mitigation based on sustainable agricultural land management. Quantification of carbon sequestration is monitored based on a newly developed carbon accounting methodology." (Woelcke, 2012)

"The Kenya Agricultural Carbon Project is not only the first project that sells soil carbon credits in Africa, it is also paving the way for a new approach to carbon accounting methodologies. As Kenya ramps up its participation in carbon markets, this project illustrates concretely how carbon finance can both support the environment and generate revenues for local communities." (Chassard, 2010)

At the same time, the project has drawn criticism pointing to the displayed high transaction costs and questions about the adequacy of the employed MRV methodology, which will not include actual soil sampling. This criticism is mostly embedded in a more general rejection of carbon markets as a suitable tool for agricultural mitigation, highlighting the large potential for leakage and impermanence, the unstable situation of carbon markets overall, and concerns about shifting the burden of emissions reductions to developing countries.

"Nearly half of the monetary benefits from the proposed offset credits would be absorbed by project developers as 'transaction costs,' with miniscule returns to the farmers who would be implementing the project. While carbon markets are promoted as a way to 'leverage' climate funding, to judge by this project, the rules being developed risk oversimplifying evolving science on climate mitigation and diverting resources from the urgent task of adaptation. [...] Given the high degree of uncertainty about this model project's mitigation benefits and high transaction costs to achieve mostly co-benefits, could such co-benefits be more efficiently achieved through direct access to finance for agricultural adaptation?" (Sharma, 2011)

Private sector and philanthropy

In the context of this section, private sector CSA investments do not mean the "transformed" agricultural investments by agribusiness or smallholders that follow CSA principles, but international private sector funding that contributes to catalysing this transition. Looking at the entire landscape of climate finance, the private sector is in fact the single largest source of financing (Buchner, 2011). However, private sector funding in the

[13] Funds managed by the World Bank's Carbon Finance Unit also include the Community Development Carbon Fund.

form of market-rate loans or capital investments is almost exclusively targeted at climate change mitigation activities in the renewable energy sector and in industrial energy efficiency. The global share of private sector climate finance in adaptation, agricultural or otherwise, is currently still negligible (Buchner, 2011). Similarly, the exclusion of agriculture from compliance carbon markets limits direct private sector investments in agricultural mitigation activities. Voluntary carbon markets, which are small but expanding, provide a channel for private CSA financing, but current volumes are still minimal, as discussed above. Overall, private sector investments at this stage provide "niche financing" that create positive impacts on CSA development at a case-by-case level, but do not play a large role in the overall landscape of CSA financing.

Nevertheless, there are a number of innovative private sector initiatives worth highlighting in this context. Usually, these are driven by a combination of three factors: a) protection of a company's value chain from climate change impacts; b) opportunities for increased profits through environmental certification schemes; and c) corporate social responsibility linked to a company's image and self-understanding. These motives particularly apply to large, multinational food-product corporations with strong interests in increasing climate resilience of agricultural production within their value chain. At the same time, these multinational companies have much to gain from creating a premium price market for products certified as "climate-friendly". Environmental certification schemes for food products are already relatively wide-spread and well established in several markets (Blackmann, 2011 and 2012). In comparison, climate change related product certification is still at its beginning. Highly publicized examples for companies' individual or joint efforts in this regard include the collaboration of Coca-Cola and the WWF on sustainable sugarcane in Brazil (see Box 14.4). One of the already existing umbrella initiatives aiming at coordinating private sector efforts in this direction is the Sustainable Agriculture Initiative Platform, which includes Nestle, Unilever, Group Danone, McDonald's, Coca Cola, Kellogg's, General Mills, and others.

Box 14.4
Private sector: promoting the advancement of sustainable sugarcane in Brazil

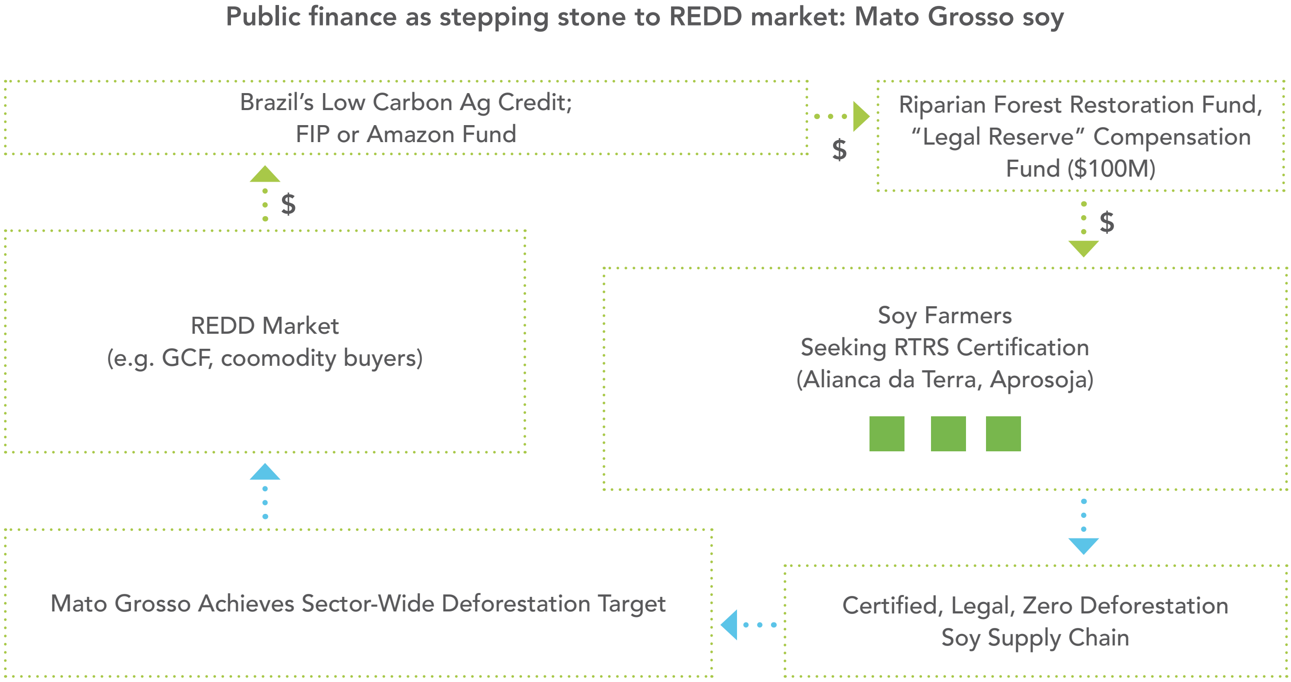
In 2007, The Coca-Cola Company and World Wildlife Fund (WWF) confirmed a joint commitment to improve water efficiency, reduce carbon emissions, and help conserve seven of the world's most important freshwater river basins. As a critical piece of this initiative, Coca-Cola affirmed the goal of advancing sustainable agriculture practices through promoting environmental stewardship and ensuring workplace rights. Among agricultural products, sustainability in the sugarcane supply chain (farm, mill, and refining processes) is a key priority for The Coca-Cola Company and a focal point of the WWF/Coca-Cola partnership. As such, they also worked with Brazilian Sugar Mill suppliers.

Coca-Cola and WWF have identified Bonsucro certification as a means of ensuring increased sustainability, and believe the newly formed standard will provide a globally recognized, third-party certification for sustainably produced sugarcane. Developed through an independent, multi-stakeholder initiative, the Bonsucro certification provides a mechanism for achieving sustainable production from sugarcane in respect of economic, social and environmental dimensions. Coca-Cola, in partnership with WWF, has collaborated with key suppliers to initiate activities that assist sugar mills to understand and work towards certification. As Coca-Cola and WWF support mills to meet certification standards, sugarcane producers will continue to benefit, with global implications of aligning the industry towards responsible and sustainable environmental stewardship.

Source: Sustainable Agriculture Initiative, 2010

Climate change related product certification is often particularly promising when catalysed through public climate financing sources. In some cases, product certification can then also be linked to market-based carbon financing. One successful example is the Round Table on Responsible Soy (RTRS) certification initiative. This widely recognized standard combines a number of components including social and labour standards, biodiversity, pesticide, soil, water use and others. The land use and zero deforestation aspect of the RTRS standard connect it to REDD+ carbon markets which again opens additional financing for further certification efforts, closing the virtuous cycle of public finance, product certification, and carbon markets (see Figure 14.6).

Figure 14.6
Public climate finance: RTRS certification and REDD+ carbon markets



Another private funding source is philanthropic contributions, usually channelled through charitable foundations or international non-governmental organizations. Organizations like the Rockefeller Foundation, the Co-operative for Assistance and Relief Everywhere, Oxfam, or Conservation International have all invested in CSA activities (Shames *et al.*, 2012). The Rockefeller Foundation's Developing Climate Change Resilience Initiative is one of the most visible programmes in this context. The Howard G. Buffett Foundation supports CSA projects in Tanzania, Burundi, Sierra Leone and Sudan through a partnership with the Cooperative for Assistance and Relief Everywhere.

A final example for involvement of private sector actors in CSA activities, albeit not in the form of direct investments, is the international insurance business. The establishment of insurance schemes to help farmers manage agricultural climate change risks, while providing incentives for risk prevention and improvement of risk information (The Geneva Asssociation, 2012), has become one of the innovative and prominently employed instruments used in the design of many CSA projects financed through international climate finance. In this, the private insurance sector is often a crucial partner and provider of tailored services and products as well as knowledge and expertise.

Prospective development in climate finance for CSA

This section began with the premise that receiving funding for CSA activities within the international climate finance landscape is challenging, but that there are signs that this situation is improving. Probably the clearest sign can be found in the ongoing discussions on the sixth replenishment of the GEF and the formulation of new GEF-6 Focal Area Strategies. The GEF's movement towards combining adaptation and mitigation activities has already been discussed. This trend continues in the draft GEF-6 Strategy for climate Change Mitigation which turns an explicit spotlight on CSA. While agriculture was hardly mentioned in the GEF-5 CCM Strategy, the current GEF-6 CCM draft highlights cross-cutting financing options as one of GEF's specific value propositions, explicitly citing CSA as an example:

Since GEF-5, an increasing number of projects that address both mitigation and adaptation are being supported by the GEF to help countries realize the low carbon and climate resilient development goals. Topics of emerging importance to address the global commons, such as urban management and climate- smart agriculture, also transcend mitigation and adaptation concerns. The flexibility of the GEF to support such initiatives by combining resources from the GEF Trust Fund and the two trust funds managed by the GEF for adaptation is a distinctive feature of the GEF." (GEF, 2013a)

The GEF-6 CCM draft mentions mitigation in agriculture in general and CSA in particular several times, cumulating in the explicit inclusion of CSA as a funding priority under "Objective 2, Programme 2: Promote Conservation and Enhancement of Carbon Stocks in Forest, and other Land-Use, and Support Climate-Smart Agriculture." In doing so, the GEF-6 strategy acknowledges the "need to go beyond GEF-5 efforts on carbon dioxide emissions and sequestration from the agriculture and forestry sectors and to include activities targeting the methane and nitrous oxide emissions of these sectors." The strategy complements this by highlighting its focus on the forest-agriculture nexus as well as the necessary strengthening of MRV of GHG emissions and carbon sequestration in forests and agriculture. The strategy lists the following examples for activities to receive financing under GEF-6: agro-forestry, conservation tillage, livestock management, methane mitigation, irrigation, and fertilizer management. The GEF through its multiple funding channels has thereby fully incorporated CSA in its financing strategy.

This significant shift has implications well beyond the GEF itself. As the financial mechanism of the UNFCCC, the GEF serves as arguably the most important source of examples and experiences for the design of the Green Climate Fund, which is envisioned to also become a UNFCCC financial mechanism. It is still unclear how the GCF will reshape the architecture of funding channels under the UNFCCC (Abbott, 2011; Lattanzio, 2013). Possible options range from the absorption of some or all of the GEF climate finance instruments into the GCF to the coexistence of all funds with the GCF taking an umbrella function, coordinating existing funds under the GEF and representing a middle ground option. However this debate turns out, the substantive upgrading of CSA in the GEF-6 Strategy is likely to be reflected to some degree in the priority setting of the GCF. This means that regardless of the ultimate structure of financing channels, the GCF will represent a clear and direct financing option for CSA activities, presumably with a significantly higher volume than current multilateral funding instruments.

Another pending development, with the outcome regarding CSA less certain, is the result of UNFCCC negotiations on the overall structure of the Post-Kyoto carbon finance system and the possible inclusion of carbon credits from REDD+ and agricultural soil sequestration in compliance carbon markets like the European Union's Emissions Trading System. The Durban Platform agreed upon at COP 17 sets out a roadmap for a Post-Kyoto binding emission reduction agreement to be finalized by 2015 and come into effect in 2020. On REDD+, great efforts have been made over the past years to work towards a comprehensive inclusion of REDD+ issues in the Post-Kyoto framework, potentially opening the door for broader market-based trading of forest carbon credits (Anger, 2008; Platinga, 2008). Initiatives like UN REDD, several Forest Carbon Funds described above as well as bilateral programmes like Australia's International Forest Carbon Initiative have prepared the ground for an inclusion of REDD+ in compliance carbon markets. Under the Kyoto Protocol, a limit set of afforestation and reforestation are already eligible for the Clean Development Mechanism, albeit with temporary credits of limited fungibility. One other important indicator for the carbon trading potential of forest carbon is the share of REDD+ certificates in voluntary carbon markets. Despite all these positive dynamics, UNFCCC negotiations on REDD+ are difficult and slow. During COP 19 in Doha, no decisions could be reached on REDD+ and intense disagreements on a number of issues, especially related to verification and financing, persist.

The difficult REDD+ situation sends a signal with regard to the inclusion of agricultural carbon sequestration in future global emission agreements. While interest in agricultural GHG emission reductions has generally been increasing in the context of voluntary carbon markets, the share of actual activities remains small. The agricultural sector, with the exception of the established niche of methane avoidance from manure management, is well behind the forest sector in addressing the methodological barriers and political controversies described in the previous sections. In combination with the great challenges that carbon markets in general are facing today, the trading of agricultural carbon credits is highly unlikely to develop into a significant source of CSA financing in developing countries in the mid-term future.

14.4 Preparing for the way forward in international CSA financing

The current dynamics in international climate finance are in favour of CSA with significant potential for new and additional opportunities to use international financing for turning public and private agriculture investments into CSA investments. Fragmentation of climate finance sources has been a particular challenge for concepts like CSA that draw their comparative advantage from the utilization of cross-cutting synergies. With the ongoing shift in focus towards integrative approaches, exploring ways to sensibly and effectively combine thematically separated channels of funding, this barrier to accessing international funding for CSA projects is gradually diminishing. This conceptual change is reinforced by an overall increasing attention on agriculture in a climate change context, representing not only the arguably most important sector for climate change adaptation, but at the same time one of the world's largest sources of GHG emissions. Especially in combination with forest degradation and competing land use, agriculture is increasingly recognized as one of the crucial parts of the global climate challenge.

While underdeveloped financing channels, like private sector investments or carbon markets, are likely to provide only limited financing for specific niches (e.g. manure management or product certification) in the mid-term, bilateral as well as multilateral public financing is starting to put more explicit emphasis on CSA activities. For example, the ongoing process of the GEF-6 replenishment is pointing in this direction. Perhaps most importantly in the mid-term future, the current design process of the Green Climate Fund might be influenced by this overall dynamic, which bodes well for the development of CSA financing. Assuming that the GCF will have a significant impact on the entire climate finance landscape, not only in structure but also in prioritization and principles, a clear focus on CSA embedded in the GCF design would make a difference for the way CSA approaches can be realized and scaled-up in the coming decades.

For developing countries, this implies an opportunity as much as a challenge. In order to successfully access, but more importantly to effectively use increasing volumes of international CSA financing, developing countries will have to ensure that the necessary prerequisites are in place. While significant readiness activities have been ongoing in REDD+ for a long period of time, there are still more gaps to be filled in the agricultural sector to improve the basis for larger-scale CSA investments. Challenges include the usual suspects, such as the quality and quantity of available data, the effectiveness of monitoring systems to institutional and technical implementation capacity as well as the suitability of policy and legal frameworks. Existing knowledge and experiences on CSA as well as the wealth of climate change needs assessments and priority setting at the national level (e.g. through NAPAs, Nationally Appropriate Mitigation Actions, etc.) provide a solid basis for concrete and country-specific preparatory measures. In order to get a head-start on CSA, developing countries could consider putting the fundamentals in place now to be ready to use new CSA opportunities as they emerge.

Notes

This module was written by Leslie Lipper (FAO) and Bjorn Conrad (FAO) with contributions from the World Bank made by Ademola Braimoh, David Treguer and Marco Van der Linden. The module was reviewed by The Global Mechanism of the UNCCD, in particular by Elisabeth Barsk-Rundquist, Camilla Nordheim-Larsen and Siv Oystese. Additional inputs were also provided by Luis Bockel (FAO), Uwe Grewer (FAO) and Savis Joze Sadeghian (FAO).

Acronyms

AF	Adaptation Fund
ASWAp	Agriculture Sector Wide Approach
CCM	Climate Change Mitigation
COP	Conference of the Parties
CSA	climate-smart agriculture
EC	European Commission
GAP	good agricultural practices
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	greenhouse gas
IFAD	International Fund for Agricultural Development
IFC	International Finance Cooperation
IPCC	Intergovernmental Panel on Climate Change
LDCF	Least Developed Countries Fund
MDBs	Multilateral Development Banks
MRV	measurement, reporting and verification
NAPA	National Adaptation Programme of Action
OECD	Organisation for Economic Co-operation and Development
PPCR	Pilot Program for Climate Resilience
PwC	PricewaterhouseCoopers
REDD+	Reducing Emissions from Deforestation and Forest Degradation
REED	Rural Energy Enterprise Development
RTRS	Round Table on Responsible Soy
SCCF	Special Climate Change Fund
SFM	Sustainable Forest Management
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WWF	World Wildlife Fund

References

Abbott, K.W. & Gartner, D. 2011. *The Green Climate Fund and the future of environmental governance.* EARTH System governance working paper No. 16.

Anger, N. & Sathaye, J. 2008. *Reducing deforestation and trading emissions: economic implications for the post-Kyoto carbon market.* Centre for European Economic Research.

Antle, J.M. & Crissman, C.C. 1990. *Risk, efficiency, and the adoption of modern crop varieties: evidence from the Philippines*. Economic Development and Cultural Change, 38(3): 517–537.

Barrett, C.B. 2007. *Displaced distortions: financial market failures and seemingly inefficient resource allocation in low-income rural communities.* In E. Bulte & R. Ruben, eds. Development Economics Between Markets and Institutions: Incentives for growth, food security and sustainable use of the environment. Wageningen, Netherlands, Wageningen Academic Publishers.

Blackman, A. & Naranjo, M.A. 2012. *Does eco-certification have environmental benefits? Organic coffee in Costa Rica.* Ecological Economics, Vol. 83. 58–66 pp.

Blackman, A. & Rivera, J. 2011. *Producer-level benefits of sustainability certification*. Conservation Biology, 25 (6):1176–1185.

Branca, G., Lipper L. & Sorrentino, A. 2012. *Benefit-costs analysis of climate-related agricultural investments in Malawi: a case study.* Paper presented at First Conference of Italian Association of Agriculture and Applied Economics. Trento, Italy.

Brooks, N., Anderson, S., Ayers, J., Burton, I. & Tellam, I. 2011. *Tracking adaptation and measuring development.* International Institute for Environment and Development Climate Change Working Paper No. 1. London, IIED.

Buchner, B., Falconer, A., Hervé-Mignucci, M., Trabacchi, C. & Brinkman, M. 2011. *The Landscape of Climate Finance: a Climate Policy Initiative* (CPI) report. (available at http://climatepolicyinitiative.org/wp-content/uploads/2011/10/The-Landscape-of-Climate-Finance-120120.pdf)

Chassard, J. 2010. *Press release: first African emission reductions purchase agreement for soil carbon signed in the Hague.*

De Janvry, A. & Sadoulet, E. 1995. *Behavior and Welfare Under Risk*. Chapter 5. Quantitative Development Policy Analysis. Baltimore, USA, Johns Hopkins University Press.

De Janvry, A. & Sadoulet, E. 2010. *Agricultural growth and poverty reduction: additional evidence.* World Bank Research Observer, 25(1): 1–20. (available at http://wbro.oxfordjournals.org/content/25/1/1.full)

Dercon, S. & Christiaensen, L. 2011. *Consumption risk, technology adoption and poverty traps: evidence from Ethiopia.* Journal of Development Economics, Vol. 96(2). 159–173 pp.

Duflo, E., Kremer , M. & Robinson, J. 2011. *Nudging farmers to use fertilizer: theory and experimental evidence from Kenya.* American Economic Review, Vol. 101(6): 2350–2390. American Economic Association.

European Commission. 2013. *Other sources of climate financing.* (available at http://ec.europa.eu/clima/policies/finance/international/other/index_en.htm)

Feder, G., Just, R. & Zilberman, D. 1985. *Adoption of agricultural innovations in developing countries: a survey.* Economic Development and Cultural Change, 33(2): 255–298.

Fafchamps, M. 1992. *Solidarity networks in pre-industrial societies: rational peasants with a moral economy.* Economic Development and Cultural Change, 41(1): 147–174.

FAO. 2007. *State of food and agriculture report: paying farmers for environmental services.* Rome. (available at http://www.fao.org/docrep/010/a1200e/a1200e00.htm)

FAO. 2009. *Food security and agricultural mitigation in developing countries: options for capturing synergies.* Rome.

FAO. 2010. *Climate-smart agriculture: policies, practices and financing for food security, adaptation and mitigation.* Rome.

FAO. 2011a. *The state of food and agriculture 2010-11: women in agriculture.* Rome.

FAO. 2011 *b.* Climate change mitigation finance for smallholder agriculture: a guidebook to harvesting soil carbon sequestration benefits. Rome.

FAO. 2011c. *Save and grow: a policymaker's guide to the sustainable intensification of smallholder crop production.* Rome.

FAO. 2012a. *The state of food and agriculture 2012: investing in agriculture for a better future.* Rome.

FAO. 2012b. *Identifying opportunities for climate-smart agricultural investments in Africa.* Rome.

FAO. 2012c. *Stability of food security in a green economy environment.* Greening the Economy with Agriculture. Rio+20 Working Paper No. 3. Rome.

FAO. 2012d. *Incorporating climate change considerations into agricultural investment programmes: a guidance document.* (available at http://typo3.fao.org/fileadmin/templates/tci/pdf/climate_change_considerations.pdf)

FAO. 2012e. *Developing a climate-smart agriculture strategy at the country level: lessons from recent experience.* (available at http://www.fao.org/docrep/016/ap401e/ap401e.pdf)

Global Agenda of Action. 2012. *Building a Global Agenda of Action.* (available at http://www.livestockdialogue.org/thematic-areas/closing-the-efficiency-gap/en/)

Global Environment Facility (GEF). 2007. *GEF-5 focal area strategies.*

GEF. 2010. *Investment guidelines for GEF's Sustainable Forest Management and REDD+ Programme.*

GEF. 2011. *Accessing resources under the least developed countries fund.*

GEF. 2013a. *Draft GEF-5 Programming Directions.* First Meeting for the Sixth Replenishment of the GEF Trust Fund. Paris.

GEF. 2013b. *Intersessional work program submitted for GEF council approval.* (available at http://www.thegef.org/gef/sites/thegef.org/files/Docs/Cover%20Note%20GEF%20IWP-April_2013.pdf)

Gitz, V. & Meybeck, A. 2012. *Risks vulnerability and resilience in a context of climate change. Building Resilience for Adaptation to Climate Change in the Agricultural Sector.* Proceedings of a Joint FAO/OECD Workshop. FAO & OECD, Rome.

Hansen, J. & Coffey, K. 2011. *Agro-climate tools for a new climate-smart agriculture.* Copenhagen, Denmark, CCAFS.

Heltberg, R. & Tarp, F. 2002. *Agricultural supply response and poverty in Mozambique*. Food Policy, 27: 103–124.

High Level Panel of Experts (HLPE). 2012a. *Social protection for food security.* A report by the HLPE on Food Security and Nutrition of the Committee on World Food Security. Rome. (available at http://www.fao.org/cfs/cfs-hlpe/en/)

High Level Panel of Experts (HLPE). 2012b. *Food security and climate change.* A report by the HLPE on Food Security and Nutrition of the Committee on World Food Security. Rome.

Hurley, T. 2010. *A review of agricultural production risk in the developing world.* Harvest Choice Working Paper No. 11. Washington D.C., International Food Policy Research Institute.

International Fund for Agricultural Development (IFAD). 2011. *Rural poverty report 2011: new realities, new challenges: new opportunities for tomorrow's generation.* IFAD, Rome.

International Finance Cooperation (IFC). 2011. *Climate finance: engaging the private sector.*

Intergovernmental Panel on Climate Change (IPCC). 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation, C.B.* Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G-K. Plattner, S.K. Allen, M. Tignor, P.M. Midgley, eds. A Special Report of Working Groups I and II of the IPCC. Cambridge, UK & New York, USA, Cambridge University Press. 582 pp.

Kassie, M., Pender, J., Yesuf, M., Köhlin, G., Bluffstone, R. & Mulugeta, E. 2008. *Estimating returns to soil conservation adoption in the northern Ethiopian Highlands.* Agricultural Economics, 38(1): 213–32.

Lattanzio, R.K. 2013. *International climate change financing: the Green Climate Fund.* Congressional Research Service.

Lowder, S., Carisma, B. & Skoet, J. 2012. *Who invests in agriculture and how much? An empirical review of the relative size of various investments in agriculture in low- and middle-income countries.* ESA Working Paper No. 12. FAO, Rome.

Mahul, O. & Stutley, C.J. 2010. *Government support to agricultural insurance: challenges and options for developing countries.* World Bank. (available at https://openknowledge.worldbank.org/bitstream/handle/10986/2432/538810PUB0Gove101Official0Use0Only1.pdf?sequence=1)

McCarthy, N., Lipper, L. & Branca, G. 2011. *Climate-smart agriculture: smallholder adoption and implications for climate change adaptation and mitigation.* MICCA Working paper No. 4. FAO, Rome.

Meybeck, A. & Place, F. 2013. *Food security and sustainable resource use - what are the resource challenges to food security?*

Nelson, G.C., Rosegrant, M.W., Koo, J., Robertson, R., Sulser, T., Zhu, T., Ringler, C., Msangi, S., Palazzo, A., Batka, M., Magalhaes, M., Valmonte-Santos, R., Ewing, M. & Lee, D. 2009. *Climate change: impact on agriculture and costs of adaptation*. Food Policy Report. Washington D.C., International Food Policy Research Institute. 30 pp. (available at http://www.ifpri.org/sites/default/files/publications/pr21.pdf)

Organisation for Economic Co-operation and Development (OECD). 2013. *Aid assistance.* (available at http://www.oecd.org/dac/stats/)

Parry, M., Arnell, N., Berry, P., Dodman, D., Fankhauser, S., Hope, C., Kovats, S., Nicholls, R., Satterthwaite, D., Tiffin, R. & Wheeler, T. 2009. *Assessing the costs of adaptation to climate change: a review of the UNFCCC and other recent estimates.* London, International Institute for Environment and Development & Grantham Institute for Climate Change.

Plantinga, A.J. 2008. *International forest carbon sequestration in a post-Kyoto agreement.* The Harvard Project on International Climate Agreements. Discussion Paper 08–11. (available at http://belfercenter.ksg.harvard.edu/files/PlantingaWeb3.pdf)

Pilot Program for Climate Resilience (PPCR). 2011. *Strategic programme for climate resilience: Zambia.* Climate Investment Funds. (available at http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/PPCR%208%20SPCR%20Zambia.pdf)

PricewaterhouseCoopers (PwC) & Rockefeller Foundation. 2011. *Agricultural carbon markets: opportunities and challenges for sub-Saharan Africa.*

Roe, T. & Graham-Tomasi, T. 1986. *Yield risk in a dynamic model of the agricultural household*. In I. Singh, L. Squire & J. Strauss, eds. Agricultural Household Models: Extension, Applications and Policy. Baltimore, USA, Johns Hopkins University Press.

Rosenzweig, M.R. & Binswanger, H.P. 1993. *Wealth, weather risk and the composition and profitability of agricultural investments.* Economic Journal, 103(416) : 56–78.

Schmidhuber, J. & Bruinsma, J. 2011. *Investing towards a world free of hunger: lowering vulnerability and enhancing resilience*. In A. Prakash, ed. Safeguarding food security in volatile global markets. Rome, FAO.

Schmidhuber, J., Bruinsma, J. & Boedeker, G. 2009. *Capital requirements for agriculture in developing countries to 2050.* Paper presented at the FAO Expert Meeting on How to Feed the World in 2050. Rome, FAO.

Sen, A. 1981. *Poverty and famines.* Oxford, Clarendon Press.

Shames, S., Friedman, R. & Havemann, T. 2012. *Coordinating finance for climate-smart agriculture.* Ecoagriculture Discussion Paper No. 9, Ecoagriculture Partners. (available at http://ecoagriculture.org/documents/files/doc_431.pdf)

Sharma, S. & Suppan, S. 2011. *Elusive promises of the Kenya Agricultural Carbon Project.* Institute for Agriculture and Trade Policy (IATP).

Skees, J., Hazell, P. & Miranda, M. 1999. *New approaches to crop yield insurance in developing countries.* EPTD Discussion Paper No. 55. Washington D.C., International Food Policy Research Institute.

Sustainable Agriculture Initiative. 2010. *Promoting the advancement of sustainable sugarcane in Brazil.* (available at www.saiplatform.org/projects/8/46/Promoting-the-Advancement-of-Sustainable-Sugarcane-in-Brazil)

The Geneva Association. 2012. *Extreme events and insurance: 2011 annus horribilis, C.* Courbage & W.R. Stahel, eds. The Geneva Reports No. 5. Geneva. pp. 39–61.

Thornton, P & Lipper, L. 2013. *How does climate change alter agricultural strategies to support food security?* (available at http://www.pim.cgiar.org/food-security-futures-conference/)

United Nations Environment Programme (UNEP). 2010. *Bilateral finance institutions and climate change: a mapping of 2009 climate financial flows to developing countries.*

UNEP Risø Centre. 2011. *Progressing towards post-2012 carbon markets.* Perspectives Series.

UNFCCC. 2010. *Terms of reference for the design of the Green Climate Fund.* Report of the Conference of the Parties on its sixteenth Session.

Woelcke, J. 2012. *More than just hot air: carbon market access and climate-smart agriculture for smallholder farmers.* IFC SmartLessons Series.

World Bank. 2008. *World development report 2008: agriculture for development.* Washington D.C.

World Bank. 2011. *State and trends of the carbon market 2011.*

MODULE 15:

DISASTER RISK REDUCTION: STRENGTHENING LIVELIHOOD RESILIENCE

Overview

This module will demonstrate how proven policies and practices in disaster risk reduction (DRR) can contribute to the objectives of climate-smart agriculture (CSA). There is a wide range of good practices in risk reduction and many potential contributions of DRR to CSA. This module presents some examples of practical methods, tools and technologies that have been applied successfully to reduce disaster risk in the agriculture sector. It also outlines the broad landscape of national institutional mechanisms, policy frameworks and strategies established in many countries for DRR, and looks at how these can create a supportive enabling environment for CSA. When capacity in DRR is combined with knowledge on adaptation, the results can be fruitful and far-reaching for CSA. Strategies designed to guide action and investment in CSA will be more holistic in addressing the multiple threats to livelihoods with short- and long-term solutions. This module focuses on the potential contribution of risk reduction policy and practice to the achievement of the second pillar on which CSA is built: "strengthening resilience to climate change and variability".

Section 15.1 provides an introduction to DDR and highlights the common ground it shares with emerging practices in climate change adaptation. Section 15.2 illustrates how a multi-hazard approach that examines the diversity of threats to agriculture is effective for building resilient agricultural landscapes that are better protected against multiple shocks. Section 15.3 looks at community-based disaster risk management (CBDRM), and how it can support CSA as a proven bottom-up participatory approach to risk assessment, planning, implementation and monitoring at local levels. Section 15.4 makes reference to the vast pool of traditional knowledge and risk reduction technologies and practices used in the agricultural sector. It shows that CSA can achieve significant increases in scale by replicating these proven good practices. Section 15.5 reviews the current wealth of national institutional arrangements, policy and planning frameworks for DRR. It indicates that the significant achievements made in this area can be harnessed in support of CSA.

Key messages

- Multi-hazard risk assessment and mapping combined with climate change scenarios provide a holistic framework for assessing all relevant hazards in specific geographic areas.
- Proven DRR technologies and practice provide a rich resource-base for promoting and scaling up CSA.
- CBDRM is a proven participatory method for assessing local risks and for informing local planning. It can be a vehicle and methodology for promoting CSA at local levels.
- At national and regional levels, well-established legislation, institutional structures, policies and plans for DRR can provide CSA with a strong supportive enabling environment.
- Building on the accumulated knowledge and practice in DRR increases the efficiency of international aid and government investments in CSA.

- For farmers, there is no distinction between risk reduction and adaptation. From their perspective, there are only threats to livelihoods and family food security from which they need to be protected. systems; improved feeding and reduced losses from disease in aquaculture; the reduction of post-harvest and production losses; and the further development of regional trade.
- The transition to CSA in fisheries and aquaculture will need to take place at all levels (individual, business, community, national and regional) and time scales. All stakeholders from private and public sectors will need to be involved in the development of context-specific options to ensure the fisheries and aquaculture sector is climate-smart.
- To make the transition to CSA in fisheries and aquaculture, it will be necessary to ensure that the most vulnerable states, production systems, communities and stakeholders have the potential to develop and apply CSA approaches.
- Markets and trade may help buffer the impact of changes in production that affect food security, consumer prices and supply-demand gaps. However, the implications of climate change impacts and climate change policies on the entire supply and value chain need to be better understood. Appropriate policy measures need to be defined and implemented.

Contents

List of Figures

List of Tables

List of Boxes

15.1 Disaster risk reduction and climate change adaptation

Climate change is expected to result in more frequent and intensive climate-related hazards. It will also reduce the predictability and change the geographic distribution of extreme climatic hazards, such as extreme temperatures, floods and droughts, heat waves, wild fires and storms. Existing vulnerabilities will be compounded by climate change-related processes, such as rising sea levels, increased glacier melt, stressed ecosystems and the degradation of natural resources (IPCC, 2007).

Meanwhile, the world continues to cope with the devastating effects of natural disasters stemming from geological and weather-related hazards. Experience shows that the negative and cumulative impact of these disasters erodes livelihoods and coping capacities over time, reduces food production and increases hunger. The clear link between disasters and hunger is an indication of the fragility of food production systems and their vulnerability to natural hazards (FAO, 2011b). Evidence reveals the direct contribution these disasters make to reversing development and the gains made in poverty reduction. Worldwide, vigorous efforts have helped to strengthen the capacity of communities and nations to cope with natural hazards, and to reduce their exposure and vulnerability. This has been accomplished through the establishment of national and local institutional structures and DRR strategies, as well as the development and effective application of methodologies, practical tools and community-based approaches to reduce risk.

Global experiences and established capacities in addressing disaster risk are directly relevant to climate change adaptation and CSA. By now, many countries have made significant progress in meeting the priorities agreed to in the Hyogo Framework for Action (HFA). Endorsed by 193 member states and implemented under the coordination of the United Nations International Strategy for Disaster Reduction (UNISDR), the HFA is a 10-year plan to make the world safer from natural hazards (UNISDR, 2005). DRR is understood as the "concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment, and improved preparedness for adverse events"(UNISDR, 2009c). While distinct in scope, DRR and climate change adaptation share a common concern over climate-related extreme events. In the agriculture sector, they both aim to build resilient livelihoods.

Recognizing this interconnectedness, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) adopted the Cancun Adaptation Framework, which calls for enhanced climate change-related DRR strategies that take into consideration the HFA where appropriate. This link is also formally acknowledged in the UNFCCC's Bali Action Plan. The United Nations Secretary-General noted that "better DRR will help the world adapt to climate change"; and that DRR should be applied "...as a first line of defence in adapting to climate change" (Ban, 2008). The aim should be to "capitalize on the common concerns of adaptation and risk reduction in policies and practical action, and to seek the triple win of lower disaster risks, adaptation to climate change, and sustainable development outcomes" (UNISDR, 2009c). Building resilience through sound safety nets, DRR and adaptation planning is one of the six priority areas for action in the recent Report of the Secretary General's High-level Panel on Global Sustainability (High-level Panel on Global Sustainability, 2012). The post-2015 United Nations development agenda agreed to at the Rio+20 conference calls for the integration of risk reduction and adaptation into sustainable development strategies (UN System Task Team on the Post-2015 UN Development Agenda, 2012). CSA will benefit significantly from following this holistic approach that blends adaptation measures with global experience in risk reduction.

15.2 Planning for resilience against multiple risks

The multiple threats to agriculture and food security

Building resilience requires that we "grasp the dimension of multiple challenges" (High-level Panel on Global Sustainability, 2012). An examination of the diversity of natural hazards affecting agriculture and food security indicates that, even without climate change, a multiplicity of hazards are already eroding livelihoods and compromising gains made in food security. These hazards contribute to the difficulties in meeting the Millennium Development Goal to halve the proportion of people who suffer from hunger by 2015. This includes geological hazards, such as earthquakes, tsunamis and volcanic eruptions; human-induced hazards, such as conflict, economic crises, high food prices; and traditional weather-related hazards, such as floods, drought and storms.

In 2012, over 18 million people faced food insecurity in the Sahel region of West and Central Africa (FAO, 2012a and b). The Sahel last experienced a major food crisis in 2010 affecting ten million people. In the Horn of Africa, the ongoing food security crisis, which began in 2011, has threatened the lives and livelihoods of over 12 million people.

In 2010, Pakistan experienced the worst flooding since 1929, with over 20 million people affected. The impact on agriculture was severe. Over two million hectares of cultivatable land and 1.3 million hectares of standing crops were damaged. Six million poultry and 1.2 million large and small animals were lost (World Bank and Asian Development Bank, 2010). Heavy rains during the 2011 monsoon season caused renewed and devastating flooding that affected almost 10 million people. On average, households lost 66 percent of their cattle and 33 percent of their poultry. The flood also caused a significant increase in commodity prices, with the price of paddy increasing by 25 percent on average. At the same time, the purchasing power of labour decreased by 13 percent (UN, 2011).

Geological hazards also cause serious direct and indirect damage to agriculture and livelihood security. The Haitian earthquake caused nearly US$ 26 million in damages to the agricultural sector (Republic of Haiti, 2010). The destruction of the Haitian capital severely affected access to markets and other production infrastructure. This, together with the migration of over half a million people from urban to rural areas, put additional pressure on rural livelihoods. In agricultural areas hit by the earthquake, debris and landslides damaged farmland irrigation systems, permanent storage facilities and processing centres, and the administrative and technical buildings of the Ministry of Agriculture. All these factors combined to produce sharp declines in income, food reserves and food availability, and helped trigger price hikes (FAO, 2010b; FAO and WFP, 2010). The tsunami of December 2004, which affected 12 countries in the Indian Ocean, had a devastating impact on the agriculture and fisheries sectors. Some 40 000 hectares of irrigated land were destroyed by floods on the island of Sumatra in Indonesia, and in Banda Aceh nearly 70 percent of the small-scale fishing fleet and associated gear was destroyed.

Frequently, disasters combine with other factors and underlying vulnerabilities to produce food insecurity and hunger. High food prices, which added 75 million people to the total number of undernourished worldwide in 2008 relative to 2003-2005 (FAO, 2008a), was the result of several factors including: the fuel crisis, slower growth in food production, lower stock levels, and increased use of agrofuels (IFRC, 2011). The current crisis in the Horn of Africa is the result of drought caused by erratic and failed rains over two rainy seasons combined with high food prices due to soaring fuel costs. In Somalia, the situation has been exacerbated by civil insecurity (USAID and FEWSNET, 2011a and b). In the Sahel, "a lethal mix of drought, high grain prices, environmental degradation, entrenched poverty and other factors is behind the crisis" (FAO, 2012a).

Not surprisingly, countries in protracted crisis situations show high levels of food insecurity. Protracted crises are characterized by recurrent natural disasters and/or conflict, longevity of food crises, breakdown of livelihoods and insufficient institutional capacity to react to the crises. On average, the proportion of people who are undernourished is almost three times as high in countries in protracted crisis as in other developing countries (FAO, 2012a).

Food crises have become more frequent since the early 1980s. There have been between 50 and 65 food emergencies every year since 2000, up from 25-45 during the 1990s (FAO, 2008a). Climate change multiplies risk by increasing the number and scale of extreme climate-related events. Disaster risks and climate change produce similar negative impacts on agriculture, and both threaten to increase hunger over time. In addition, there is growing probability of 'simultaneous crises' where different hazards occur at the same time, 'sequential crisis' where hazards trigger cascading disasters in a range of interlocked systems, and 'synchronous failures' where different risks converge and interact (FAO, 2008a). The challenge is to ensure food security in the face of multiple hazards and climate change.

Mapping multiple risk scenarios for sustainable planning

Understanding risk is a vital part of policy formulation, planning and decision making. The assessment of threats to agriculture or 'agricultural risks' is a necessary first step in designing effective risk reduction measures for food security. Hazard, vulnerability and risk assessments or mapping are some of the practical tools that have been developed and applied in many countries as the basis for planning appropriate DRR policies and practices. Increasingly, they have been used in sustainable land-use planning and development investments. Given that effective strategies can only be achieved by understanding the risks already facing farmers, these tools can also support planning for climate change adaptation and CSA.

Hazard maps delineate the geographic areas exposed to a specific type of hazard, such as floods, earthquakes, drought or tsunamis. Typically, they indicate the likelihood or probability of occurrence, frequency and potential severity or magnitude. Hazard maps are based on historical data and knowledge of past events. Vulnerability mapping identifies the elements exposed to hazards that may be adversely affected, such as populations, property, agricultural areas, livelihoods, services, health facilities, etc. Vulnerability assessments may also include social or economic dimensions, including livelihoods. Risk is determined through the combined analysis of potential hazards and existing conditions of vulnerability. Hazard and risk maps can be developed at different spatial scales to display the risk distribution across geographical areas. They can be site-specific, encompass municipal or provincial administrative areas and other subnational landscapes, such as river basins, or they can be national and even regional in scope.

Figure 15.1
Risk Assessment and Mapping

Hazards

Vulnerability

Risk

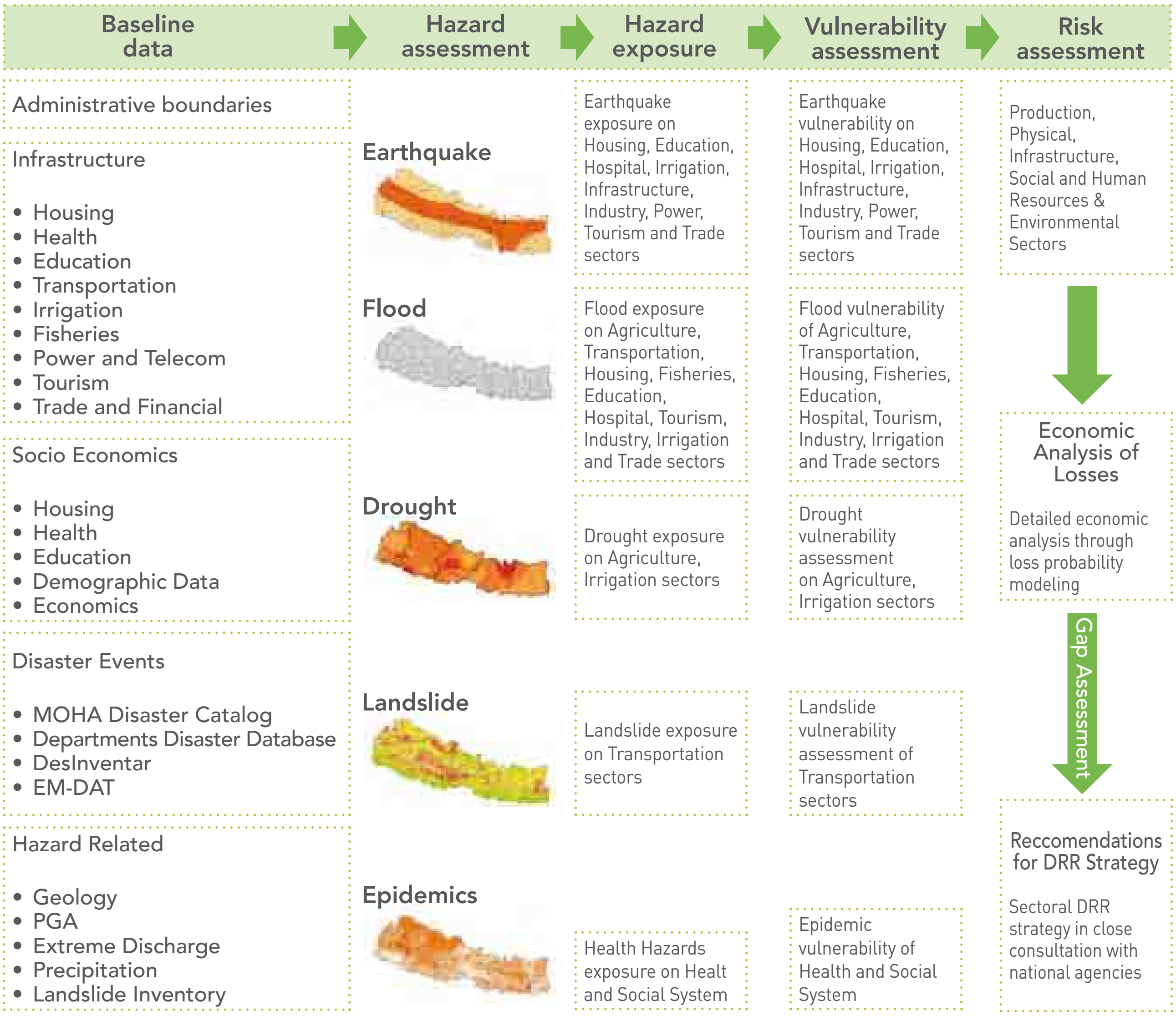
Used to inform:

- DRR-specific plans
- Adaptation-specific plans
- CSA strategies
- Land-use or territorial planning
- Development investments
- Post-disaster recovery planning

Photo Credits:
Hazards - Republic of Nicaragua, Direccion de Hidrologia Superficial
Vulnerability - ©FAO, Thomas Hofer
Risk - ©FAO, Truls Brekke

Methodologies and tools used in hazard and risk assessment and mapping vary considerably, but some of the most advanced follow an all-hazards, all-risks approach. Effective planning always needs to consider every spatially relevant hazard and not limit the focus to only one hazard or threat. Mapping multiple-risk scenarios at different spatial scales is the key to understanding the various hazards affecting the same exposed geographic area or landscape. This makes it possible to assess the cumulative consequences of hazards and their potential interactions. For instance, some areas may be prone to drought during the dry season but also to floods during the wet season. This has important implications for the design of appropriate risk reduction and adaptation measures. Following an all-hazards, all-risks approach also reduces the likelihood that efforts to safeguard against one type of hazard will not be lost to another hazard or increase vulnerability to other hazards. For instance, regulations that seek to protect socio-economic investments against floods, such as safe location or flood-resistant infrastructure, will only provide a partial solution unless it safeguards against earthquakes in areas that are also prone to seismic activity. Risk assessments and mapping provide an effective tool for spatial planning and for supporting sound decision making. Figure 15.2 below shows an example of the comprehensive multi-hazard risk assessment framework used in Nepal to guide risk reduction measures (Federal Democratic Republic of Nepal *et al.*, 2011). The framework included a hazard assessment of earthquakes, floods, droughts, landslides and other hazards at the national level. The assessment was based on historical information, with maps indicating the spatial distribution of hazards in the country, and was followed by an analysis of exposure, vulnerability and risk for various physical, social and infrastructural assets, including agriculture.

Figure 15.2
Nepal risk assessment and mapping framework



Source: Adapted from Federal Democratic Republic of Nepal *et al.*, 2011

In the Bicol region of the Philippines local-level planning for DRR was based on the use of a multi-hazard assessment that identified the threats to agriculture and the farming practices that made farmers more vulnerable to natural hazards. It was instrumental in the selection of the most appropriate DRR technologies and practices.

Box 15.1
Multihazard assessment for DRR in Bicol Region, Philippines

In a DRR project implemented by FAO in the Bicol region, a situation assessment was carried out in pilot areas as a starting point to evaluate a variety of factors, including: the physical and environmental context and local hazards; the socio-economic conditions, livelihoods and agricultural land use; the existing vulnerabilities of vulnerable groups, their capacity and coping strategies and their existing agricultural practices (e.g. crops, livestock, fisheries, forestry, homestead); and the local institutional disaster risk management systems.

The multi-hazard assessment identified eight types of threats to agriculture, including geological and climate-related hazards, and assessed the level of risk and impact of each. In the diagram below, when the intensity level goes up, the further from the centre, the greater is the hazard and its impact on the elements at risk.

Figure 15.3
Threats to agriculture

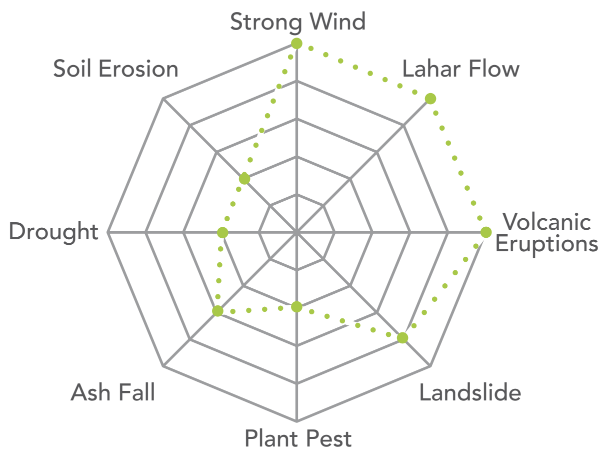
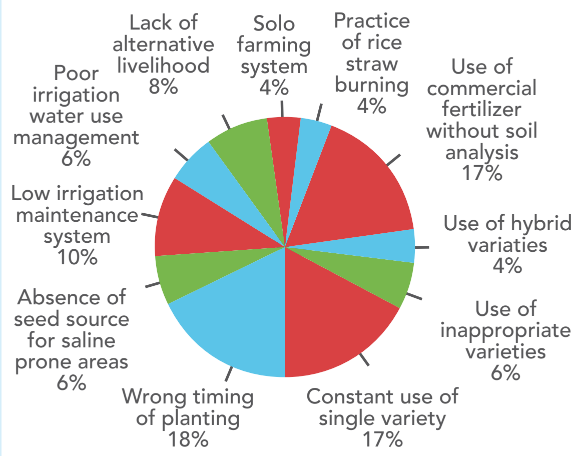


Figure 15.4
Farming practices resulting in vulnerability to hazards



In addition to the types of threats to agriculture, the assessment in Bicol identified farming practices that made farmers more vulnerable to hazards, such as the use of inappropriate crop varieties or incorrect timing for planting.

Source: Republic of the Philippines Department of Agriculture and FAO, 2010

The value of risk assessments is well recognized. A number of countries have institutionalized the use of risk assessments as the basis for planning risk reduction strategies. For instance, South Africa's policy framework on disaster risk management underscores the importance of disaster risk assessments as a guide for national, provincial and municipal DRR efforts. All national government bodies are required to carry out disaster risk assessments to identify priority disaster risks relevant to their work. They are also committed to developing "a national standard for conducting comprehensive disaster risk assessments, including guidelines for the application of a uniform disaster risk assessment methodology and approach, as well as the standardization of reporting formats for disaster risk assessments" (NDMC, 2005). The disaster management model in Bangladesh, illustrated in Box 15.2 below, is another good example of an institutionalized risk assessment model.

Box 15.2
The standardized community risk assessment model in Bangladesh

Bangladesh promotes the use of scientific analysis, including the analysis of climate change impacts, as the basis for accurately assessing future risk related to all hazards, all sectors and all geographical areas. The country's Disaster Management Model gives priority to defining the risk environment as the basis for developing 'risk treatment options'. In this model, defining the risk environment involves:

- understanding the social, political and community environment (establishing the context);
- establishing the likely threats (identifying hazards and risks);
- understanding the likelihood and consequences (analyse the risks);
- ranking risks in priority (evaluate risks); and
- determining what can be done to eliminate, reduce or manage risk (identify risk treatment strategies).

The Ministry of Food and Disaster Management executed a Comprehensive Disaster Management Programme (CDMP) as a national multi-hazard, multi-sector and multi-stakeholder strategy to build the capacity of local authorities and their communities to understand disaster management, assess risk, and provide local funding to implement priority DRR measures.

The CDMP supports local authorities and Union Disaster Management Committees to conduct standard community risk assessments (CRA) using participatory processes that identify, analyse and evaluate hazards, risks and vulnerabilities combining local knowledge with scientific data and predictions. The assessments follow an all-hazards, all-risks approach and are used in the formulation of risk-reduction plans and development projects. Guidelines for CRA and for risk-reduction action planning procedures have been developed to facilitate this process. Roughly 611 union action plans have been prepared following these guidelines (Djalante *et al.*, 2010). The CRA process is considered a successful example that can be replicated across all risk environments. The intention is to expand its use across the country.

Source: UNISDR, 2010a

The application of risk assessments for various planning objectives is growing. Risk assessments are now used in land-use planning and territorial development, urban planning, the design of public infrastructure, scenario analysis and disaster preparedness. Some countries are starting to carry out risk assessments for development planning and public investment. Peru has been one of the pioneers in this respect. It has formally incorporated disaster risk into its National System for Public Investment. A legal framework now requires disaster risk to be included in the evaluation criteria for public investment projects. The approval of financing rests on this evaluation. This ensures projects are not vulnerable to future disasters (UNISDR, 2010a). To support the mainstreaming of DRR into the National Public Investment System, particularly the project development and approval cycle, Peru's Ministry of the Economy and Finance has developed standard methodologies and tools for national and local public institutions and government authorities. This includes an analysis of the location of public investments, its potential exposure to risks identified and the factors that can make them vulnerable.

In post-disaster situations, risk assessments are being used to guide prospective disaster risk management measures, such as sustainable land-use planning during the recovery process. These assessments enable sound spatial planning that can prevent the reconstruction of infrastructure in high risk areas exposed to recurrent natural hazards. Following the 2010 earthquake in Haiti, the Office of the Special Envoy, in partnership with government agencies and other international organizations, undertook a rapid multi-hazard analysis to map the risk of floods, wind, tsunamis, landslides and earthquakes in the affected areas. They have used the results to guide the safe positioning of transitional shelters and support long-term recovery efforts. In Chile and Mexico, risk assessments are used to establish prerequisites for their Global Catastrophe Mutual Bonds. In the Pacific Islands, the assessments are used to determine the viability of financial risk pooling opportunities.

Combining risk assessment and climate change scenarios for effective CSA

CSA proposes a shift away from single-objective production systems to the management of landscapes with multiple objectives (see for example Module 2 on landscape approach). This demands integrated planning and management. Risk assessments and mapping, as described above, can be instrumental for achieving this goal. Integrated landscape management requires an understanding of all natural hazards affecting a given landscape combined with an assessment of the potential impact of climate change on agricultural systems.

This blended approach provides the evidence-base to help countries at the national or local level to design holistic CSA policies, strategies and practices (see also Module 13 on policies) that are based on geographic-specific assessments of current disaster risks and future climate change scenarios. For this to happen, it is necessary to develop a harmonized framework that integrates data and analysis of natural hazards with projected climate change scenarios using computer modelling (see also Module 18 on assessments, monitoring and evaluation). This gives planners short-, medium- and long-term perspectives that can help in the design and implementation of appropriate measures along the same timescale. Recent risk assessment approaches that are used in combination with climate change models may shape future practices and bring about innovations that are needed to scale up CSA. An example of such an approach can be found in a pilot project from Jamaica, which is illustrated below in Box 15.3.

Box 15.3
Jamaica -the Risk and Vulnerability Assessment Methodology (RiVAMP)

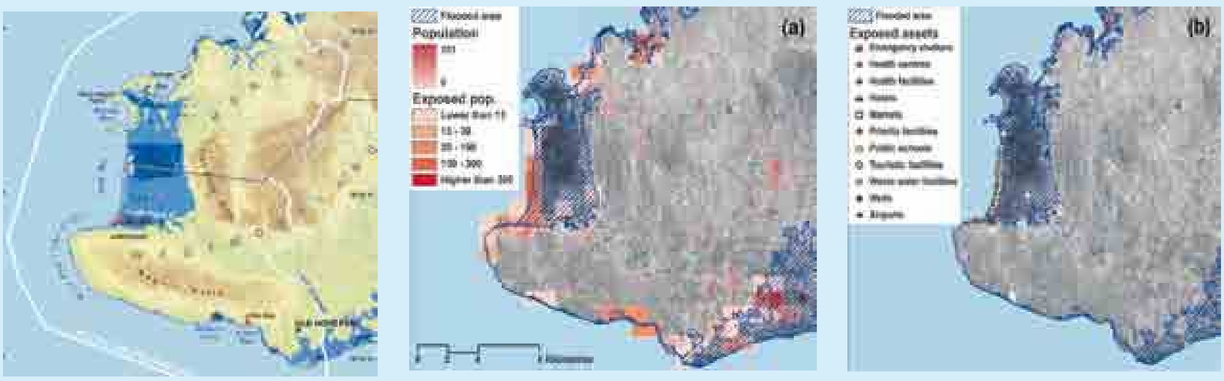
Jamaica is exposed to frequent meteorological hazards, particularly hurricanes. As a small island state, it is also highly exposed to rising sea levels, which could worsen the secondary impacts of tropical cyclones along the coast. At the same time, Jamaica's tourism industry and growing population are putting pressures on its diverse ecosystems and rich biodiversity.

A Risk and Vulnerability Assessment Methodology (RiVAMP) was piloted in Negril on the western coast of Jamaica. It is an evidence-based assessment tool that assists national and local decision makers in making informed choices that reduce risk and support sustainable development through improved ecosystem management. RiVAMP was designed particularly for land-use and spatial development planners, as well as for key stakeholders in natural resource management and disaster management. It is innovative in that its risk assessment method integrates climate change and environmental considerations, including ecosystem degradation.

The project examined the impacts of tropical cyclones and their secondary effects, particularly storm surges and flooding, as well as the potential impacts of rising sea levels. Environmental features were analysed to determine the extent to which coral reefs and sea grasses serve as a natural protective barrier for shorelines against storm surges and rising sea levels.

RiVAMP used a blend of proven scientific methods, such as risk mapping with the use of the Geographic Information System (GIS), satellite imagery analysis and other remote sensing techniques, statistical analysis and the modelling of buffering effects of coastal ecosystems (coral and sea grass). The science-based analysis was complemented by stakeholder interviews and consultation workshops.

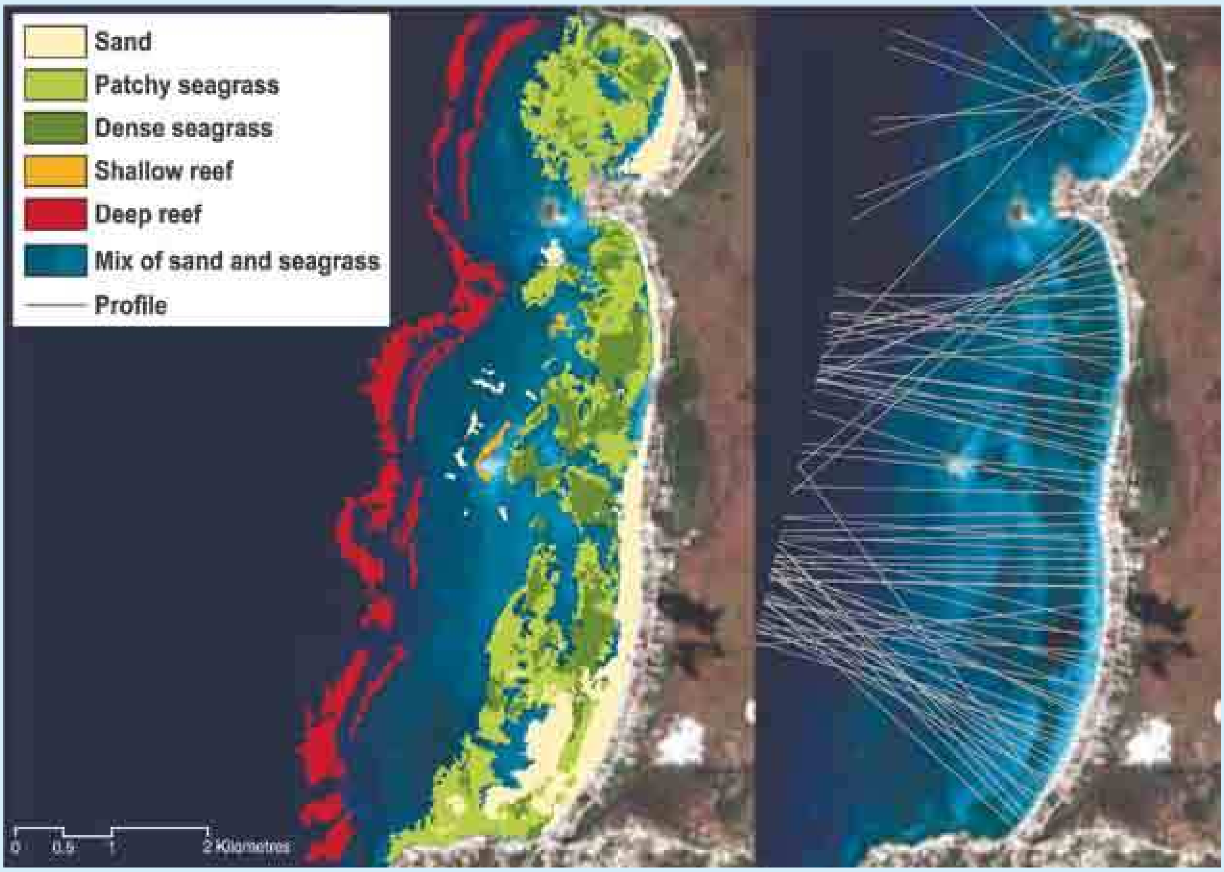
Figure 15.5
Maps of Negril pilot area



Flood hazard map

50-year return period exposure for a) population and b) assets

Figure 15.6
Distribution and location of coastal ecosystems



GIS mapping and analysis assisted in the computation of exposure to storm surge and flooding associated with tropical cyclones. The analysis included population distribution, infrastructure and other exposed assets. Remote sensing used high resolution satellite images and aerial photographs from 1968 to determine the types and distribution of coastal ecosystems, especially coral and sea grasses. These images and photographs were also used in the analysis of coastline erosion due to tropical cyclones and rising sea levels. An ensemble of six widely-used, numerical models were applied to assess the range of shoreline retreat of Negril beaches under various rates of sea level rise and storm surges. Multiple regression analyses were used to identify the positive influence of coral reefs and sea grass meadows on the observed beach erosion patterns along the Negril coastline.

Estimations based on global projections of long-term or accelerated sea level rise (ASLR) together with local predictions of extreme storm waves and surges showed that by 2060, the combination of ASLR and extreme wave surges will have a devastating impact on Negril's beaches and the coastal infrastructure behind it. This has significant implications for risk reduction and adaptation planning. RiVAMP was intended to be used for Small Island Developing States (SIDS) with similar risks as Jamaica, and holds potential for other island states highly exposed to rising sea levels.

Source: UNEP, 2010

and mapping. The Probabilistic Risk Assessment Initiative (CAPRA) is an example of a state-of-the-art, open-source multi-hazard tool for risk assessment and visualization, with a platform that integrates databases with exposure and physical vulnerability data. It facilitates the evaluation of risk in terms of physical damage and direct economic and human losses in standard risk metrics to visualize hazards and risk on GIS. CAPRA was developed by Latin American experts and governments with the support of the Central American Coordination Centre for Disaster Prevention in partnership with a number of international organizations. Another available resource is the large collection of geospatial information on disaster risks for Pacific Island countries that is accessible through the Pacific Risk Information System (PacRIS) platform. PacRIS includes detailed country-specific information on hazards, assets, population and risks for 15 countries in the region. It also contains the most comprehensive analysis of building, infrastructure and cash crop exposure (World Bank, 2012).

15.3 Building on community-based approaches to DRR and adaptation

CSA promotes integrated planning and management at many levels, including local site-specific landscapes. The DRR and climate change adaptation communities of practice have complementary community-based approaches that can support local-level CSA planning. In spite of their inter-connectedness, however, community-based disaster risk management (CBDRM) and community-based adaptation (CBA) are often implemented separately. Overcoming this division presents a challenge. Nevertheless, it is possible for CSA to articulate both of these community-based approaches and harness the benefits of this blended approach.

CBDRM was developed in the 1980s as a process through which at-risk communities can become actively engaged in the identification, analysis, treatment, monitoring and evaluation of disaster risks, to reduce their vulnerabilities and enhance their capacities. Communities, including the most vulnerable, participate in decision making and implementation. In the CBDRM process, the assessment of hazard exposure and analysis of vulnerabilities and capacities (discussed in the previous section) forms the basis for activities, projects and programmes to reduce disaster risks (Asian Disaster Preparedness Center, 2004).

CBA has evolved more recently and has been applied to promote adaptation in the agriculture sector. CBA shares a similar definition and approach with CBDRM. It is understood as "a community-led process, based on communities' priorities, needs, knowledge, and capacities, which should empower people to plan for and cope with the impacts of climate change." (IIED, 2009).

Given the evolution and distinct history of climate change adaptation, CBA and CBDRM are differentiated in practice through separate projects and funding mechanisms. The need for an integrated approach is clear at the local community level, where multiple risks converge and threaten the lives and livelihoods of households and farming communities, and where solutions in risk reduction and adaptation in agriculture can be mutually reinforcing. CBDRM and CBA have the same objective of enhancing livelihood resilience at local levels, use the same bottom-up grassroots approach, target the same populations and apply the same participatory methods at the community level.

CSA should build on the valuable opportunities found in the short- and long-term measures that CBDRM and CBA offer through joint projects and partnerships at the local level. Through existing CBDRM practices, CSA can support measures that farmers prioritize because they address known and immediate risks and provide tangible improvements to families' food security. For local authorities, providing support for short-term risk reduction measures is more viable than investing in adaptation against future uncertainties. At the same time, CBA projects can complement these initiatives by addressing the longer-term impact of climate change through innovative measures. These projects may involve bringing scientific knowledge and climate change data and predictions to communities that would otherwise not have access to it. It may also involve addressing emerging risks associated with climate change, such as rising temperatures, changes in rainfall patterns, rising sea levels, melting glaciers and other expected changes.

This blended approach enables more holistic local planning processes. It has the additional advantage of making available for CSA local institutional structures and partnerships already established for CBDRM and CBA projects, such as farmers' networks, cooperatives, women's groups, etc. and involving all relevant stakeholders in the local landscape (see also Module 12 on institutions). Initiatives that promote CSA can realize this approach by basing projects on a situation analysis that maps existing CBDRM and CBA initiatives, key stakeholders, institutional partnerships and local DRR projects. For local authorities, an integrated approach to CSA will help remove the administrative burden and cost of managing a diversity of CBA and CBDRM projects in an environment already facing institutional and financial constraints. Such win-win benefits optimize resources and make aid more cost-effective.

While practices in linking CBDRM and CBA still need to be explored further, the example below of Papua New Guinea provides a practical framework that demonstrates the value of combining DRR and climate change adaptation at the community level to guide agricultural practice.

Box 15.4
Integrated community approaches to DRR and adaptation in Papua New Guinea

In Papua New Guinea the community-based framework for addressing DRR, which had been previously developed with some indigenous communities in Papua New Guinea, was used and adjusted to address climate change at the village level.

The original community-based framework for DRR used participatory techniques, such as guided discovery, mapping exercises, timelines and matrix rankings to collect information from community members on village history, hazards and event timelines, maps, and environmental and social trends. This baseline information was used to identify, in collaboration with communities, underlying vulnerability factors, both external and internal. Lastly, communities identified past and present indigenous and scientific strategies used, and prioritized possible risk and vulnerability reduction strategies. This DRR framework addressed short-term DRR needs as well as addressed floods, storms, landslides, and volcanic eruptions.

The framework was then used as a practical entry point for discussing why and how communities are also vulnerable to climate change and what measures could be taken to address these challenges. The concerns and priorities of communities identified in the original DRR framework were combined with information about how global climate change was linked to local conditions. The assessment of climate change impacts, vulnerability, and adaptation on SIDS prepared by Center for International Climate and Environmental Research – Oslo (CICERO) and the United Nations Environment Programme (UNEP) was used as a baseline (CICERO and UNEP/GRID-Arendal, 2008). External scientific information on the historical and potential future consequences of climate variability and change, such as satellite observations and downscaled climate projections, were integrated for short- and long-term scenarios. Invasive species were identified as an additional threat that could change the pest or disease profile of local agricultural systems. To identify indigenous strategies for reducing vulnerability to climate change, the focus was on determining how local communities had responded to longer-term changes in the past.

The combined community-based framework for DRR and climate change adaptation articulates local and global knowledge, linking community knowledge with external scientific information and approaches. The process resulted in a combination of short-term solutions such as appropriate cropping patterns and land use, with longer-term solutions using external knowledge such as identifying previously unknown suitable crops or crops grown locally.

Source: Kelman et al., 2009

The expansion and institutionalization of CBDRM in many parts of Asia and Latin America offers a wide platform on which CSA can build. In some Asian countries, CBDRM has been institutionalized and mainstreamed. Cambodia, the Philippines and Viet Nam have developed national strategic CBDRM plans for legislative and executive approval. A wide range of key stakeholders have been involved in the process to ensure support and institutionalization, including top-level government leaders, related line ministries, non-governmental organizations (NGOs), local governments, grassroots organizations, donors and other agencies (EC *et al.*, 2008a).

In addition, in Southeast Asia, progress has been made in mainstreaming CBDRM into socio-economic development policies that build the resilience of communities, including action plans at national, subnational and local levels to support CBDRM (EC *et al.*, 2008a). In the Philippines, CBDRM is practiced nationwide, and in Viet Nam it has evolved since the early 1990s to become an example of good practice with strong involvement and commitment from local and national governments (EC *et al.*, 2008b). Recently, the government of Viet Nam approved a national CBDRM programme to establish CBDRM initiatives in 6 000 of the most vulnerable communes and villages in the country by 2020, a decision that will significantly up-scale CBDRM throughout Viet Nam (UNISDR, 2011b). These robust enabling environments for CBDRM can support community-based efforts in CSA.

15.4 Scaling up proven technologies and practices for resilient livelihoods

Building on and expanding DRR knowledge and practice in agriculture

CSA promotes the application of proven practices and approaches and recognizes the need for increased scale. Knowledge and practice gained from DRR offers a resource pool from which to draw proven approaches and technologies that are effective in building resilient livelihoods.

Research has shown that indigenous peoples cultivate an enormous diversity of traditional crop varieties using a variety of effective traditional practices (IIED, 2011a). Five elements of traditional knowledge systems can be useful for climate change adaptation in agriculture (IIED, 2011b):

1. resilient properties (resilient crop species and varieties for adaptation);
2. plant breeding (conservation of local landraces and seed selection for preferred and adaptive characteristics);
3. wild crop relatives (crop improvement and domestication as well as to supplement diets);
4. farming practices (water, soil or pest management, erosion control and land restoration); and
5. climate forecasting (traditional knowledge for forecasting weather and predicting extreme events).

In many societies, resilience has been a natural, evolving process for absorbing shocks and adjusting to changes that impact people's livelihoods (Pandey *et al.*, 2003). Numerous case studies on indigenous knowledge of risk reduction have been documented[1]. For instance, in many regions of the world, a diversity of rainwater harvesting and management practices has evolved over millennia to cope with climate variability, particularly drought. In South Asia, rainwater harvesting dates back over 8 000 years. In India alone, more than 1.5 million traditional village tanks, ponds and earthen embankments harvest rainwater in 660 000 villages across the country (Pandey *et al.*, 2003; IUCN, 2008).

In the Andes, mixed farming systems, agricultural diversity and crop biodiversity have evolved over time as farmers adjusted to shifting environmental conditions (see also Module 6 on genetic resources). For generations, local farmers have domesticated, improved and conserved traditional crop species and varieties. In Peru, where about 4 000 varieties of potatoes are grown, the conservation and cultivation of a rich diversity of potatoes is well recognized as an effective traditional technology for reducing the risk of loss and for protecting against pests and diseases. Farmers identify the varieties that have the capacity to resist drought, cold temperatures or frost. Planting in a diversity of altitudes and terrains also contributes to the conservation of potato varieties and helps to ensure that crops survive in some locations even when they fail in others (EC and Practical Action, 2010).

In the rangelands of the Horn of Africa, pastoralism emerged thousands of years ago and has evolved and adjusted as a response to weather uncertainty. It is a resilient livelihood mechanism for coping with the harsh environment of arid and semi-arid lands and optimizing the use of its natural resources. It allows rural communities to manage risk and conserve their resource base (WISP *et al.*, 2009; HPG, 2009b). "Pastoralism is highly compatible with conservation and makes the most of livestock production opportunities within variable and unpredictable rangeland ecosystems. Pastoral strategies of herd diversity, flexibility and mobility are rational and crucial for survival in risk prone environments and are based on the need to respond rapidly to changing climatic and vegetative conditions" (WISP *et al.*, 2007) (see also Module 8 on climate-smart livestock).

Government investments in DRR, which have increased over the past several decades, can provide examples of effective practices that can be replicated. In India, the government has adopted a number of national programmes for reducing the impact of drought, including: the 1973 Drought Prone Areas Programme; the

[1] See for example SAARC Disaster Management Center, 2008 and UNISDR *et al.*, 2008.

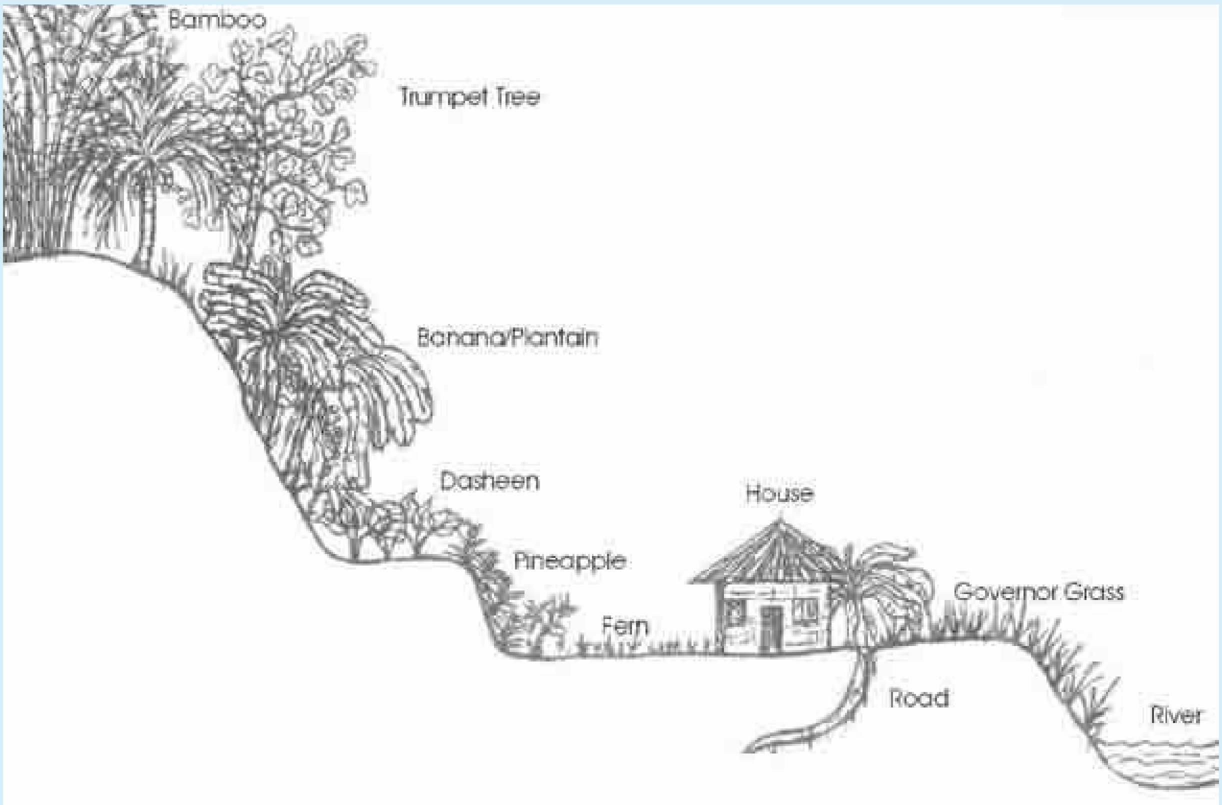
Desert Development Programme initiated in 1977-78; and the Watershed Programme, which is seen as a key vehicle for drought proofing in rainfed areas. The country has introduced specific schemes, such as the 1985 Comprehensive Crop Insurance Scheme to "provide a measure of financial support to farmers in the event of crop failure due to droughts, floods, etc." (Venkateswarlu, 2010; Republic of India Ministry of Agriculture, 2009).

Box 15.5
Local practices in hazard risk management in Jamaica

In Jamaica, communities that are affected each year by hurricanes, floods and landslides, utilize a variety of trees as a water velocity reduction strategy to enhance slope stability and reduce landslide susceptibility. Reduced runoff also helps to diminish or mitigate inundation in the lower lands. Trees that are used include: bamboo, coconuts, grass, growstick, hibiscus, sugar cane, pineapple and other fruit trees.

To regulate soil moisture, farmers utilize larger trees with high moisture absorption capacity. They plant them in waterlogged areas of farms to reduce the probability of flooding.

Figure 15.7
Use of biodiversity to mitigate hazard impact on a flood and landslide susceptible house plot



Water tolerant crops such as dasheen are planted in waterlogged areas to reduce water velocity and thereby prevent damage to more valuable crops. Along the edges of drains and other waterways, water-tolerant crops serve to stabilize banks and prevent the spread of floodwater. Governor grass (*Vetiveria zizanoides*) is planted along the riverbank to reduce the potential loss of land, crops and homes during flooding.

Source: FAO, 2008b

There are an extensive number of technologies and practices for reducing the vulnerability of farming systems and building their resilience. Some examples include: crop diversification, crop insurance schemes, drought or flood-tolerant crop varieties, hazard-proof grain storage facilities and livestock shelters, strategic fodder reserves, bio-security of animal production systems, water reserves to buffer droughts and resilient animal breeding (FAO, 2011b). Because of their adaptive value, many of these practices are also promoted by adaptation strategies. Some practices, such as conservation agriculture, serve multiple functions. Conservation agriculture is an approach promoted for both risk reduction and adaptation because it is particularly suitable for areas that have low soil productivity and are exposed to difficult climatic conditions, such as drought and rainfall irregularity (see for example Module 7 on climate-smart crop production systems). It is also seen as a way to manage agro-ecosystems for improving and sustaining productivity and food security while preserving and enhancing the resource base and the environment (FAO, 2011a).

Technologies and practices promoted by DRR and climate change adaptation can be delivered as a coherent package of solutions to climate variability and change. CSA can provide the common platform for integrating these technologies. At the same time, CSA can achieve significant increases in the scale of its implementation by adopting and promoting DRR practices that are already field tested and proven for building resilient livelihoods. Given the long history of DRR practices, these validated practices offer a large portfolio and broad evidence base for significantly scaling up CSA. The design of CSA initiatives should begin with mapping existing local-specific good practices. One challenge is to identify practices that are effective across different landscapes and against different types of hazards. Where DRR technologies are known and proven to be effective locally, they can serve as immediate entry points to CSA.

Scaling up proven risk reduction practices can be achieved through policies that support their systematic expansion. Nepal provides a good example of a country that has made knowledge sharing a core priority of its integrated strategy for disaster risk reduction and climate change adaptation. Box 15.6 below describes this in more detail.

Box 15.6
Nepal's strategy on knowledge sharing and management in climate change adaptation and DRR

Nepal's Priority Framework for Action on Climate Change Adaptation and Disaster Risk Management in Agriculture represents an innovative policy framework that addresses climate change adaptation and DRR in an integrated and coherent manner. The Framework acknowledges the existence of good practice technologies and approaches, and the vital importance of knowledge sharing. The following is a summary of the framework's strategy for knowledge management.

Priority Area III: Improved knowledge management, database and awareness-raising on climate change impacts, adaptation and disaster risk management.

Objective: Use knowledge to build a culture of innovation and resilience, and institutionalize training on climate change adaptation and disaster risk management in agriculture.

Some key activities planned:

- organizing local-level awareness raising campaigns and training programmes for farmers on lessons learned and best practices of disaster risk management, sustainable land management and climate change adaptation;
- developing information centres for documentation of local knowledge, risks and vulnerabilities at the village and district level;
- establishing a good practice database (includes indigenous and local practices) relevant to agriculture and livestock for climate change adaptation and DRR;
- integrating climate change, disaster risk management and sustainable land management into farmer field schools and promoting agricultural extension systems that can demonstrate and disseminate good practices;
- promoting the establishment of model demonstrations at regional research centres by involving local communities to showcase relevant good practice examples on climate change adaptation and disaster risk management;
- organizing periodical capacity development and knowledge sharing sessions with staff, local institutions and farmers on aspects of climate change adaptation and disaster risk management; and
- disseminating tested good practice examples of climate change adaptation and disaster risk management.

Source: Federal Democratic Republic of Nepal Ministry of Agriculture and Cooperatives *et al.*, 2012

The scale of CSA activities can also be expanded through existing local, national and regional networks, knowledge fairs and South-South cooperation. Within traditional societies, the transfer of indigenous knowledge and technologies is often limited by oral communication and confined to local groups. If this knowledge is to have significant impact, external support is required to share these proven practices with a wider audience. Extension programmes and farmer organizations are recognized as viable cost-effective vehicles for the sharing of knowledge, the transfer of technology and know-how, and developing capacity (see more on capacity development in Module 17). In Peru, the Association for Nature and Sustainable Development (ANDES) is an indigenous NGO that has contributed to the establishment of the protected areas known as Indigenous Biocultural Heritage Areas. The Potato Park brings together six Quechua communities to protect a 12 000 hectare area as a microcenter of origin of the potato and other native Andean crops. ANDES works in close collaboration with formal and informal Quechua technicians in researching, training and developing adaptive management models for indigenous biocultural heritage. Working together, they organize South-South learning exchanges in the Potato Park for the design and implementation of indigenous biocultural territories as agrobiodiversity conservation areas (IIED, 2008).

CSA provides a fresh opportunity to tackle some long-standing challenges. For instance, there has been inadequate investment made to support and strengthen the coping capacity of pastoralists in the Horn of Africa. This is partly the result of the underestimated value of pastoralist systems as a viable way of life. It is also due to political marginalization of pastoral communities and adverse policies and practices, such as restrictions on their mobility and access to key natural resources (HPG, 2009a; IIED *et al.*, 2008). Yet, the resilience of pastoralist livelihoods has untapped potential that can be strengthened through CSA. Pastoralist systems can be an effective measure against rising temperatures and the increased incidence of drought expected over the next four decades based on regional climate projections for East Africa. As one study shows: "...of all the natural resource-based land uses in the drylands, pastoralism functions best within the prevalent context of wide rainfall variability and unpredictability... [It] has an important role to play where other livelihoods are likely to fail... Evidence suggests that...it would be more effective to enable and strengthen the inherent adaptive capacity of pastoralists, finding ways to encourage their autonomous adaptation... Pastoralism is a rational use of the drylands. Pastoralists respond to and use, even choose and profit from, variability. This allows for a vibrant and productive livelihood system in some of the harshest landscapes in the world" (HPG, 2009b).

Combining DRR knowledge with innovations in climate change adaptation

In addition to the expansion of indigenous knowledge and risk reduction practices as valuable measures to advance adaptation and CSA, there are other opportunities and benefits for combining DRR and CSA efforts. Climate change creates risks that are not addressed by risk reduction measures (e.g. rising sea levels, increased temperatures and the expected spread of plant pests and diseases). In some cases, local knowledge is useful for reducing risks, but it is insufficient to cope with climate change. For this reason, local expertise needs to be combined with scientific knowledge, research and technological innovations. In practice, there are still only a few cases where DRR and climate change adaptation technologies have been combined. The example below in Box 15.7 on potatoes in the Andes illustrates how traditional risk reduction practices can be effectively combined with new adaptive technologies.

Box 15.7
Building the resilience and adaptive capacity of potatoes in the Andes

In some regions of the world, climate change is expected to increase plant diseases and pests that affect potato production. This phenomenon is already being observed in some areas. Late blight, the fungus responsible for the Irish potato famine in the 1800s, is expected to expand into previously unaffected areas. In addition, increases in temperature will put additional pressure on the potato's wild relatives. By the year 2055, 16-22 percent of all wild potato species will be threatened with extinction. This is an urgent problem given the importance of wild relatives as gene pools for breeding new varieties. Potatoes constitute the fourth most important food crop after rice, wheat and maize. They are vital to the diets and livelihoods of millions of people.

Although Andean communities have demonstrated their resilience to adverse weather and changing environments, additional assistance can help strengthen this capacity. This assistance can also bridge science and traditional knowledge and generate innovative solutions. A project by Association Andes supports Andean potato farmers through the protection of traditional knowledge and conservation efforts that prevent the disappearance of potato varieties from local fields. This ensures farmers have more options for dealing with the impact of climate change. The project includes the following:

- conservation of 1 345 accessions of local potatoes through the Potato Park communities;
- establishment of a database of native potatoes, traditional knowledge and climate change;
- collection of information on the effects of climate change on the cultivation of local potato varieties;
- documentation of traditional knowledge about climate change and extreme events; and
- transfer of land for the construction of the Centre for Traditional Knowledge and Native Potatoes in the Potato Park.

Another new potato breeding initiative in Bolivia is helping local farmers cope with the increasingly shorter rainy seasons and the resulting declines in yields. The project, implemented by the International Potato Center (IPC) and the Fundación para Promoción e Investigación de Productos Andinos breeds potato varieties that are better adapted to the short rainy season without any loss in yield. With local farmers, the project tests new varieties in the field under real conditions.

The IPC, together with local organizations, is evaluating the tolerance to water and temperature stress of the genetic resources of its potato collection and those of new varieties that are being bred. The IPC can draw on the world's largest genetic reservoir of potato varieties. Its gene bank contains 5 000 distinct types of cultivated potatoes and more than 2 000 wild relatives of the potato belonging to around 140 wild species. The goal is to identify the desired key characteristics and genes that determine tolerance to abiotic stress. Climate change and other factors that increase pressure on ecosystems are threatening the existence of many wild relatives. The establishment and maintenance of gene banks is intended to curb the loss of this diversity in varieties. To date, the IPC has repatriated over 400 native potatoes varieties among communities across the Andes. The long-term goal is to establish community gene banks to ensure that the genetic resources underpinning the food supply are secured.

Sources: Centre for Development and Environment, 2008;
International Treaty on Plant Genetic Resources for Food and Agriculture, 2011

DRR and climate change adaptation both acknowledge one vital area: the importance of an ecosystem approach and sustainable natural resource management in strengthening resilience (see also Module 2 on landscape approach and management of ecosystems). DRR recognizes the inherent interconnectedness between the environment and natural hazards (UNISDR, 2004b). Deforestation, the degradation of catchments and watersheds, the degradation of land and desertification, the depletion of reefs and coastal ecosystems (especially of corals and mangroves) reduce nature's defence capacity against climate-related hazards and aggravate the impact of disasters such as floods, landslides, storm surges, hurricanes and drought (FAO, 2011b). In upland watersheds, deforestation and destruction of the protective cover of vegetation can accelerate soil erosion, reduce the soil's water-retention capacity and make sloping areas more prone to flooding and landslides. Eroded material may be carried downhill into rivers and streams, choking channels with gravel, sand and sediments. This can influence the frequency and severity of flooding and increase downstream damage (UNESCAP, 1997). Disasters in turn contribute to ecosystem degradation and loss, such as deforestation, declining rangeland quality, salinisation of soils and reduced biodiversity. On the island of Sumatra, the 2004 Asian Tsunami damaged approximately 20 percent of sea grass beds; 25-35 percent of wetlands; about 60 000 hectares of agricultural land; nearly 49 000 hectares of coastal forests: and 32 000 hectares of mangroves (UNEP, 2005; UNEP, 2007). Increased environmental degradation reduces the goods and services available to local communities, shrinks economic opportunities and livelihood options, and ultimately contributes to greater food insecurity and hunger (FAO, 2011b).

Effective risk reduction depends significantly on the ability to promote sound environmental and natural resource management practices and the sustainable use of ecosystems. Healthy and diverse ecosystems are more resilient to natural hazards. Forests and reforestation are used as shelterbelts and windbreaks, and play an important role in protecting against landslides, floods and avalanches. Trees stabilize riverbanks and mitigate soil erosion (see also Module 9 on climate-smart forestry). Wetlands serve to store water and provide storm protection, flood mitigation, shoreline stabilization and erosion control (FAO, 2011b).

There are numerous examples of ecosystem approaches that have been promoted through risk reduction measures. Since the 1960s, Bangladesh has been investing in coastal afforestation and creating coastal green belts, such as mangroves, to reduce the impact of cyclones and tidal surges. In the watersheds of the Suchiate, Coatán and Cahoacán Rivers on the border area between the department of San Marcos, Guatemala, and the state of Chiapas, Mexico, integrated watershed management is helping to restore ecosystems through soil conservation and sustainable agricultural practices by securing downstream water supply to settlements, agriculture and livestock, reversing watershed degradation and reducing the risk of devastating floods caused by tropical storms and hurricanes. Sri Lanka's Road Map for Disaster Risk Reduction outlines a range of activities that integrate both risk reduction and environmental management objectives, including the integration of DRR in environmental impact assessments and the promotion of coastal vegetation or green belts (PEDRR and The Council of Europe, 2010).

Recognizing the interconnectedness between risk reduction and good environmental stewardship, the HFA identifies the "reduction of the underlying risk factors" as one of its five Priorities for Action. One of the key areas emphasized under this priority for action is environmental and natural resource management, which includes the following objectives: encourage the sustainable use and management of ecosystems; implement integrated environmental and natural resource management approaches that incorporate DRR; and promote the integration of risk reduction associated with existing climate variability and future climate change into strategies for the reduction of disaster risk and adaptation to climate change (UNISDR, 2005).

Ecosystem-based approaches are also well recognized as a critical element of adaptation by the UNFCCC and constitute a fundamental pillar in CSA (see for example Module 10 on climate-smart fisheries and aquaculture). Ecosystem services will become more vulnerable and fragile as climate change affects rainfall patterns and increases surface temperatures. Existing ecosystem-based DRR measures can strengthen adaptation efforts under CSA. Some examples of initiatives that combine DRR and climate change adaptation objectives are starting to emerge. In Mexico, for example, a large-scale coastal wetland and mangrove swamp restoration project is addressing coastal protection against hurricanes and saltwater intrusion due to rising sea levels (PEDRR and The Council of Europe, 2010). The project is also improving local water supply and food production. Box 15.8 illustrates a watershed management approach in Uganda that integrates DRR and climate change adaptation in project design.

Box 15.8
Community-based integrated watershed management approach to DRR and climate change adaptation in Uganda

Uganda is prone to droughts, floods, windstorms and hailstorms, landslides and crop and livestock diseases. The water-related hazards make up over 90 percent of the natural disasters and each year destroy an average of 800 000 hectares of crops (UNDP *et al.*, 2009). These natural hazards are exacerbated by increasing environmental degradation. The most disaster-prone communities are located along the dry arid and semi-arid areas of the Cattle Corridor that stretches across the country. According to Uganda's 2007 National Adaptation Program of Action, the country experienced seven drought episodes between 1991-2000 (Uganda NAPA, 2007). Also, in recent years, floods and landslides triggered by tropical cyclones and severe storms have become one of the most devastating natural hazards in Uganda.

FAO Uganda is currently promoting a community-based integrated watershed management (CBIWM) approach to planning, which integrates DRR and climate change adaptation strategies. The approach addresses socio-economic development, the restoration of the environment's ecological integrity and institutional capacity development. This integrated, intersectoral approach places communities at the centre of the process and enables them to make qualified decisions about DRR based on watershed ecosystem functions and their interaction with natural resource management practices. Building and strengthening watershed organizations and linking them with District Disaster Management Committee and Village Disaster Management Committees is crucial. Farmer field schools are used to increase the knowledge and skills of farmers and pastoralists. Farmers can then solve problems for themselves and undertake their own initiatives in DRR and climate change adaptation. The conceptual and operational framework of community-based integrated watershed management for DRR and climate change adaptation is presented in Figures 15.3 and 15.4 below.

FAO conducted a week-long intensive training for personnel from local district governments, the United Nations and NGOs in the Karamoja region in North Eastern Uganda to enhance their knowledge and skills in planning, implementing, monitoring and evaluating CBIWM programmes. Each district that participated developed draft action plans on how to apply and replicate the approach in their local environment. As a result of the training, the Local Government of Moroto District has initiated an improved community-based watershed management programme in the Musopo watershed.

The CBIWM is consistent with, and supports the current efforts of the Uganda Ministry of Water and Environment to put into action catchment–based water resources management. Also, a recent Joint Programming Agreement between FAO and the World Food Programme in Uganda is being operationalized using a CBIWM approach in five districts of Karamoja.

Figure 15.8
The conceptual and operational framework of CBIWM for DRR and CCA

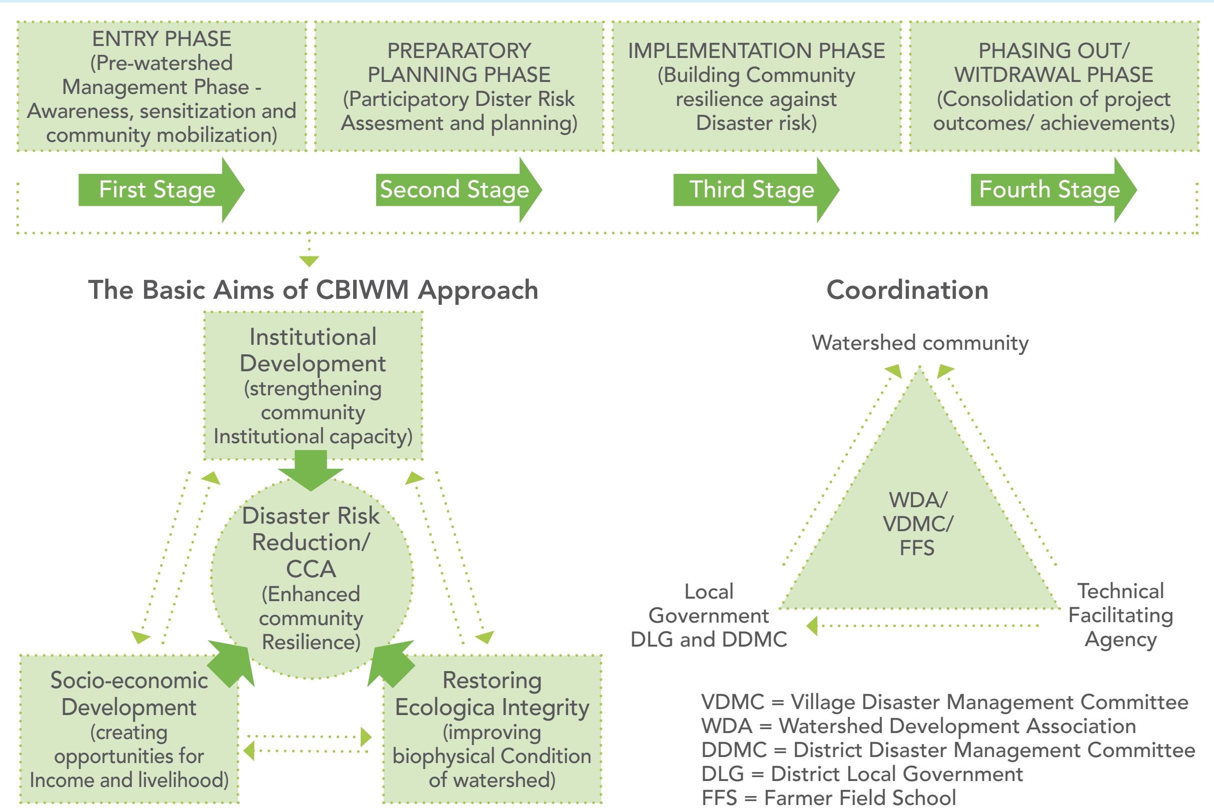


Figure 15.9
The CBIWM activities by phases

ENTRY PHASE (Pre-watershed Management Phase - Awareness, sensitization and community mobilization)	PREPARATORY PLANNING PHASE (Participatory Dister Risk Assesment and planning)	IMPLEMENTATION PHASE (Building Community resilience against Disaster risk)	PHASING OUT/ WITDRAWAL PHASE (Consolidation of project outcomes/ achievements)
First Stage (2 months)	Second Stage (4 months)	Third Stage (24 months)	Fourth Stage (6 months)
• Community orientation, sensitization and awareness on DRR/ CCA and watershed management approach • Participatory identification of community watershed boundaries	• Conducting participatory disaster risk assessment (PDRA) including climate risk & land degradation assessments • Developing watershed management and land use plan • Developing a community-based DRR and CC adaptation plans using a watershed approach • Developing community based early warning system • Developing contingency Plans	Implementation of community DRR and CC adaption plans focusing on: • Improving bio-physical condition of the watershed. • Creating opportunities for income, livelihood diversification and distributional equity among watershed communities • Strengthening coordination and institutional capacities of watershed communities and Farmer Field Schools for disaster risk reduction and CCA	Further strengthening Coordination and linkages between watershed DRR and CCA community groups, Farmer Field School and local government Institutions and relevant Development partners

Protecting and building the resilience of rural livelihoods against disaster risks and climate change depends largely on sustainable practices in natural resource management. Sustainable ecosystem management provides 'the unifying base' for promoting DRR and climate change adaptation and maximizing opportunities for achieving livelihood security (PEDRR and The Council of Europe, 2010). As the example from Uganda illustrates, the integrated approach to watershed management necessarily brings together a diversity of stakeholders from governments, civil societies and the international community in the pursuit of win-win outcomes in risk reduction and adaptation.

15.5 The enabling framework of DRR to support CSA

Governance: national institutional structures and policy frameworks for DRR

An enabling environment and institutional partnerships are vital for achieving CSA's multiple objectives. CSA supports the use of existing institutional arrangements, policies and incentives that enable and empower farmers to adopt climate-smart practices as well as recognizes the importance of improved coordination for collective decision making and action (Global Science Conference on Climate-Smart Agriculture, 2011; FAO, 2010a). This section presents elements of the existing enabling architecture for DRR that can support CSA.

Many countries have national legislations, institutional arrangements, policies and planning frameworks for DRR. Experience over the past decades has shown that good practice in DRR requires vertical links between a national enabling environment and decentralized support and implementation with adequate resourcing. Ultimately, the success of local action depends on political will, legislative commitment, institutional structures and public investment to provide the necessary enabling environment for effective local action.

The 1990s witnessed the introduction or reform of disaster risk reduction and disaster risk management legislation in many countries. According to a report on the global state of DRR, of the 119 countries reporting, 80 percent indicated having some form of legislation for disaster management (UNISDR, 2004a). Legislation is binding and hence critical for ensuring accountability in DRR. Despite growing awareness and commitment to climate change adaptation, relatively few countries have legislation on climate change adaptation. There are opportunities for strengthening legislation on DRR to support adaptation and CSA, as well as to make use of this legislation as an enabling framework for CSA.

Between 73 and 80 national platforms for DRR exist today (UNISDR, 2013a). As national multistakeholder coordinating bodies for DRR, these platforms provide a solid foundation from which to build interinstitutional collaboration for CSA and catalyse CSA action. National DRR systems are at the core of countries' capacity to cope with disaster risks. They typically bring together ministries, agencies, donors, NGOs, and civil society organizations around common DRR goals. Many of these national DRR platforms are multisectoral. In Sri Lanka, the National Disaster Management Coordination Committee represents 35 members from key sectors, including representatives of the Ministries of Environment, Home Affairs and Agriculture, the Department of National Planning, the Coastal Conservation Department, the Department for Irrigation and the Department of Meteorology (UNISDR, 2008).

Many of the same countries with national platforms also have Strategic National Action Plans for Disaster Risk Reduction (UNISDR, 2013b), which guide the direction of risk reduction actions and set priorities at the country level. Some countries have DRR structures and planning frameworks specifically for the agriculture sector. Ethiopia's Ministry of Agriculture established the Disaster Risk Management and Food Security Sector to co-ordinate activities related to disaster prevention and preparedness. Jamaica has developed an Agriculture Disaster Risk Management Plan, and Belize has formulated a Plan of Action for Disaster Risk Reduction in Agriculture and Fisheries Sector. Nepal has also recently developed an integrated strategy, the Priority Framework for Action on Climate Change Adaptation and Disaster Risk Management in Agriculture.

In some countries, national policies and plans exist that are not specifically related to DRR but support risk reduction. Examples include: Namibia's 1997 National Drought Policy and Strategy; Zimbabwe's 1998 National Policy on Drought Management, which emphasizes forward planning, preparedness, prevention, mitigation response, recovery and rehabilitation (FAO, 2004); and Kenya's 2002 National Action Plan to Combat Desertification & Drought.

At the same time, considerable advances have been made in building national institutional mechanisms and policies for climate change adaptation. National adaptation policies are articulated in National Adaptation Programmes of Action (NAPAs). Progress in climate change adaptation efforts has been rapid and has led to a multitude of important initiatives. Experience, however, shows that these governance structures at national and local levels have developed separately from those for DRR. There is a need for greater coordination between the institutional arrangements, policies and planning designed for climate change adaptation and those that have been set up for DRR (IISD, 2011). Figure 15.10 below illustrates the parallel mechanisms in place for climate change adaptation and DRR in countries in the Pacific region (UNISDR *et al.*, 2012).

Supporters of CSA recognize the need for greater coherence and coordination, and that a "lack of coherence can prevent synergy capture and render the pursuit of the stated policy objectives ineffective" (FAO, 2010a). An inclusive and coherent pathway for CSA would include partnerships with the institutional architecture of both DRR and climate change adaptation, as well as joint dialogue and collective action in the agriculture sector for the benefit of farmers (see also Module 13 on policies). Given the institutional constraints and limited resources in many developing countries, this is a rational and cost-effective approach. On the ground, people at risk also need coherent policies and support.

Figure 15.10
Institutional structures supporting DRR and CCA in the Pacific region

GLOBAL	ISDR System/ GFDRR	Hyogo Framework	Global Platform for DRR	International CC Community	Kyoto Protocol	UNFCCC/ GEF
	The Pacific Plan for strenghtening Regional Cooperation and Integration					
REGIONAL	Pacific DRM Partnership Network	Madang Framework	Pacific Platform for DRM	Development Partners for Climate Change	PIFACC	Pacific CC Roundtable
NATIONAL	Government/ Donors/ Int. & Reg. Org./ NGOs	NationalDRM Action Plans (NAPs)	Local Government & Community Development Commitees	Government/ Donors/ Int. & Reg. Org./ NGOs	National Adaptation Plans of Action (NAPAs)	Nationl CC Tasks Forces
LOCAL	Local Government / NGOs/CSO	Local & Community Development Commitees	Local Government & Community DRM Commitees	Local Government/ NGOs/CSCs	Local Government & Community Development Commitees	Local Government & Community Development Commitees

CSA can be the conceptual framework that connects DDR and climate change adaptation, fosters consistency and coherence in the agriculture sector and provides a unifying force within agriculture line agencies. By acknowledging the multiple challenges and the importance of aligning approaches, CSA can help to overcome "the legacy of fragmented institutions established around single-issue 'silos'; and move towards integrated thinking and policymaking", a flaw that has been recognized by the High-level Panel on Global Sustainability (High-level Panel on Global Sustainability, 2012). A strategic approach for planning CSA programmes should begin by taking stock of what is already in place at the country level and identifying the key gaps that need to be addressed to better manage risks and climate change in the agriculture sector.

Examples of good practice are emerging out of national enabling environments that combine the shared concerns over disaster risk and climate change. In Nepal, the Ministry of Agriculture in collaboration with FAO and the United Nations Development Programme (UNDP) recently developed the Priority Framework for Action for Climate Change Adaptation and Disaster Risk Management in Agriculture. The Framework promotes policy coherence by drawing on the actions previously outlined in the NAPA and National Strategy for Disaster Risk Management. Nepal's integrated framework is a promising example of good practice. It can serve as an ideal platform for advancing CSA in the country by offering opportunities for partnerships, coordination and synergy in reaching practical technical solutions. Box 15.9 looks at the Philippines and provides a more detailed example of a country that has recently developed climate change legislation and policy that integrates DRR.

Box 15.9
The enabling environments in the Philippines integrating DRR and CCA

The Philippines is the third most-disaster-prone country in the world. The country has the highest number of people exposed to natural disasters and displaced annually as a result of these disasters (UNISDR, 2009a). The country is prone to earthquakes and tsunamis, volcanic eruptions, drought and typhoons that trigger secondary effects, such as landslides, floods, flash flooding and storm surges. The Philippines is also affected by the periodic occurrence of El Niño and La Niña events. Many areas are exposed to multiple hazards: 22.3 percent of the land area is exposed to three or more hazards and 62.2 percent is exposed to two or more. The Philippines is expected to experience substantial rise in sea levels, with seventy percent of the 1 500 municipalities located along the coast vulnerable. Agriculture represents one-fifth of the total economy (18 percent of its gross domestic product) and generates one-third of national employment.

In 2010, the country enacted a Disaster Risk Reduction and Management Act, which included a policy to mainstream DRR and climate change into socio-economic development planning, budgeting, and governance, including the agriculture sector. Under the Act, Local Government Units (LGUs) are now obliged to use at least 5 percent of their budgets for DRR. The formulation of a disaster risk reduction and management plan by the LGUs forms the basis for the disbursement of the funds. The country also has a Strategic National Action Plan (SNAP) on DRR 2009-2019, which spells out the road-map for DRR. The Plan's overall goal is to contribute to the country's sustainable development and poverty alleviation agenda (Republic of the Philippines National Disaster Coordinating Council, 2009).

The Philippine´s Climate Change Act was enacted in 2009. The first of its kind in Southeast Asia, the Act recognizes that climate change and DRR are closely interrelated and that effective disaster risk reduction will enhance climate change adaptive capacity (UNISDR, 2011a). The Act mentions that "...the State shall integrate disaster risk reduction into climate change programs and initiatives".

The Act also establishes a Climate Change Commission attached to the Office of the President and an advisory board composed of all relevant line Ministries, with the provision that "At least one of the sectoral representatives shall come from the disaster risk reduction community" (Republic of the Philippines, 2009). Among the functions of the Commission is ensuring the "...mainstreaming of climate change, in synergy with disaster risk reduction, into the national, sectoral and local development plans and programs", and partnership with the National Disaster Coordinating Council in order to increase efficiency and effectiveness..." (Republic of the Philippines, 2009).

The National Framework Strategy on Climate Change 2010-2022 recognizes that the Philippines "faces increasing disaster risks with geological/seismic dangers closely interacting with...meteorological hazards". The Strategy integrates DRR, including the enhancement of monitoring, forecasting and hazard warning systems, and mainstreams DRR and climate change adaptation into development and land-use planning based on disaster risk assessments.

Similarly, the national Development Plan identifies three goals for the agriculture sector, one of which is to increase "sector resilience to climate change risks" (Republic of the Philippines National Economic and Development Authority, 2011), which will include:

- reducing climate change-related risks and the vulnerability of natural ecosystems and biodiversity;
- increasing the resilience of agriculture communities through the development of climate change-sensitive technologies, climate-resilient agricultural infrastructure and climate-responsive food production systems;
- strengthening the agriculture and fisheries insurance system as an important risk sharing mechanism;
- incorporating natural hazards and climate risk in the agricultural land use plan;
- strengthening the capacity of communities to respond effectively to climate risks and natural hazards; and
- continuing vulnerability and adaptation assessments, especially in food production areas.

Source: Republic of the Philippines, 2009

Since the above example of the Philippines is recent, it remains to be seen how it will translate into practice. Nonetheless, it illustrates an effective approach, based on an understanding of the multidimensional nature of risks, to improve coherence at the highest government level through explicit legislation and national policy with concrete strategies that better harmonize risk reduction and adaptation objectives.

Region-wide platforms and inter-governmental strategies for DRR

DRR initiatives at regional levels also offer great potential for collaborative arrangements and for catalysing CSA. Worldwide, there are six regional platforms on DRR in place, such as the Regional Platform for Disaster Risk Reduction of the Southern Africa Development Community and the Regional Platform for Disaster Risk

Reduction in the Americas. Working through or with these networks enhances coherence, helps to build synergies and taps into existing expertise and practice.

In addition to the regional platforms, a number of regional inter-governmental organizations have developed disaster risk reduction strategies or frameworks for cooperation in DRR at the regional level, such as the ASEAN Regional Programme on Disaster Management. The African Union has developed the Africa Regional Strategy for Disaster Risk Reduction and adopted a Programme of Action for the Implementation of the Africa Regional Strategy for DRR. Africa's Regional Economic Communities (RECs), including the Economic Community of Central African States, the Economic Community of West African States (ECOWAS), the Southern Africa Development Community and the Inter-Governmental Authority on Development (WB and GFDRR, 2010), are key partners in the implementation of the strategy. In 2009, Andean countries developed the Andean Strategy for Disaster Prevention and Relief. Central American heads of state adopted in 2010 the legally binding Central American Integrated Policy on Disaster Risk Reduction, which aims at an improved regional commitment to DRR through a common guiding framework (ISDR, 2011a).

At regional levels, links between DRR and climate change adaptation are not yet common. However, pioneering regional initiatives are underway, such as the Incheon REMAP in Asia, illustrated in Box 15.10 below.

Box 15.10
A Regional Approach to Joint DRR and climate change adaptation: the Incheon REMAP in Asia

In 2010, the Fourth Asian Ministerial Conference on Disaster Risk Reduction approved a five-year regional roadmap, the Incheon REMAP. The Incheon REMAP initiative is an example of how governments are providing an enabling policy environment and commitment for joint initiatives in DRR and climate change adaptation at the regional level. Fifty Asian and Pacific region governments agreed to: "By 2015, establish climate resilient disaster risk management systems that contribute to sustainable development at regional, national, subnational and community levels" (Fourth Asian Ministerial Conference on Disaster Risk Reduction, 2010). The roadmap promotes regional cooperation in Asia on DRR through climate change adaptation. It includes the integration of DRR and climate change adaptation into development for green growth.

The following priority targets were agreed:

- 10 countries with integrated approach and institutional structure to promote synergistic financing between disaster risk management and climate change adaptation;
- DRR and climate change adaptation investment tracking in place in 10 countries; and
- all regional partners combine DRR and climate change adaptation programme or funding.

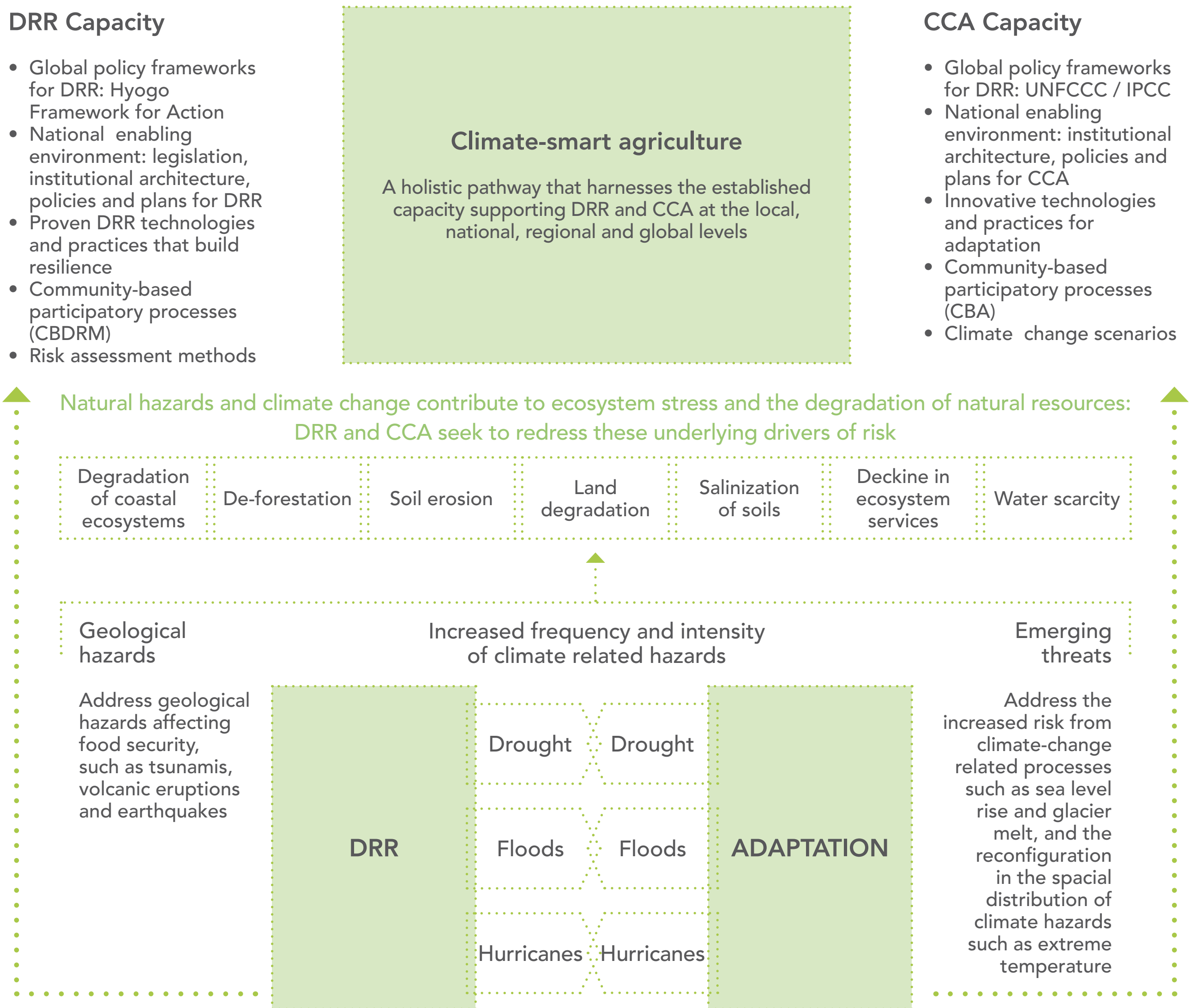
Other initiatives in the roadmap include: promoting multi-hazard risk assessments and capacities in local settlements; developing and sharing information, technology, sound practices, and lessons learned in climate and disaster risk management; collecting sound practices and lessons learned in DRR and climate change adaptation; developing a platform for sharing information, technologies and sound practices in DRR and climate change adaptation; improving linkages between climate change adaptation and DRR institutions at national and regional level; and implementing joint DRR and climate change projects in selected countries.

15.6 Concluding remarks and recommendations

To achieve its multiple objectives, CSA promotes the application and scaling up of proven practices and approaches. It follows a holistic pathway that brings together a number of areas of expertise. An enabling environment and institutional partnerships are vital for achieving CSA. As a contribution to reaching these objectives, this module has illustrated how proven policy and practice in DRR provides a rich resource-base for promoting and scaling up CSA. Key areas in DRR that can support CSA are summarized in Figure 15.11. DDR's contribution specifically supports CSA's objective of strengthening resilience to climate change and variability.

CSA follows a landscape approach with multiple objectives, and integrated landscape management requires an understanding of all natural hazards affecting a given territory. Multi-hazard risk assessments and mapping was introduced in this module as an example of a tool that can help inform the design of appropriate CSA initiatives, identify the spatial distribution of hazards (climate-related hazards and geological hazards) at different scales, assess the exposure to and vulnerability of farming systems to these and evaluate the overall level of risk. The combined analysis of multi-hazard risk assessment and mapping with downscaled climate change scenarios provides a harmonized framework for assessing all spatially relevant hazards in specific geographic areas, providing a complete picture of how food security is affected today by hazards and how it may be impacted in the future by climate change. This combined analysis facilitates short- and long-term holistic planning for CSA.

Figure 15.11
A holistic approach that builds on established DRR and CCA capacities to Support CSA



*Note: CCA in this figure stands for climate change adaptation

CBDRM was presented as a proven participatory method for the assessment of local risks and for guiding local planning. It can serve as a vehicle and methodology for promoting CSA at local levels. Given the widespread application of CBDRM and its institutionalization across many countries, it provides considerable scope for contributing to CSA. Using joint community-based DRR and climate change adaptation approaches creates links with existing local institutional networks and builds coherence within communities and local authorities. In addition, there are many examples of local knowledge and risk reduction technologies and practices that have proven effective for reducing disaster risks. They represent a rich resource pool from which to draw to scale up CSA. Knowledge sharing can be a vital strategy for CSA to gain scale given the wealth of proven DRR practices across most countries. By making use of technologies and practices that support both risk reduction and climate change adaptation, CSA can provide win-win benefits for farmers.

At the national and regional levels, well-established legislations, institutional structures, policies and plans for DRR provide CSA with a strong supportive enabling environment. By working in partnership with the national institutional architecture of DRR and climate change adaptation, CSA can act as a unifying force within agriculture line agencies. In this way, integrated and coherent plans for CSA can be articulated based on existing DRR and climate change adaptation policies and strategies.

Developing strategic frameworks to guide action on and investment in CSA at the country level will require mapping the national institutional landscape, policies and plans that can enable and catalyse CSA. This will be a challenging process, given the wide array of disciplines, actors and frameworks that are relevant to CSA and the complex relationships among them. Unquestionably, the mapping exercise should include DRR policies and practices relevant to livelihoods and food security. Table 15.1 presents suggestions for harnessing existing DRR capacities to help reach CSA objectives. The table draws on the examples given in this module and on experience elsewhere.

Table 15.1
Strategic entry areas in risk reduction for CSA and integration opportunities with climate change adaptation

Enabling Environment	Practical Tools	Knowledge Sharing
Work with existing national platforms and institutional mechanisms for coordinating disaster risk reduction and adaptation. Promote multistakeholder dialogue to identify opportunities and partnerships between the DRR and climate change adaptation communities, jointly address gaps and harmonize plans for CSA. Take stock of and build coherence with national policies and plans already developed for reducing disaster risk and for adaptation in the country, including those that may be hazard-specific, such as drought mitigation policies.	Conduct integrated analysis of multiple risks to agriculture and food security, based on the collection of available information (data and maps) on hazards, vulnerabilities and risk assessments. Enhance tools that blend risk assessments of current risks and downscaled climate change scenarios for improved and more holistic analysis. Design CSA project initiatives that integrate adaptation and risk reduction measures, and that are in line with national DRR and climate change adaptation goals. Implement CSA locally through integrated DRR and climate change adaptation community-based approaches that combine immediate short-term measures to reduce risks with long-term adaptation measures to slow-onset climate change.	Take stock of and promote proven traditional local knowledge. Map and promote DRR technologies and practices that have been effective in reducing disaster risks to help meet the objectives of CSA. Promote knowledge sharing among farmers, practitioners and policy makers on effective DRR and climate change adaptation technologies. Support generation of integrated knowledge and practice. Support stronger engagement of the DRR community.

Source: adapted from UNISDR, 2009b

The need for increasing the scale of CSA activities is becoming more urgent due to the pace of climate change. Southern Africa, for example, will be heavily affected by climate change with projections that indicate temperature increases of up to six degrees Celsius and a decrease in rainfall by as much as 40 percent in some parts of the region over the next 70 years. CSA offers fresh opportunities to improve food security. Those working to advance CSA should make DRR a core element, harvest the wealth of good practice in DRR and forge strong partnerships with established institutional arrangements. Building on the accumulated expertise in

DRR increases the efficiency of international aid and government investments. This is a critical factor given the already severely constrained human resources and institutional environments in developing countries and aid budgets that are increasingly less able to attend to recurring and simultaneous disasters worldwide. For farmers, ultimately, there is no distinction between risk reduction and adaptation, but rather threats to livelihoods and family food security from which they need to be protected.

Notes

This module was written by Monica Trujillo (FAO) with contributions from Stephan Baas (FAO) and reviewed by Jim Hancock (FAO) and Kennedy Igbokwe (FAO).

Acronyms

ADPC	Asian Disaster Preparedness Center
ANDES	Association for Nature and Sustainable Development
ASLR	accelerated sea level rise
CAPRA	Probabilistic Risk Assessment Initiative
CBA	community-based adaptation
CBDRM	community-based disaster risk management
CBIWM	community-based integrated watershed management
CCA	climate change adaptation
CDMP	Comprehensive Disaster Management Programme
CECI	Centre for International Studies and Cooperation
CICERO	Center for International Climate and Environmental Research – Oslo
CRA	community risk assessments
CSA	climate-smart agriculture
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EC	European Commission
ECOWAS	Economic Community of West African States
GEF	Global Environment Facility
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographic Information System
HARITA	Horn of Africa Risk Transfer for Adaptation
HFA	Hyogo Framework for Action
HPG	Humanitarian Policy Group
IIED	International Institute for Environment and Development
IISD	International Institute for Sustainable Development
IPC	International Potato Center
IPCC	Intergovernmental Panel on Climate Change
LGUs	Local Government Units
NAPA	National Adaptation Programme of Action
NDMC	National Disaster Management Centre
NEPAD	New Partnership for Africa's Development
NGI	Norwegian Geotechnical Institute
NGO	non-governmental organization
PacRIS	Pacific Risk Information System
PEDRR	Partnership for Environment and Disaster Risk Reduction
RECs	Regional Economic Communities
RiVAMP	Risk and Vulnerability Assessment Methodology
SIDS	Small Island Developing States
SNAP	Strategic National Action Plan
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNISDR	United Nations International Strategy for Disaster Reduction
USAID	United States Agency for International Development
WFP	World Food Programme
WISP	World Initiative for Sustainable Pastoralism

References

Asian Disaster Preparedness Center (ADPC). 2004. *Community-based disaster risk management: field practitioners handbook, by I.* Abarquez & Z. Murshed.

BAN, K. 2008. *Risk reduction and climate change.* Speech by the United Nations (UN) Secretary-General, New York, USA, UN Headquarters.

Centre for Development and Environment. 2008. *Potatoes and climate change.* In InfoResources: Focus. No. 1.

CICERO and United Nations Environment Programme (UNEP)/GRID-Arendal. 2008. *Many strong voices: outline for an assessment project design.* Norway. (available at http://www.cicero.uio.no/media/6359.pdf)

Djalante, R., Halder, *S.R.,* Mulyasari, F. & Khan, S. 2010. Linking disaster risk reduction and climate change adaptation: comparing experiences from developed and developing countries. In Disaster Risk Reduction and Climate Change Adaptation: Case Studies from South and Southeast Asia. Studies of the University: Research, Counsel, Education. Publication Series of UN University and Environment and Human Security. No. 14. (available at http://www.ehs.unu.edu/file/get/7666)

European Commission (EC) & Practical Action. 2010. *Climate change adaptation in Peru: the local experiences.* Lima.

EC, United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) & ADPC. 2008a. *Regional experiences on the integration of CBDRM into the local development planning in South East Asia, by E.Torrente, J.* Zhang & T. Le-Huu.

EC, UNESCAP & ADPC. 2008b. *CBDRM and poverty reduction in PDR-SEA4, by E.Torrente, J.* Zhang & T. Le-Huu. (available at http://www.unescap.org/esd/Energy-Security-and-Water-Resources/water/projects/pdr_sea/documents/new/cbdrm&poverty.pdf)

FAO. 2004. *Drought impact mitigation and prevention in the Limpopo River Basin: a situation analysis.* Land and Water Discussion Paper. No. 4. Rome.

FAO. 2008a. *The state of food insecurity in the world.* Rome.

FAO. 2008b. *Good practices for hazard risk management in agriculture: summary report Jamaica.* Rome.

FAO. 2010a. *'Climate-smart' agriculture: policies, practices and financing for food security, adaptation and mitigation.* Rome.

FAO. 2010b. *Executive brief: Haiti emergency and rehabilitation response.* Rome.

FAO. 2011a. *Evaluation of supporting conservation agriculture for sustainable agriculture and rural development (CA for SARD).* Phase II report.

FAO. 2011b. *Resilient livelihoods: disaster risk reduction for food and nutrition security.* Rome.

FAO. 2012a. *The Sahel crisis: executive brief.* March. Rome.

FAO. 2012b. *The Sahel crisis: executive brief.* July. Rome.

FAO & WFP. 2010. *Crop and food security assessment mission to Haiti.* Rome.

Federal Democratic Republic of Nepal, ADPC, Norwegian Geotechnical Institute (NGI) & Centre for International Studies and Cooperation (CECI). 2011. *Nepal hazard risk assessment part 2: exposure, vulnerability and risk assessment.* (available at http://www.gfdrr.org/sites/gfdrr.org/files/documents/Nepal_HazardAssessment_Part2.pdf)

Federal Democratic Republic of Nepal Ministry of Agriculture and Cooperatives, FAO & United Nations Development Programme (UNDP). 2012. *Priority framework for action on climate change adaptation and disaster risk management in agriculture: 2011—2020.*

Fourth Asian Ministerial Conference on Disaster Risk Reduction. 2010. *Incheon regional roadmap and action plan on DRR through CCA in Asia and the Pacific.* Disaster Risk Reduction Through Climate Change Adaptation. Incheon, Korea.

Global Science Conference on Climate-Smart Agriculture. 2011. *The Wageningen statement: climate-smart agriculture –science for action.* (available at http://www.gscsa2011.org/LinkClick.aspx?fileticket=eDIto5l7E0E=)

High-level Panel on Global Sustainability. 2012. *Resilient people, resilient planet: a future worth choosing.*

Humanitarian Policy Group (HPG). 2009a. *Pastoralists' vulnerability in the Horn of Africa: exploring political marginalization, donors' policies, and cross-border issues: literature review, by S.* Pavanello. London, Overseas Development Institute.

HPG. 2009b. *Pastoralism and climate change: enabling adaptive capacity.* HPG Synthesis Paper. London.

International Federation of Red Cross and Red Crescent Societies (IFRC). 2011. *World disasters report 2011: focus on hunger and malnutrition.* (available at http://www.ifrc.org/PageFiles/99868/307000-WDR-2011-FINAL-email-1.pdf)

International Institute for Environment and Development (IIED). 2008. *Association ANDES: conserving indigenous biocultural heritage in Peru, by A.* Argumedo & T. Stenner. Peru.

IIED. 2009. *Community-based adaptation to climate change.*

IIED. 2011a. *Protecting and promoting the rights of indigenous people benefits us all, by K.* Swiderska. (available at http://www.iied.org/protecting-promoting-rights-indigenous-people-benefits-us-all)

IIED. 2011b. *Adapting agriculture with traditional knowledge, by K.* Swiderska. IIED Briefing.

IIED, UNDP & International Union for Conservation of Nature (IUCN). 2008. *Drylands – an economic asset for rural livelihoods and economic growth, by M.* Mortimore.

International Institute for Sustainable Development (IISD). 2011. *Review of current and planned adaptation action: southern Africa.* Adaptation Partnership.

Intergovernmental Panel on Climate Change (IPCC). 2007. *The fourth assessment report of the IPCC.* 104 pp. (available at http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html)

IPCC. 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation (SREX).*

International Treaty on Plant Genetic Resources for Food and Agriculture. 2011. *Peruvian 'guardians' lead potato park to a secure future.* FAO. (available at http://www.planttreaty.org/sites/default/files/FACTSHEET%20PERUok.pdf)

IUCN. 2008. *Indigenous and traditional peoples and climate change: issues paper, by M.* Macchi.

Kelman, I., Mercer, *J.* & West, J.J. 2009. Combining different knowledges: community-based climate change adaptation in small island developing states. In IIED Participatory Learning and Action 60: Community-based Adaptation to Climate Change. (available at http://pubs.iied.org/G02812.html)

National Disaster Management Centre(NDMC). 2005. *A policy framework for disaster risk management in South Africa.* (available at http://www.ndmc.gov.za/LinkClick.aspx?fileticket=woMQMWNuU9k%3D&tabid=61)

Pandey, D.N., Gupta, *A.K.* & Anderson, D.M. 2003. Rainwater harvesting as an adaptation to climate change. Current Science, 85(1): 46—59. 2003.

Partnership for Environment and Disaster Risk Reduction (PEDRR) & The Council of Europe. 2010. *Demonstrating the role of ecosystems-based management for disaster risk reduction.*

Republic of Haiti. 2010. *Haiti earthquake PDNA: assessment of damage, losses, general and sectoral needs.*

Republic of India Ministry of Agriculture. 2009. *Manual for drought management.* New Delhi.

Republic of Philippines. 2009. *Climate change Act of 2009 (Republic Act 9729).*

Republic of the Philippines Department of Agriculture & FAO. 2010. *Strengthening capacities for climate risk management and disaster preparedness in selected provinces of the Philippines (Bicol region): situation assessment report.*

Republic of the Philippines National Disaster Coordinating Council. 2009. *Strengthening disaster risk reduction in the Philippines: Strategic National Action Plan 2009—2019 (SNAP).*

Republic of the Philippines National Economic and Development Authority. 2011. *Philippine development plan 2011-2016.*

Uganda National Adaptation Programmes of Action (NAPA). 2007. *Climate change.* (available at http://unfccc.int/resource/docs/napa/uga01.pdf)

UN. 2011. *Multi-sector damage needs assessment in Sindh and Balochistan provinces, Pakistan.*

UNDP, National Environment Management Authority (NEMA) & UNEP Poverty Environment Initiative. 2009. *Enhancing the contribution of weather, climate and climate change to growth, employment and prosperity.* Kampala.

UNEP. 2005. *After the tsunami: rapid environmental assessment, Indonesia.* Nairobi.

UNEP. 2007. *Environment and reconstruction in Aceh: two years after the tsunami.*

UNEP. 2010. *Linking ecosystems to risk and vulnerability reduction: the case of Jamaica.*

UNESCAP. 1997. *Guidelines and manual on land use planning and practices in watershed management and disaster reduction.*

United Nations Framework Convention on Climate Change (UNFCCC). 2011. *Framework convention on climate change.*

United Nations International Strategy for Disaster Reduction (UNISDR). 2004a. *Summary of national information on the current status of disaster reduction.* Background for the World Conference on Disaster Reduction. Kobe, Hyogo, Japan. (available at http://www.unisdr.org/2005/mdgs-drr/national-reports/summary-national-reports.pdf)

UNISDR. 2004b. *Living with risk: a global review of disaster reduction initiatives.* New York, USA and Geneva, Switzerland.

UNISDR. 2005. *Hyogo framework for action: building the resilience of nations and communities to disasters.*

UNISDR. 2008.Towards *national resilience good practices of national platforms for disaster risk reduction.*

UNISDR. 2009a. *Global assessment report on disaster risk reduction: risk and poverty in a changing climate.* Geneva, Switzerland, United Nations.

UNISDR. 2009b. *Adaptation to climate change by reducing disaster risks: country practices and lessons.* UNISDR Briefing Note 02.

UNISDR. 2009c. *UNISDR terminology on disaster risk reduction.*

UNISDR. 2010a. *Local governments and disaster risk reduction: good practices and lessons learned.*

UNISDR. 2011a. *Disaster risk reduction legislation as a basis for effective adaptation, by S.* Llosa & I. Zodrow. In Global Assessment Report on Disaster Risk Reduction 2011.

UNISDR. 2011b. *Viet Nam ministry plans to implement a community-based disaster risk management programme in 6 000 communes by 2020.* (available at http://www.unisdr.org/archive/20925)

UNISDR. 2013a. *Countries and national platforms.* (available at www.unisdr.org/partners/countries)

UNISDR. 2013b. *Strategic National Action Plan (SNAP) for disaster risk reduction.* (available at www.unisdr-apps.net/confluence/display/bib/Strategic+National+Action+Plan+%28SNAP%29+for+Disaster+Risk+Reduction)

UNISDR, World Bank, & UNDP. 2012. *Disaster risk reduction and climate change adaptation in the Pacific: an institutional and policy analysis.* Suva, Fiji.

UN System Task Team on the Post-2015 UN Development Agenda. 2012. *Realizing the future we want for all: report to the Secretary-General.* New York, USA.

United States Agency for International Development (USAID) & Famine Early Warning System (FEWSNET). 2011a. *East Africa food security outlook update.* July.

USAID & FEWSNET. 2011b. *East Africa food security outlook update: Horn of Africa drought executive brief.* August.

Venkateswarlu, B. 2010. *Agricultural drought management in India.* In Proc. Workshop on Drought Risk Management in South Asia. SAARC. New Delhi.

WISP, IUCN & FAO. 2009. *Harnessing pastoralists' indigenous range management knowledge for drought-resilient livelihood systems in the Horn of Africa.*

World Initiative for Sustainable Pastoralism (WISP), Global Environment Facility (GEF), UNDP & IUCN. 2007. *Pastoralists as shrewd managers of risk and resilience in the Horn of Africa.* WISP Policy Brief No. 4.

World Bank. 2012. *Improving the Assessment of Disaster Risks to Strengthen Financial Resilience.*

World Bank & Asian Development Bank. 2010. *Pakistan floods 2010: preliminary damage and needs assessment.*

World Bank & Global Facility for Disaster Reduction and Recovery (GFDRR). 2010a. *Report on the status of disaster risk reduction in Sub-Saharan Africa.*

Additional Resources

FAO. 2011c. *Climate-smart agriculture: managing ecosystems for sustainable livelihoods.* Rome.

GIZ & UNISDR. 2010. *Experiencia en la incorporación de la gestión del riesgo en los proyectos de inversión pública en el Perú, by N.* Zapata. In Lecciones Aprendidas de la Gestión del Riesgo en Procesos de Planificación e Inversión para el Desarrollo: Memoria del Taller Internacional.

Ministerio del Ambiente del Peru. 2010. *Plan de accion de adaptacion y mitigacion frente al cambio climatico.*

New Partnership for Africa's Development (NEPAD). 2009. *CAADP pillar III: Framework for African Food Security (FAFS).* In Comprehensive Africa Agriculture Development Programme (CAADP). South Africa.

SAARC Disaster Management Center. 2008. *Indigenous knowledge for disaster risk reduction in South Asia.* New Delhi.

United Nations (UN). 2002. *Report of the World Summit on Sustainable Development.* Johannesburg, South Africa, 26 August- 4 September 2002.

UNCSD. 2012. *Disaster risk reduction and resilience building.* RIO 2012 Issues Briefs. No. 8.

UNEP. 2009. *Rainwater harvesting: a lifeline for human well-being.*

UNEP. 2012. *Applying ecosystem-based approaches for disaster risk reduction and climate change adaptation.* Sub-theme Statement delivered by UNEP during UN General Assembly Debate on Disaster Risk Reduction.

UNISDR. 2010b. *Strengthening climate change adaptation through effective disaster risk reduction.* Briefing Note 03.

UNISDR. 2011c. *Preparing for Rio+20: redefining sustainable development.* UNISDR Discussion Paper.

UNISDR. 2011d. *Global assessment report on disaster risk reduction 2011: revealing risk and redefining development.* Geneva, Switzerland, United Nations.

UNISDR, European Union & Kyoto University. 2008. *Indigenous knowledge for disaster risk reduction: good practices and lessons learned from experiences in the Asia-Pacific Region.* Bangkok.

World Bank. 2011. *Climate-smart agriculture: a call to action.*

World Bank & GFDRR. 2010b. *Disaster risk management in Latin America and the Caribbean region: GFDRR country notes: Peru.*

MODULE 16:

MAKING CSA WORK FOR THE MOST VULNERABLE: THE ROLE OF SAFETY NETS

Overview

This module addresses how safety nets can support the transition to climate-smart agriculture (CSA) in the context of vulnerability and food insecurity. The focus is on adaptation, resilience and productivity elements of CSA, while potential mitigation co-benefits will only be outlined briefly. The module begins with a short overview of different types of social protection and safety nets. It then outlines the potential links between safety nets and CSA, illustrated with several case studies. The module concludes with some institutional and design issues to be considered in the establishment of safety nets.

Key messages

- Growing climate-related risks result in greater protection needs for the most vulnerable from shocks and stresses.
- The poorest and most food insecure households and communities are risk avert and face significant barriers to adopting livelihood strategies that would allow them to enhance their food and nutrition security in the face of increased climate risks.
- Resource transfers provided through safety nets ensure access to food and protect lives, livelihoods and potential development gains in CSA.
- At the same time, resource transfers can enable poor and food insecure people and communities to invest in disaster risk reduction measures that contribute to resilience building and adaptation, and in many cases support efforts to enhance productivity.

Contents

List of Figures

List of Boxes

16.1 Introduction

One of the main challenges for the transition to CSA is to make it work for the most vulnerable communities. As highlighted in Module 12 on local institutions, "evidence shows that households that are the least food secure are those that are least likely to take up new CSA practices" (Kristjanson *et al.*, 2012). There are many reasons for this: where communities are faced with food insecurity, climate change adds to an already highly complex set of interrelated risks, often perpetuating cycles of poverty, food insecurity, vulnerability, unsustainable production systems and overexploitation of natural resources.

The transition to resilient, adaptive and productive livelihood strategies, as envisaged by the concept of CSA, is an important element of the response to the food security and climate change challenge. But for CSA to be effective and implemented at the required scale, it must be inclusive. That means it must be an accessible option also for the poorest and the most food insecure, and linked to efforts that ensure their access to food and nutrition. For this, CSA must be context-specific and part of a broader approach to build resilience and empower marginalized communities to take up opportunities – such as CSA – that could lift them out of hunger and poverty.

This module will look closer into how social protection, and in particular safety nets, can support the transition to CSA in the context of vulnerability and food insecurity. The focus will be on adaptation, resilience and productivity elements of CSA, while potential mitigation co-benefits will only be outlined briefly. The module begins with a short overview of different types of social protection and safety nets. It will then outline the potential links between social protection and CSA, illustrated with several case studies. The module will conclude with some institutional and design issues to be considered in the establishment of safety nets.

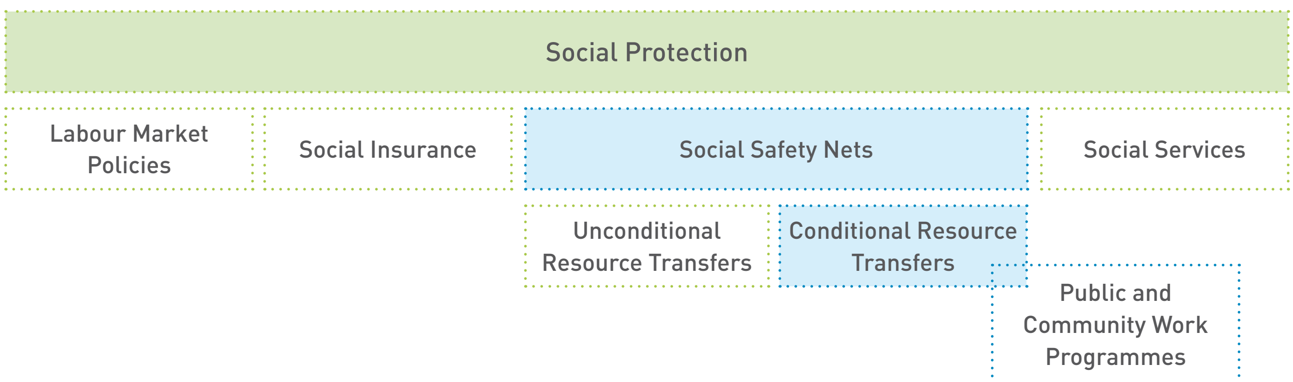
16.2 Social protection and safety nets – a conceptual overview

Social protection

The recent Committee of World Food Security High Level Panel of Experts (CFS HLPE) Report on Social Protection used the following definition of social protection: "Social protection describes all initiatives that: (1) provide income (cash) or consumption (food) transfers to the poor; (2) protect the vulnerable against livelihood risks; and (3) enhance the social status and rights of the excluded and marginalised" (HLPE, 2012a).

Beside safety nets, there are three other main types of social protection: labour market policies; social insurance, such as health insurance; and social services (e.g. access to social services for education, health, nutrition and agriculture). Figure 16.1 provides an overview of different elements of social protection, including safety nets, which will be covered in more detail in the next paragraph.

Figure 16.1
The Different Elements of Social Protection



Safety nets

Safety nets are a sub-set of social protection. They can be defined as formal or informal non-contributory resource transfers (cash, food or vouchers) provided to people vulnerable to or living in poverty, malnutrition and other forms of deprivation. They can be provided publicly and privately and require no payment from beneficiaries (WFP, 2012a). However, they can be conditional, i.e. recipients must commit to undertaking certain actions, such as sending their children to school or fulfilling certain work norms in public work programmes in order to receive these transfers. Unconditional transfers, in turn, provide people in need with direct support, without reciprocal activities – such as general food distribution.

Public works programmes – also referred to as "productive safety nets" or food-/ cash-for-work programmes[1] – are a sub-category of conditional resource transfers. These can range from simple, labour-intensive activities such as maintenance of feeder roads, to more sophisticated, higher-quality asset creation programmes, such as those linked to natural resource management (Grosh , 2008). As will be discussed further below, the latter are of particular relevance in the context of CSA.

The terms "safety nets", "social transfers" and "social assistance" all refer to non-contributory resource transfers. However, there is some ambiguity and discomfort with the term "safety net." This is because of, for example, difficulties in translating the term into national languages, or the possibly disturbing image of catching people as they fall (WFP, 2012a). Safety nets are both viewed as an instrument to protect people from becoming poor as a result of a shock, as well as a tool to reduce poverty and spur pro-poor economic growth among those who have already fallen into destitution (Devereux, 2009). In the 1990's, a definition had been proposed that captures well the dual function of safety nets – both of which are important, as will be discussed further on:

> *"Safety nets are programs which protect a person or household against two adverse outcomes in welfare: chronic incapacity to work and earn (chronic poverty); and a decline in this capacity from a marginal situation that provides minimal livelihood for survival with few reserves (transient poverty)"*
>
> Devereux, 2009

16.3 Key functions of safety nets in relation to CSA

Safety nets are likely to become increasingly important in the context of climate change (FAO, 2011). As indicated above, there are two main reasons for this: first, mounting climate-related risks result in greater protection needs from shocks and stresses. Second, especially the poorest and most food insecure households and communities, who are unable to access food and other resources to meet basic needs, evidently face significant barriers to adopting more resilient and productive livelihood strategies that would allow them to enhance their food and nutrition security in the face of climate change in a sustainable manner (which includes reduced greenhouse gas emissions). Providing resource transfers through safety nets is increasingly recognized as a potential means to help the poor overcome these barriers (FAO , 2012).

In line with this, the key functions of safety nets in relation to CSA can be summarized as

- Ensuring access to food and protecting lives, livelihoods and potential gains in development – and CSA – from climate-related and other shocks; and
- Enabling poor and food insecure communities to invest in measures that build resilience, support adaptation, enhance productivity and ensure long-term access to food.

The subsequent sections will look more closely at the ways in which safety nets can support an inclusive transition to CSA. In this context it is important to note that usually interventions involving safety nets deliver

[1] WFP has shifted away from using the term "food-for-work" towards "food-assistance-for-assets", but for the sake of simplicity this paper will use the term food-for-work.

multiple benefits for the communities involved. Hence the outcomes listed below should not be understood as mutually exclusive, but in fact closely linked to and often enforcing each other.

Protecting lives, livelihoods and potential gains in CSA

Vulnerability to climate change and other risks can increase over time, and potential gains on the path towards more resilient, productive and sustainable livelihoods can be at risk if households face repeated shocks that steadily erode their assets and with that their resilience to future shocks. Resource transfers can play a role in preventing this from happening by providing cash, vouchers, food or other resources during periods of crisis and during the cyclical 'hungry season' (WFP, 2011a). Resource transfers, conditional and unconditional, have in fact been an important and well-performing part of the response to major natural disasters in the past (Heltberg *et al.*, 2010).

For example, in Kenya, more than 450 000 people received cash or vouchers for participating in the World Food Programme (WFP)-supported food-assistance-for-assets (FFA) programmes in response to drought in 2012. As a result, nearly 10 000 hectares of land were cultivated with both physical soil and water conservation measures and biological stabilization or agro-forestry techniques (WFP, 2012b). During the period from 2006 to 2010, these FFA programmes had contributed to conserve nearly 38 500 hectares of land, restore 343 irrigation systems, repair 194 kilometres of feeder roads and produce 170 000 tree seedlings (WFP, 2011b). Government, non-governmental organization (NGO) partners and communities were trained on effective rainwater harvesting, such as soil and water conservation techniques, through a special arrangement with the World Agroforestry Centre. The resource transfers provided participation by the communities to the FFA programmes, preventing a further erosion of livelihood assets during the crisis, while the assets created with the support of resource transfers were an investment in future resilience (WFP, 2012b).

In Pakistan, where many households lost both productive and non-productive assets as well as their income in the floods of 2010, FAO's emergency and rehabilitation response programme included a large cash-for-work component. The cash-for-work intervention was undertaken in three provinces where the floods had ruined thousands of irrigation channels filling them with debris and silt. The intervention sought to repair and de-silt on-farm irrigation channels and restore and improve water availability for crop production. In total, the cash-for-work component of the response programme directly benefited 69 931 households who repaired 1 065 irrigation channels, recovering 114 655 hectares of irrigated land (FAO, 2012). The provision of cash to affected communities was found to be very relevant to their needs at a time when other sources of income had been lost and households needed cash to procure food and livelihood assets. Furthermore, in many cases, the cash provided through the intervention has been invested in livelihood assets (physical and human) that will provide continuing benefits. In addition, the long-term effect of the water channel repairs is the impact on future crop yields (FAO, 2012).

As these examples illustrate, resource transfers can prevent seasonal malnutrition among vulnerable populations, reduce debt and increase savings and productive investment, even in areas that are subject to recurrent crises (FAO, 2012). They provide poor households with an alternative from having to revert to so-called "negative coping strategies" that leave them more vulnerable. These include selling their productive assets—such as farm tools or livestock— to buy food, taking children out of school (which has irreversible impairments to their long-term socio-economic potential and resilience) or over-exploiting lands and forests (WFP, 2011a).[2]

In other words, safety nets play a critical role in protecting human, social, physical, financial and natural capital, which are the foundations of resilient and productive livelihoods (HLPE, 2012b; PHI *et al.*, 2011; Davis, 2011; WFP, 2011a; see also Module 15 on disaster risk reduction). This is both relevant for protecting the poorest and the most food insecure people and communities from falling into destitution, and for protecting those who are better off and already moving towards more resilience, productivity and sustainability from falling (back) into poverty. In this regard, safety nets could also protect potential gains and achievements in CSA.

[2] This points to the potential mitigation co-benefits that safety nets can generate, which will be addressed further on.

Enabling poor and food insecure communities to invest in CSA

Agriculture is inherently risky, and may be even more so in the future with more extreme climate events. For poor farmers, adopting new technologies and production strategies may be beyond their tolerance for risk, given that failure may be catastrophic (FAO *et al.*, 2012). It also often requires a certain investment, which – even if minimal – may be beyond their capacity. Kristjanson *et al.* (2012) found a strong negative relationship between household food security and innovation – in the sense that there is a correlation between the lack of innovation in farming practices and the number of food deficit months. Many poor households are simply unable to save sufficiently to invest in high-return strategies (Prowse and Scott, 2008).

This applies also to many climate-smart production strategies. As the HLPE Report on Climate Change and Food Security stresses, financial capital for investment in adaptation as well as human and social capital to implement adaptation are major obstacles for poor farmers (HLPE, 2012b). Many innovations that could make them more resilient, for example weather-index based insurance, are therefore difficult to access by those in greatest need. If market failures in credit, insurance and other areas are not addressed, households will be limited in their ability to adapt to climate change – or manage any other risk (Davis, 2011).

Safety nets offer significant potential to meet these challenges, which is often underestimated, as they continue to be predominantly viewed as a last resort "when adaptation fails" (HLPE, 2012b) – certainly also because of misleading connotations with the term "safety net". However, there is increasing recognition of the contribution of safety nets to building resilience, reducing risks and enhancing adaptive capacity among vulnerable communities.[3] As Kristjanson *et al.* (2012) point out, some kinds of safety nets targeted at poor or vulnerable households, such as transfers of cash, vouchers, food, or other goods, may be needed before these households will be able to make any changes to their farming practices that will result in their being better adapted to changing circumstances.

Various empirical studies and impact evaluations have indeed shown that safety nets can spur economic growth among poor communities, which relates to the productivity element of CSA.[4] The role of social protection and safety nets in making growth inclusive has placed them firmly in the discussions on sustainable development and on an "inclusive green economy" (see also Module 13 on policies). By providing a basic level of consumption below which people know they cannot fall, and by boosting a household's asset base, resource transfers can allow poor farmers to invest further in education, health, skills development and productive assets. Predictable resource transfers can also precipitate savings and encourage prudent risk taking, technology adoption and entry into high-return strategies (Davis, 2011; Prowse and Scott, 2008). All of these are not only prerequisites for productive and sustainable livelihoods, but also critical elements of adaptive capacity and resilience (UN TT SDCC, 2011).

According to a recent meta-analysis of impact evaluations, public works programmes can have significant impact in terms of temporary employment creation and increases in participant's current incomes (Kimmis *et al.*, 2009). In addition, public works programmes that guarantee employment when needed, effectively provide insurance. Agriculture-related public works activities, such as hillside terracing or soil and water conservation, can improve farm yields and generate sustainable benefits for household food security. They can also create community assets and infrastructure critical for adaptation. Studies of the long-term impacts of natural resources management activities undertaken through food-for-work projects (in particular those that included terracing, agro-forestry and water capture and spreading) have found significant impacts in terms of increased crop yields as well as increases in vegetation diversity and cover. Furthermore, women benefited from the improved supply of water, fuel-wood, and other tree products (Reij *et al.*, 2009). In many cases, such as with Ethiopia's Productive Safety Net Programme (PSNP), supported by WFP and others, public works programmes have strengthened household resilience against recurrent drought-induced food insecurity (see Box 13.9 in Module 13 and Box 16.1 on PSNP below). There are, however, a number of challenges related to promoting sustainable natural resource management through public works programmes, as will be discussed in the section on challenges and lessons learned.

[3] See, for example, The World Bank and IDS 2011 and Béné, 2012.

[4] See, for example, Barrientos, 2012 and Alderman & Hoddinott, 2009.

Box 16.1
Ethiopia's Productive Safety Nets Programme

In Ethiopia, land degradation is a major cause of the chronic food insecurity widely experienced by the country's largely rural population. In addition, Ethiopia is ranked the ninth most susceptible country in the world to natural disasters and weather-related shocks, with climate change likely to exacerbate this situation (Tongul and Hobson, 2013).

In 2005, the government of Ethiopia, with the support of WFP and other partners, introduced a new way of supporting vulnerable and chronically food insecure households, replacing continual appeals for emergency food aid and ad hoc responses with a more predictable safety net (Tongul and Hobson, 2013). The Productive Safety Nets Programme (PSNP) is a social transfer programme in which beneficiaries receive both cash and food support. The PSNP covers several thousand watersheds in 319 chronically food insecure woredas (districts) in six regions as well as two urban administrative areas.

With an annual budget of approximately US$ 450 million, the programme targets around 7.8 million people in a normal year (and that rose to around 11.6 million during the regional drought of 2011). It is the largest social protection program in Sub-Saharan Africa outside of South Africa and has reached around 12 percent of the population in Ethiopia (Cooper *et al.*, 2012). The PSNP delivers 46 000 public works 'projects' every year. The public works are aimed at restoring local environments degraded by years of overuse and poor management, including, for example, the establishment of area enclosures, woodlots, construction of hillside terraces, shallow wells and ponds and stream diversion for irrigation, in accordance with the Ethiopian Ministry of Agriculture and Rural Development procedures on Community-Based Participatory Watershed Development (Berhane *et al.*, 2011), as well as building social infrastructure such as education and health facilities for the local community. In addition, the PSNP provides the poorest and most vulnerable households, who are unable to contribute to public works due to labour constraints, with regular, predictable support through cash transfers (Tongul and Hobson, 2013). As such, the PSNP provides a planned systematic approach in addressing chronic and seasonal hunger in Ethiopia (Berhane *et al.*, 2011; Sabates-Wheeler and Devereux, 2010; Cooper *et al.*, 2012).

The PSNP is complemented by the Household Asset Building Programme (HABP), which seeks to improve household's income generating and asset holding abilities. While the PSNP is designed to protect existing assets and ensure a basic level of food consumption, the HABP is designed to assist households in increasing incomes generated from agricultural activities and to build up assets so that they will be able to 'graduate' off PSNP (Berhane *et al.*, 2011). A household has graduated from PSNP when it is deemed to have moved from being dependent on assistance to a 'food sufficient' situation without the need of external support (Berhane *et al.*, 2011).

A recent impact assessment showed that PSNP public works:

- reduced sediment in streams by 40-53 percent in areas closed to grazing and cultivation;
- increased woody biomass and forage production three to four-fold;
- increased water availability and quality;
- increased ground water recharge and improved downstream base flow of streams;
- lessened damage from seasonal floods (by soaking up rain water in areas closed to grazing and cultivation);
- enhanced down-stream crop production through soil and water conservation interventions;
- stored carbon (estimates from just two of several thousand watersheds calculated over a million tonnes of carbon dioxide equivalent had been sequestered);
- increased biodiversity;
- increased social cohesion by improving livelihoods; and
- improved access to social services (for example 3 900 schools and 450 health posts have been constructed or refurbished) (Tongul and Hobson, 2013).

More specifically, Berhane *et al.* (2011) found that in 2010, 70 percent of PSNP households in the survey perceived their overall economic condition as better or the same compared to the previous year, an increase from 41 percent in 2008. The survey also found that from 2004 to 2010, the level of assets had increased and distress sales had declined, regardless of beneficiary type. Participation in PSNP was found to raise the likelihood of using fertilizer by 19.5 percentage points. Other studies showed that households with access to both PSNP and complementary packages of agricultural support were more likely to borrow for productive purposes, use improved agricultural technologies, and operate their own non-farm business activities (FAO *et al.*, 2012).

From a CSA perspective, Cooper *et al.* (2012) conclude that PSNP has helped a very large number of Ethiopians cope better with climate-induced risks, although challenges in the implementation of PSNP remain. Some of these are addressed in the section on challenges and lessons learned.

Safety nets can also serve as a platform for enhancing access to innovative risk management tools, such as weather-index based insurance.[5] For example, "insurance for work" can be used not only to expand access to insurance, but can be added to existing labour-based safety nets to protect beneficiaries and reduce costs for governments and donors from the disruptions caused by climate disasters. This is the objective of the R4 Rural Resilience Initiative launched by WFP and Oxfam America (see Box 16.2 on R4 below).

Box 16.2
R4 – Scaling up good practice through partnership and innovation

In 2010, WFP and Oxfam America partnered to scale up an innovative approach to strengthen poor farmers' resilience to climate-related shocks. The Rural Resilience Initiative (R4) combines improved resource management (risk reduction), insurance (risk transfer), microcredit (prudent risk taking), and savings (risk reserves). The initiative builds upon the Horn of Africa Risk Transfer for Adaptation (HARITA) programme, which was successfully implemented in Ethiopia's Tigray region by Oxfam America with funding from the Rockefeller Foundation and Swiss Re.

R4 allows poor, food insecure households who already benefit from food-for-asset or public works schemes such as PSNP to pay for insurance with their labour. Through "insurance-for-work" poor farmers work on small-scale, community-identified public projects in return for insurance coverage. Farmers with more cash can also purchase this insurance outright.

The insurance reduces uncertainty from climate variability and allows the poorest and most vulnerable farmers to make investments that increase their productivity. In case of a drought, farmers receive automatic insurance pay-outs if rainfall drops below a predetermined threshold. With the insurance pay-out, the farmers do not have to sell off livestock, tools or other productive assets to survive and will be able to afford the seeds and inputs necessary to plant in the following season.

R4 is now targeting nearly 19 000 households in the Tigray region of Ethiopia. The initiative reached a major milestone in 2012 when more than 12 000 drought-affected households received an insurance pay-out of over US$ 320 000. This is the first time that a weather index insurance programme in Ethiopia has delivered pay-outs at such a large scale directly to small farmers. In addition, farmers received the funds when they needed them the most, thanks to an early warning system based on advanced satellite technology that calculates when the crops begin to suffer and triggers the pay-outs.

The R4 Initiative demonstrated that safety nets can provide an effective and cost-efficient platform to make insurance accessible to the chronically poor. The initiative represents a new kind of partnership, bringing together public and private sector actors in a strategic large-scale initiative to innovate and develop better tools to help the most vulnerable people build resilient livelihoods. It also constitutes a first step towards developing a sustainable insurance market for poor people, an essential factor in ensuring farmers' livelihoods and food security over the long term. In 2012, R4 began expanding to Senegal where it expects to reach 18 000 farmers by 2015. In 2013, R4 is further scaling up in Ethiopia and is expected to be piloted to two additional countries by 2015.

Source: WFP and OXFAM AMERICA, 2012

Another area where safety nets can make a significant contribution is in fostering human and social capital, which set the stage for and maximize the impact of adaptation interventions (UN TT SDCC, 2011). Investments in early childhood nutrition can spur economic growth, as these investments have long-term effects on cognitive skills and productivity.[6] Safety nets can also provide a platform for introducing specific CSA-related activities – for example capacity development on skills and adaptation practices and technologies to be applied in homestead vegetable production or agro-forestry – and for targeting these activities towards the poorest and most vulnerable, who are often women. The Government of Bangladesh's Vulnerable Group Development (VGD) programme, for example, provides monthly wheat flour rations and entrepreneurship training to the poorest, most marginalised women in Bangladesh. Roughly 10 million women and their families have benefited from the VGD programme since it was launched three decades ago. Participating women attend regular training sessions where they discuss social issues and learn about their rights. They also

[5] See also Balzer and Hess, 2010.

[6] For example, analysis by the Boston Consulting Group showed productivity gains of up to US$ 1 782 for every US$ 146 invested in Kenya's school feeding programmes (WFP and Boston Consulting Group, 2009).

participate in a savings plan and are encouraged to start their own businesses, mainly in vegetable production or in animal rearing (WFP, 2006). In Sudan, as part of a project to promote fuel-efficient stoves (see section 16.3.2.1), over 200 000 women took part in food-for-training on making fuel-efficient stoves and briquettes, compost and bio pesticides using locally available resources, and setting up community nurseries and woodlots (WFP, 2013).

Mitigation co-benefits

Food and nutrition security being their main objective, safety nets will never have mitigation as their primary intention. Still, those safety net programmes that entail a component of asset creation or rehabilitation can also provide significant mitigation co-benefits, as Box 16.2 about Darfur illustrates.

Box 16.3
Safe Access to Firewood and Alternative Energy (SAFE)

Women in North Darfur traditionally collect dead trees or branches for cooking, but with the onset of the war – and the resulting displacement and environmental degradation – the supply is limited. Women have to venture into disputed territory, risking harassment and rape, in the daily or weekly business of collecting firewood. As environmental degradation progresses, women are increasingly forced to travel longer distances to collect grass and wood while confronting greater risk of attack. At the same time, the cost of firewood has become prohibitive with the continued conflict – and households are purchasing it at the expense of other needs, including selling food rations. Interviews with women revealed that they can spend a full day's wage on firewood alone. Often children are also required to bring firewood to school to help communities with the burden of cooking school meals. Firewood consumption has also become a major contributor to rapid deforestation. Darfur is already vulnerable to climatic changes and poor in environmental resources; stripping the land jeopardizes the resumption of agriculture and livestock practices that were common prior to the war.

WFP is using practical measures to address these problems not just for internally displaced people (IDP) living in camps, but also for the host communities who live on fragile lands that are affected by the processes of desertification. These are vital tools for conflict prevention and peace building. With the "Safe Access to Firewood and alternative Energy (SAFE)" initiative, WFP has adapted its emergency programme to respond to the evolving needs of displaced and other vulnerable people. Targeting both IDP and host communities, WFP has supported the establishment of 34 SAFE training centres in four rural communities and three major IDP camps. To implement the programme, WFP has built the capacity of 73 Women's Interest Groups and 16 Farmers' Interest Groups to manage training centres, monitor SAFE activities, and continue developing the community centres. As a result, close to 200 000 women were trained on adult literacy, vocational training, environmental conservation and in making fuel-efficient stoves and briquettes.

Thanks to SAFE, women have reported reducing firewood collection trips (86 percent reported less or no harassment as they replaced firewood with briquettes). They report saving time to invest in childcare and productive activities, and saving money from using briquettes instead of purchasing cooking fuel (an average of one US$ saved per day). They are also selling fuel-efficient stoves and briquettes in the market, generating an additional income of US$ 30 per month. The mitigation benefits occur from a reduction of fuel wood, as well as from the improvement of soil properties of the marginal lands in the area through reforestation and sustainable land management. Thirty-four tree nurseries have been established with a capacity of 500 000 plantlets per annum. Newly transplanted seedlings that are maintained by the communities under community forestry have covered 678 hectares of land so far. The trees cultivated are a) income generating species like Acacia (gum Arabic) and Jatropha (bio fuel); b) forestry trees for sustainable firewood supply; and c) nutritional value and fruit trees like moringa, lemon and oranges. In addition, five Agri Business Centres have been set up where beneficiaries learn how to make compost and bio pesticides using locally available resources, and applying good agricultural practices (WFP, 2013; see more details on energy-smart food in Module 5 and climate-smart forestry in Module 9).

16.4 Challenges and lessons learned

There are a number of challenges as well as important design and implementation issues that need to be considered in the development of safety nets and in using resource transfers as an incentive to encourage CSA practices.

Towards integrated approaches focused prevention and resilience

Safety nets are emerging as a platform for breaking the cycle of recurrent emergencies, which are increasing in view of climate change. This is based on evidence that large shares of vulnerable and food insecure populations would need long-term assistance, not only in response to shocks and disaster events. Their needs are therefore largely 'predictable', and a corresponding predictable level of support is required to address their food and nutrition needs with meaningful investments at the household and community levels before disasters occur, rather than with ex-post emergency assistance.

Important support that well designed safety nets can provide in this regard is through the enhancement of productive capacities, and the creation and rehabilitation of household and community assets. Often it is less the severity of shocks that determine the long-term outcome of crisis, than the ability of households to avoid falling beneath critical asset-holding levels (Prowse and Scott, 2008). In this respect, resource transfers provided through safety nets can be used as effective "enablers" for communities to build or enhance livelihood assets and capacities in a forward-looking manner, thus avoiding poor farmers falling into situations of increasing impoverishment and deprivation after recurring shocks, as well as avoiding the adoption of negative risk management, coping and adaptation strategies (Prowse and Scott, 2008).

There has been an increasing focus on pursuing a systems-based approach, as opposed to the ad hoc, project-based, short-term approach that dominated in the past. This is based on an understanding that more systematic and predictable risk-management tools with a focus on enhancing long-term resilience are likely to contribute to a sustainable graduation out of poverty. The systems approach is relevant not only in development contexts but also in emergency and early recovery contexts where shocks can be recurrent (e.g. Ethiopia, the Sahel, Yemen) or one-off. It is a way to move beyond a purely relief-focused approach towards multi-year safety net programmes such as the PSNP in Ethiopia whereby chronically food-insecure households receive support for up to five years, and the Hunger Safety Net Programme in Kenya (FAO *et al.*, 2012).

Matching predictability with flexibility

To be effective enablers of poor farmers' risk management strategies and capacities, safety nets must be both predictable and flexible enough to be scaled-up rapidly in times of a crisis, or reduced once a crisis is over. This is particularly relevant as climate-related shocks become more frequent and difficult to predict.

There are a number of efforts under way to make safety nets more responsive to climate-related shocks and hence more effective in preventing negative coping strategies, and more sustainable by ensuring flexibility. For example, the PSNP offers a vehicle for delivering timely livelihood protection to the chronically food insecure. However, the programme had difficulties in responding flexibly to weather related shocks, and emergency responses were often too slow to prevent the affected people from having to sell crucial assets such as livestock and equipment; many poor households that can sustain a livelihood during normal times are then at risk of slipping into chronic food insecurity. Resulting household asset depletion as well as increased levels of destitution in this segment of the population threaten the sustainability of PSNP.

In response to the above, in a second phase of PSNP, starting in 2008, the Government of Ethiopia, in collaboration with WFP and the World Bank, developed a risk management framework for PSNP. The Livelihoods, Early Assessment and Protection (LEAP) project aimed to facilitate predictable disbursement of resources for less predictable problems, in effect allowing the immediate scale-up of PSNP activities in response to localized, intermediate or severe extreme weather events. The concept is to coordinate a pool of contingent resources that can be readily and appropriately allocated through the PSNP in the event many more households become food insecure or existing beneficiaries require additional months of assistance following weather shocks. In case of a severe drought or flood, an early warning system based on a weather index can trigger additional financial resources for the PSNP from a contingency fund in the initial stages of the drought or flood – up to four months sooner than traditional crisis aid (see Balzer and Hess, 2010; see also Modules 13 on policies and 15 on disaster risk reduction).

Targeting: reaching the "most vulnerable" versus community-wide action

Effective targeting is key for maximizing efficiency and program impact. Using safety nets as targeting platforms for introducing specific CSA-related activities can be a practical measure to help make sure that CSA benefits the poorest and most vulnerable. On the other hand, in some low-income contexts where massive poverty still prevails, it becomes challenging to strike a balance between ensuring benefits reach the most vulnerable populations, and avoiding artificial boundaries between and within almost equally-vulnerable communities.

In practical terms, for example, CSA approaches must be implemented holistically and through broad participatory approaches when aimed at enhancing the resilience of entire watersheds or landscapes where different communities reside, some poorer than others. In fact, this is the same philosophy that guides much of the transformative landscape interventions implemented through safety nets in poor and vulnerable areas, whereby the achievement of collective and communal benefits impose more participatory approaches.

As not all households that share the same land-use unit have the same labour profile and wealth, resource transfers can help enable the poorest households within this unit to work to conserve the land. One study on the impact of food-for-programmes has concluded that the farmers would not have collectively constructed the large-scale improvements without food as an incentive (Reij *et al.*, 2005). At the same time, concomitant self-help contributions of the better off community members are necessary to ensure the involvement of the entire community and achieve the required coverage and scale.

In this regard, participatory planning procedures that recognize both people and ecosystems' requirements are critical to identify viable projects, enhance participation of food insecure households—women headed households in particular— and ensure the involvement of the community across different levels of wealth. This is also critical for ownership and sustainability of interventions that include resource transfers, as the next section highlights.

Community ownership and sustainability

When applied in situations of top-down approaches, limited or insufficient technical standards and support, tenure insecurity and a missing legal framework, incentives in the form of resource transfers are not only ineffective, but also potentially detrimental in terms of ownership building and sustainability.

A basic village or community-level participatory planning approach improves people's participation and increased sense of ownership over assets created or rehabilitated, with a positive impact on management and sustainability. Community level decision-making and targeting may be strengthened, particularly if the most vulnerable (including the young and women), are involved in project selection, design and implementation. The approach can also help identify and promote self-help efforts within the community on needs outside of the intervention scope.

The need for context-specific approaches

Depending on the specific context, safety nets and resource transfers can contribute to resilience, adaptation and other aspects of CSA to various degrees. In low capacity contexts, (e.g. where there is weak governance, instability and conflict) interventions that require significant expertise that is not realistically available should be avoided. Instead, low-tech and low-risk interventions are usually more appropriate. Such interventions do not mean low quality work, but involve less technical inputs and are more in line with specific time commitments that participants can contribute. Examples include drainage and irrigation canals clearing, dike establishment or community emergency preparedness training.

In higher capacity contexts, more sophisticated and integrated approaches can be considered. Sustainable land management, for example, integrates ecological and social approaches through a set of land management principles and interventions encompassing community-based approaches within defined landscape units. Similarly, community-based participatory watershed planning brings people and their livelihoods together with the natural environment by focusing on water catchments as the centre of planning of activities.

These approaches can bring about significant results in resilience building, reversing land degradation, risk reduction and adaptation to climate shocks, but they are not always possible. Of course, applying techniques – such as participatory watershed management approaches – to their full potential requires significant capacities and investments not only from the communities, but also from local institutions and government authorities. Ensuring and sustaining the planning and management effort over a long period of time among both communities and governments is an indispensable factor, especially in poor and degraded environments.

Scale, timeframes, continuity and impact

Social protection and safety nets interventions can deliver different results and outcomes depending on the institutional, programming and funding structures. Well-established national safety nets programmes may offer the necessary social, institutional and operational framework for interventions to have ambitious targets and long-term horizons. Conversely, interventions, programmes and initiatives of shorter durations may inevitably have to set more limited targets and objectives. In practical terms, and to remain on the example of a large-scale community-based watershed management programme, experience shows that in order to succeed and "reach scale", these interventions normally require longer timeframes and continuity of institutional, technical and political efforts. Other activities of shorter duration may have to operate at a lower level with less ambitious targets.

However, this does not mean that only long-term interventions can generate sustainable results. Much of the current debate about "building resilience" stresses the role that even more limited interventions can play in supporting livelihoods and productive enhancements among poor communities. Therefore, one of the main challenges is to ensure a convergence and continuity of efforts and an alignment of short and more long-term interventions within the parameters set by a broader policy environment targeting poor and food insecure communities. CSA interventions will have to follow the same logic, as disaster risk reduction, adaptation and resilience building activities supported by resource transfers also need to take these aspects into account. Continuity of programmes increases the ability to achieve the required transformational changes.

The impact of resource transfers on productivity and resilience is of course linked to the objective of the intervention, which should always be informed by the specifics of the context in which it is undertaken. For example, the main objective of large-scale safety nets, such as Ethiopia's PSNP or Kenya's Hunger Safety Net Programme that cover millions of food insecure households, is to meet their food needs and to prevent more people from falling into poverty. This is a tremendous challenge in itself, particularly in view of increasing climate related risks. Given the limited capacities, also in terms of funding, there is an obvious trade-off between ensuring basic food security on the one hand, and enhancing productivity and resilience on the other.

Transfer selection, timing, incentives and disincentives

One often discussed programming area centres on transfer selection, or more narrowly the longstanding 'cash versus food' debate. It is now widely recognized that the choice of the most appropriate safety net transfers – in cash, food or vouchers – hinges on properly assessed context-specific conditions. These include programme objectives, the spatial and temporal functioning of markets, the availability of implementation capacities and delivery mechanisms, cost-efficiency analysis, and beneficiaries' preferences (Gentilini, 2007). For example, the use of vouchers or smart cards in Kenya was found to be particularly appropriate for pastoralists, as it did not tie them to one place (WFP, 2012c; see also WFP, 2009).

The timing of resource transfers, particularly in the context of food-for-work activities, is another important issue to be considered. Without careful planning, participation in food-for-work programmes might provide essential food today, but hinder labour investments in future productivity. Conducting food-for-work activities during the agriculture productive season and providing transfers that are above prevailing market rates can divert labour from peoples' farms. In turn, timing in the non-productive season and at a net level at or below market rates would not pull labour from private production, and gains made could be redirected into private agricultural investment (WFP, 2012d).

Lastly, care should be taken that resource transfer, including insurance, does not discourage or impede autonomous actions adaptation by households. Providing transfers that shift risks to more aggregate levels could cause farmers to be less inclined to change their production techniques and livelihood strategies (FAO, 2011). This can be avoided by "rewarding" change in production techniques, such as sustainable management of natural resource. In the case of the R4 Resilience Initiative already outlined in Box 16.2, for example, poor farmers can obtain insurance if they fulfil certain work norms as part of the PSNP, which are aimed at enhancing resilience and reducing disaster risk.

16.5 Conclusions

Growing climate-related risks result in greater needs for effective social protection systems and services shielding the most vulnerable from shocks and stresses. The poorest and most food insecure households and communities face significant barriers to adopting more resilient and productive livelihood strategies that would allow them to enhance their food and nutrition security in the face of climate change. Specific policies and interventions need to be deployed to ensure that these challenges are turned into opportunities for the most vulnerable.

This module addressed how safety nets can support the transition to CSA in the context of vulnerability and food insecurity. Focusing on the adaptation, resilience and productivity elements of CSA, the module argued that, if properly designed, resource transfers provided through safety nets can protects lives, livelihoods and potential gains in development as well as CSA from climate-related risks. In addition, it was outlined how safety nets can enable poor and food insecure people and communities to invest in productivity, adaptation and resilience building measures.

There is growing recognition of the role of safety nets in enhancing adaptive capacity and building resilience to climate change. Safety nets are emerging as a platform for breaking the cycle of recurrent emergencies, which are increasing in view of climate change. This is based on evidence that large shares of food insecure populations would need long-term assistance, independently of the occurrence of shocks. Some chronic needs are therefore 'predictable', and a corresponding predictable level of support is required to address these needs ex-ante, rather than with ex-post emergency assistance. Such a future oriented, anticipatory risk management approach offers important opportunities for cross-fertilizing social protection with adaptation and disaster risk reduction efforts (see also Module 15 on disaster risk reduction).

In addition, safety nets can allow for the acquisition of human capital, the skills and assets that poor farmers need to sustainably escape food insecurity and poverty and become resilient in the long run. A key function of safety nets in this regard is the rehabilitation and creation of livelihood assets, as was demonstrated within the various boxes. Exploiting this potential of resource transfers, however, requires a long-term, forward looking and preventive approach that focuses on strengthening the asset base of vulnerable households. The notion of a threshold, below which households have so few assets that they are forced to adopt negative risk-management and coping strategies, offers a floor level above which pro-poor adaptation measures should seek to lift households (Prowse and Scott, 2008).

The effective use of safety nets as enablers of resilient and sustainable development also requires a shift towards integrated approaches that link resource transfers with resilience building and productivity enhancing agricultural interventions. This calls for a move away from viewing safety nets as being triggered in response to agricultural failure, towards recognizing the positive linkages between agricultural interventions and social protection (Devereux and Guenthe, 2009). In the context of CSA, this implies that safety nets can and should be used more systematically to enhance productivity, resilience and adaptive capacity, and should become an integral part of developing pro-poor CSA strategies.

Notes

This module was written by Catherine Zanev (WFP) and Carlo Scaramella (WFP) with contributions from Ugo Gentilini (WFP) and was reviewed by Niels Balzer (WFP), Volli Carucci (WFP), Alexandra Guyetsky (FAO), Nyasha Tirivayi (FAO) and Tamara van 't Wout (FAO).

Acronyms

CFS HLPE	Committee of World Food Security High Level Panel of Experts
CSA	climate-smart agriculture
FAO	Food and Agricultural Organization
FFA	food-assistance-for-assets
FFW	food-for-work
HABP	Household Asset Building Programme
HARITA	Horn of Africa Risk Transfer for Adaptation
IDP	internally displaced people
IFAD	International Fund for Agricultural Development
LEAP	Livelihoods, Early Assessment and Protection
NGO	non-governmental organization
PHI	Public Health Institute
PSNP	Productive Safety Net Programme
R4	Rural Resilience Initiative
SAFE	Safe Access to Firewood and Alternative Energy
UNSCN	UN Standing Committee on Nutrition
UN TT SDCC	United Nations Task Team on the Social Dimensions of Climate Change
VGD	Vulnerable Group Development
WFP	World Food Programme

References

Balzer, N. & Hess, U. 2010. *Climate change and weather risk management: evidence from index-based insurance schemes in China and Ethiopia.* In S.W. Omamo, U. Gentilini and S. Sandström, eds. Revolution: from food aid to food assistance – innovations in overcoming hunger, pp. 103–122. Rome, WFP.

Berhane, G., Hoddinott, J., Kumar, N. & Taffesse, A.S. 2011. *The impact of Ethiopia's productive safety nets and household asset building programme: 2006–2010.* Washington D.C. The International Food Policy Research Institute.

Center for Public Health and Climate Change at the Public Health Institute (PHI), World Food Programme (WFP), UN Standing Committee on Nutrition (UNSCN) and Action Against Hunger (ACF). 2011. *Enhancing women's leadership to address the challenges of climate change on nutrition security and health.* UNSCN.

Cooper P.J.M., Cappiello S., Vermeulen S.J. & Campbell B.M. 2012. *The large-scale implementation of adaptation and mitigation actions in the agriculture and food sector*. Draft for Discussion. Copenhagen, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Davis, B. 2011. *Cash transfer programs in SSA: recent developments and implications for climate change adaptation.* Presentation for session on Building resilience to climate change in smallholder agricultural systems, FAO ICABR, Frascati.

Devereux, S. 2009. *Social protection for agricultural growth in Africa.* FAC Working Paper No. SP06.

Devereux, S. & Guenthe, B. 2009. *Agriculture and social protection in Ethiopia*. FAC Working Paper No. 8.

Food and Agricultural Organization (FAO). 2011. *"Climate-smart" agriculture policies, practices and financing for food security, adaptation and mitigation.* Rome.

FAO. 2012. *FAO policy on cash-based transfers.* Rome.

FAO, International Fund for Agricultural Development (IFAD) & WFP. 2012. *Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition.* The state of food insecurity in the world 2012. Rome.

Gentilini, U. 2007. *Cash and food transfers: a primer.* Occasional Paper No.18. Rome, WFP.

Grosh, M., Del Ninno, C., Tesliuc, E. & Ouerghi, A. 2008. *For protection and promotion: the design and implementation of effective safety nets.* Washington D.C., The World Bank.

Heltberg, R., Siegel, P. B. & Jorgensen, S. L. 2010. *Social policies for adaptation to climate change, in social dimensions of climate change: equity and vulnerability in a warming world,* R. Mearns & A. Norton, eds. Washington D.C., The World Bank.

HLPE. 2012a. *Social protection for food security.* A report by the CFS HLPE. Rome.

HLPE. 2012b. *Climate change and food security.* A report by the CFS HLPE. Rome.

Kimmis, J., Bose, R. & White, H. 2009. *Public works: an effective safety net for the poor?* International Initiative for Impact Evaluation Brief No. 1. (available at http://www.3ieimpact.org/en/evidence/policy-briefs/3ie-briefs/details/public-works-an-effective-safety-net-for-the-poor/)

Kristjanson, P. Neufeldt, H., Gassner, A., Mango, K. Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Forch, W., Thornton, P.K., & Coe, R. 2012. *Are food insecure smallholder households making changes in their farming practices?* Evidence from East Africa, Food Security, 4(3): 381–397.

Prowse, M. & Scott, L. 2008. *Assets and adaptation: an emerging debate.* IDS Bulletin, 39: 42–52.

Reij, C., Tappan, G. & Belemvirec, A. 2005. *Changing land management practices and vegetation on the central plateau of Burkina Faso (1968–2002)*. Journal of Arid Environments, 63: 642–659.

Reij, C., Tappan, G. & Smale, M. 2009. *Agroenvironmental transformation in the Sahel: another kind of "Green Revolution."* International Food Policy Research Institute Discussion Paper No. 914.

Sabates-Wheeler, R. &Devereux, S. 2010. *Cash transfers and high food prices: explaining outcomes on Ethiopia's Productive Safety Net Programme.* Food Policy, 35(4): 274—285. (available at http://www.sciencedirect.com/science/article/pii/S0306919210000230)

Tongul, H. & Hobson, M. 2013. *Scaling up an integrated watershed management approach through social protection programmes in Ethiopia: the MERET and PSNP schemes*. A New Dialogue: Putting People at the Heart of Global Development, Conference Papers. Hunger, Nutrition, Climate Justice Conference 2013. Dublin. Irish Aid, Climate Change Agriculture and Food Security, Mary Robinson Foundation – Climate Justice and World Food Programme.

United Nations Task Team on Social Dimensions of Climate Change (UN TT SDCC). 2011. *The social dimensions of climate change.* Discussion draft. (available at http://www.who.int/globalchange/mediacentre/events/2011/social-dimensions-of-climate-change.pdf)

WFP. 2006. *Bangladesh country programme 2006-2010.* Rome.

WFP. 2011a. *Policy on disaster risk reduction and management.* Rome.

WFP. 2011b. *Kenya: an evaluation of WFP's portfolio: 2006-2010.* Rome.

WFP. 2012a. *Update of WFP's safety net policy.* Rome.

WFP. 2012b. *Standard project report 2012: protecting & rebuilding livelihoods in arid and semi-arid areas.* Rome.

WFP. 2012c. *Annual evaluation report 2011.* Rome.

WFP. 2012d. *Terms of reference: evaluation of the impact of food for assets on livelihood resilience – phase II countries.* Rome.

WFP. 2013. *Safe Access to Firewood and Alternative Energy (SAFE) in Sudan.* Information Leaflet. Rome.

WFP and Oxfam America. 2012. *R4 Rural Resilience Initiative: partnership for resilient livelihoods in a changing climate.*

Additional Resources

Alem, Y. & Broussard, N. H. 2013. *Do safety nets promote technology adoption? panel data evidence from rural Ethiopia*. Working papers in economics. Department of Economics, Göteborg University, 556 pp.

Alderman, H. & Hoddinott, J. 2009. *Growth-promoting social safety nets*. In J. von Braun, R. Vargas Hill & R. Pandya-Lorch, eds. The poorest and hungry: assessments, analyses, and action. Washington D.C., International Food Policy Research Institute.

Barrientos, A. 2012. *Social transfers and growth: What do we know?* What do we need to find out? World Development, 40(1): 11–20

Béné, C. 2012. *Social protection and resilience to climate and disaster.* Programme Briefing. Brighton, UK, Institute of Development Studies.

Davies, M. 2009. *DFID social transfers evaluation summary report.* Research report No. 60. Brighton, UK, Institute of Development Studies.

Gentilini, U. & Omamo, S.W. 2011. *Social protection 2.0: exploring issues, evidence and debates in a globalizing world.* Food Policy, 36(3): 329–340.

Haddad, L. 2010. *Has social protection in Africa lost its way?* Development Horizons weblog.

World Bank & Institute of Development Studies (IDS). 2011. *Social protection and climate resilience.* An International Workshop on Making Social Protection Work for Pro-Poor Disaster Risk Reduction and Climate Change Adaptation. Addis Ababa.

WFP. 2009. *Vouchers and cash transfers as food assistance instruments: opportunities and challenges.* Rome.

WFP & the Boston Consulting Group. 2009. *School feeding: a sound investment.* Rome.

MODULE 17:

CAPACITY DEVELOPMENT FOR CLIMATE-SMART AGRICULTURE

Overview

Complementing and building on the previous modules of the Sourcebook, Module 17 addresses the overarching question on how the transition towards climate-smart agriculture (CSA) practices can be achieved. Given the knowledge-intensive, multi-stakeholder characteristics of climate-smart agriculture, the module illustrates through case studies the necessary practical ingredients to succeed in this transformation. These elements include a comprehensive and gender-sensitive capacity development approach aligned with and driven by national priorities, applying knowledge management and effective learning approaches, facilitating multi-stakeholder processes, strengthening agricultural innovation systems and leveraging information and communication technologies (ICTs) and communication for development (ComDev) approaches.

Key messages

- Making agricultural production and management systems climate-smart is a knowledge-intensive process requiring a comprehensive capacity development approach of all stakeholders that builds on sound assessments of country needs across the individual level, organizational level and the enabling environment.
- Due to the uncertain and dynamic nature of climate change impacts, a transition towards climate-smart agriculture requires socio-institutional learning processes with a strategic approach to skills development for climate-smart agriculture at country level including strong engagement of national and local formal and informal education and training institutions.
- Agricultural innovation systems with public and private research, extension and advisory services play a key role in supporting the transition towards climate-smart agriculture by generating, documenting, blending and sharing indigenous and scientific knowledge, facilitating learning processes and network-based development and innovation.
- In order to improve policy coherence and effectiveness, strengthen local institutions and mainstream CSA into national policies and programmes, it is important to create inclusive, gender sensitive spaces that promote multi-stakeholder dialogue about CSA, such as cross-ministerial roundtables, multi-stakeholder platforms for strategy development and efforts to coordinate regional bodies.
- Information and Communication Technologies (ICT), participatory Communication for Development (ComDev) approaches and knowledge sharing methods are important vehicles to improve access to information and knowledge, facilitate dialogue between stakeholders, and trigger learning across levels with knowledge networks and platforms to provide a venue where the diverse actors can connect.

Contents

List of Figures

List of Tables

List of Boxes

17.1 Introduction

How will the transition towards CSA materialize? Who will own and drive this transformation at country-level? What are the national capacities that are in need to be developed and how will countries be supported in this process? Addressing these questions starts with the recognition that making agricultural production and management systems climate-smart is a highly knowledge-intensive process. Therefore, current gaps in knowledge and capacity—particularly at country-level— need to be addressed systematically. Due to the uncertain and dynamic nature of climate change impacts, a transition towards climate-smart agriculture requires a comprehensive capacity development approach that stimulates socio-institutional learning processes and utilizes the innovation potential of agricultural systems.

What do we mean by capacity development and why is it so important for CSA?

"What we need to develop is people, not things,
and people can only develop themselves"

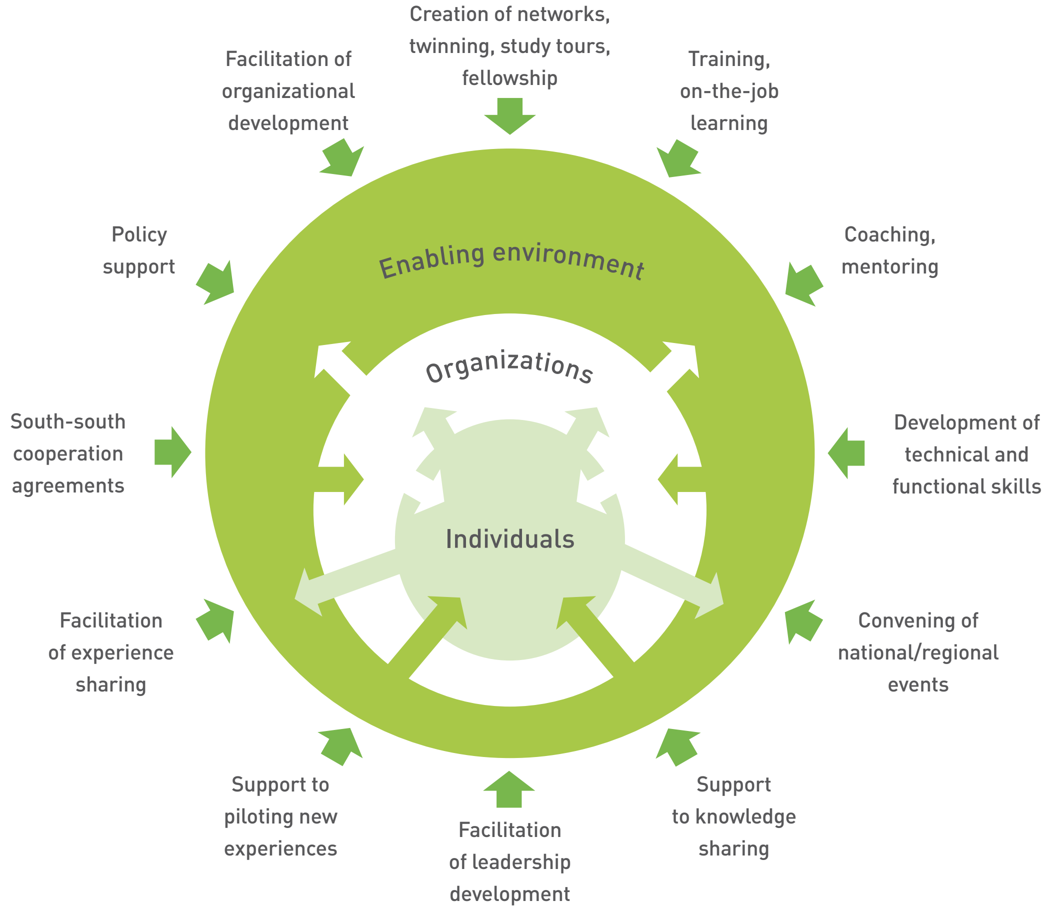
Arusha Declaration, 1967

Capacity is defined as "the ability of people, organizations and society as a whole to manage their affairs successfully. Capacity development (CD) is defined as "the process whereby individuals, organizations and society as a whole unleash, strengthen, create, adapt and maintain capacity...to set and achieve their own development objectives over time" (OECD, 2006). Effective CD goes beyond training, technical assistance and policy support but instead aims to facilitate a sustainable and endogenous development process rooted in national empowerment that enables developing countries to be in the driving seat of their own destiny. In a capacity development approach, developing countries own, lead and drive the development process with external actors (such as FAO) facilitating this change process, thus contributing to more sustainable and impactful results. CD encapsulates both the overall aim of development (i.e. developing comprehensive capacities to strengthen country systems) as well as the process by which more sustainable results with higher impacts can be achieved (i.e. the modality or the "how"). This emphasis on a more comprehensive approach to CD is in line with the international consensus on development effectiveness stating that "without robust capacity—strong institutions, systems and local expertise— developing countries cannot fully own and manage their development processes" (OECD, 2008).

Figure 17.1 illustrates the three different dimensions of CD—the individual, organizational and enabling environment/policy level. The enabling environment dimension addresses the systemic impediments covering political commitment and vision, policy, legal and economic frameworks: national public sector budget allocations and processes; governance and power structures; and incentives and social norms. The organizational dimension includes public and private organizations, civil society and networks of organizations. It addresses strategic management functions, structures and relationships; operational capacities, human and financial resources; and knowledge and information resources and infrastructure. The individual dimension refers to the skill levels and attitudes of individuals. These can be addressed through facilitation, training and competency development (see FAO, 2010a).

To achieve any systemic and more sustainable change, all three dimensions of CD need to be addressed interdependently. This is particularly relevant in the context of CSA, which aims for systemic change in the way food is sustainably produced.

Figure 17.1
Dimensions of capacity development and support modalities



Source: FAO, 2012b

Learning and knowledge sharing play a key role in the capacity development process. Figure 17.1 lists support modalities for supporting and facilitating endogenous, contextualized change processes led by national actors. It covers a wide range of approaches that trigger learning and knowledge sharing, from classical class-room training to more innovative approaches such as South-South cooperation agreements, coaching, institutional twinning and network creation and facilitation. Many innovative approaches in capacity development foster social learning, for example through E-learning or web/ICT-supported multi-stakeholder platforms and networks (FAO, 2011a). For CSA, enabling continuous individual and institutional learning is fundamental given the complexity of the topic and the unpredictable evolution of climate change impacts on farming systems and local communities.

Key methodologies and success factors

A set of success factors for effective capacity development in the agriculture sector can be identified and are shown in Table 17.1. It also features examples specific to the CSA context.

Good capacity development practice recommends addressing all of the above success factors to increase the likelihood of greater long-term success for development interventions. Here we discuss three of the success factors in more detail in the CSA context:

Table 17.1
Success factors for effective capacity development for CSA

Success Factor	Explanation	CSA Examples
Applying a systematic approach across 3-dimensions and develop both technical and functional capacities	CD involves three dimensions (3D) which are interlinked: individuals, organizations and the enabling environment. Successful initiatives usually address all three dimensions. Non-technical (i.e. functional capacities) are increasingly considered a necessary complement to technical CD, as they empower actors to apply the new knowledge/skills effectively, and scale up the intervention's results.	CD for trans-boundary, integrated water resources management comprises technical and negotiation skills (e.g. support of the Lower Mekong River Commission).
National Ownership through aligning programmes with national priorities	National needs and priorities anchored in national ownership, rather than UN agency priorities, should guide interventions. For example, FAO follows country priorities as laid out in Country Programming Frameworks, National Agriculture Sector Plans, Poverty Reduction Strategy Papers, and as per the Aid Effectiveness Agenda. Use national Project Management Unit whenever possible.	Development of national reduced emissions from deforestation and forest degradation (REDD) strategies in line with country strategies. See Box 17.3. Setting up comprehensive CSA policy approaches in Malawi, Zambia and Vietnam
Assessing capacities	Undertaking a careful assessment of needs to diagnose what and whose capacities need to be developed is a fundamental pre-condition for all successful and sustainable development projects. Such assessments ensure the context is understood and existing capacities and needs are identified, allowing the project or programme to be customized to the local situation.	See Box 17.1 for CSA capacity needs assessments in Kenya and Tanzania.
Anchoring programmes to local or national institutions and systems	Sustainable interventions anchor programmes in local or national institutions, national systems, procedures, organizations, and/or budgets are developed to ensure long-term continuity even after external funding for development projects ends.	CSA interventions linked to National Climate Change Commissions or Offices.
Promoting engagement with local & national actors	Encouraging national/local involvement in project/programme identification, formulation, implementation and monitoring and the use of participatory communication approaches ensure the endogenous support essential for sustaining projects in the long term.	The formulation of National Climate Action Programmes/ Plans (NAPAs, NAPs, NAMAs) under the United Nations Framework Convention on Climate Change (UNFCCC) emphasizes this factor. See Box 17.7 on inclusive communication tools.
Using capacity development modalities beyond training	Alongside the delivery of training, other successful capacity development modalities include coaching, South-South cooperation, policy support, support to organizational development, creation of networks and convening for national/regional events.	See Box 17.2 on climate change learning approaches in the Philippines and Figure 17.1
Understanding national or regional contexts	Paying attention to national, regional and sub-regional contexts helps identify key drivers of change.	REDD + interventions have to be based on a sound understanding of the drivers of deforestation in a country.
A long breath—Giving the CD process time	CD takes considerable time, particularly at organizational and policy levels, and it happens gradually. Ensuring a medium to long-term horizon, through different forms, scales or funding mechanisms if necessary, can foster deep-level CD.	The shift in CSA interventions from a project to a programmatic approach supports this
Tracking capacity development	Although complex and challenging due to its non-linear nature of assessing change, tracking national capacity-related activities across the three dimensions is critical to measure progress. Capacity-related indicators should be an integral part of any programmatic results framework including assessing political commitment at country level.	Transformation to CSA practice is knowledge-intensive, requiring learning and change of practice calling for innovative approaches to track this complex change process.

Source: Adapted from FAO, 2011d

Anchoring programmes to local or national institutions and systems

In order to anchor CSA in national institutions it is crucial to support national actors in internalizing changes, such as by:

- facilitating the adoption of new or revised CSA related policies and providing for their implementation as a national priority;
- supporting the incorporation of CSA related knowledge into national curricula;
- implementing new procedures in the functioning of institutions; and/or
- encouraging internal changes that prepare staff to utilize new competencies in daily tasks.

Tracking CD

CD is fundamentally about change. Monitoring the effects of capacity-related interventions is crucial, although the complex and non-linear nature of the CD process makes it difficult to attribute impacts to particular activities. Nevertheless, good CD practice recommends that capacity-related indicators should be an integral part of any programmatic results framework. This includes assessing capacities and political commitment at country-level (FAO, 2013 forthcoming) and establishing a simple and sound monitoring and evaluation system that can help fill in knowledge gaps and demonstrate which approaches work best so that CSA pilot actions can be effectively scaled up (see Module 18 on M&E).

Assessing Capacities

To ensure quality at entry with successful capacity development from the outset, capacity assessments are critical. A capacity assessment can help determine what and whose capacities need to be developed but also provide a benchmark to measure progress and identify what the adoption constraints are and to ensure that the envisioned CD-related interventions for the CSA project address some of these.

An assessment compares the existing capacities across the three dimensions of the capacity system (individual, organizational and enabling environment) with those needed to reach future development results. It is guided by the following key questions: Where are we now? Where do we want to go? What is the best way to get there?

Below, Box 17.1 illustrates the application of the FAO capacity assessment methodology when tailored to CSA projects in Kenya and Tanzania.

Box 17.1
Capacity needs assessment: a tool for planning capacity development interventions in CSA projects in Kenya and Tanzania

Context

In Kenya and the United Republic of Tanzania, a FAO Programme has developed pilot projects to help build climate-smart farming systems. The two pilot projects provide capacity development, including technical support to assist smallholder farmers in adopting climate-smart farming practices. During the pilot projects' initial phase, a capacity needs assessment was undertaken in collaboration with the project partners and FAO country offices. In Kenya, the project partners are the World Agroforestry Center (ICRAF) and the East Africa Dairy Development Project (EADD). In the United Republic of Tanzania, the project partner is Cooperative for Assistance and Relief Everywhere (CARE).

Methodology

The objective of the assessments was to identify and prioritize the capacity needs that must be addressed to mainstream climate-smart agriculture into smallholder farming systems given the existing capacities and gaps at the national, district and project level. The assessments served as the starting point for planning capacity development activities and an excellent opportunity to enhance collaboration among all stakeholders.

The methodology used was based on FAO's Capacity Assessment Toolkit and especially tailored to address climate change adaptation and mitigation in agriculture. The assessments helped identify the main stakeholders, policies, plans and strategies related to climate change already in place. Moreover, the participating stakeholders could assess their own organizational and individual capacities and needs through open discussions and working groups to strengthen ownership. To analyse farmers' capacities and needs regarding the adoption of climate-smart practices, the assessments considered the different existing agricultural land uses and management practices, as well as topical climatic and environmental problems.

The assessment process was carried out on multiple levels and involved a variety of participatory and consultative activities.

At the national level, a stakeholders' mapping and context analysis was carried out with representatives from the Ministries of Agriculture, Livestock, Environment, non-governmental organizations (NGOs), research institutions and United Nations agencies working on climate change.

At the district level (project area), consultative workshops were held with project staff, extension officers and district staff from Ministries of Agriculture, Livestock, Water, Forestry and Environment.

At the project and community level, the assessment team organized focus group discussions with farmers and local leaders, interviewed farmers and conducted field visits.

Outcome

The assessments in Kenya and the United Republic of Tanzania successfully identified entry points for capacity development activities and made recommendations for the promotion and implementation of CSA practices in both pilot projects.

Full assessment reports are available at FAO, 2012a
For Tanzania's report: FOA, 2011b
For Kenya's report: FAO, 2010

Improving technical and functional capacities across the individual, organizational and policy level

In numerous developing countries sector agencies may be developing technical capacities successfully (increasing the competencies to intensify production sustainably or manage natural resources more effectively, for example). However, unless such provisions are adequately integrated into planning and policies, it will not be possible to efficiently scale them up. Moreover, non-technical (i.e. functional) capacity development is often not prioritized. These soft skills include the ability to manage personnel and organizations, good governance principles such as dialogue and communication with stakeholders and resource allocation within policy frameworks that aim for equity and poverty alleviation, transparency and accountability (UNESCO-IHE & UNW-DPC, 2009). Last but not least, the lifelong learning of individuals and organizations is important to keep up with evoking the tasks and trigger innovation. This requires financial, personal and managerial support mechanisms to foster knowledge generation and sharing. More specifically, in 2010 FAO's renewed corporate approach to CD recommends that the following functional capacities should be enhanced (complementing technical capacity strengthening) to enable countries and regions to plan, lead, manage and sustain change initiatives:

- Implementation capacity: implement and deliver programmes and projects, from planning to monitoring and evaluation.
- Partnering capacity: engage in networks, alliance and partnerships
- Knowledge capacity: access, generate, manage and exchange information and knowledge
- Policy and normative capacity: formulate and implement policies and lead policy reform

Table 17.2 provides some examples of required capacities at the different levels.

Table 17.2
Examples of required technical and functional capacities for climate-smart agriculture by level

	Individual level	Organizational level	Policy level
Technical capacity (technical)	Regularly updated knowledge and skills. Understanding of broader technical context of CSA.	Appropriate knowledge and skills mix, such as agronomic, environmental, engineering, economic, social, legal, financial, institutional knowledge; knowledge on investment procedures	Policy for critical review of knowledge and information; allocation of adequate resources for CSA related capacity development requirements
Implementation capacity (functional)	Skills for CSA project and finance management; personnel/team management/mentoring skills, ability to deliver, leadership, mediation skills.	Ability to set goals/strategies. Financial and people management; staff rotation; incentive systems, project management including proper planning and M&E, ability to deliver in a timely manner.	Sound task assignments and clear mandate of sector agencies; cross-sectoral collaboration mechanisms; sound finance and budgeting systems, facilitating proper organisational management.
Partnering capacity (functional)	Ability to engage stakeholders, apply inclusiveness; capacity for collective action	Transparent decision-making processes (including budgets and plans); accountable procedures for stakeholder consultation and empowerment.	Policy to ensure inclusiveness, transparency and accountability; conducive regulations.
Knowledge capacity (functional)	Desire to keep learning and attend trainings, self reflection of performance; skills for knowledge sharing and management.	Procedures for continuous performance review; mechanisms and rewards to support information/ knowledge exchange and learning; support for communities of practice.	Policy to promote an open work atmosphere and inclusiveness; openness to continuous sector performance review and implementation of adjustments.
Policy and normative capacity (functional)	Ability to meaningfully engage in CSA-related policy and planning processes	Ability to formulate and implement policies and lead policy reform, including climate change mainstreaming in policies.	Capacity to administer legal and institutional frameworks, including those related to UNFCCC.

Source: based on UNESCO-IHE & UNW-DPC 2009, adapted for CSA with different classifications of functional capacities

In many cases, a strategic approach to skills development and learning for CSA is required. For instance, the *One UN* initiative, UN CC:Learn, advocates the development of National Strategies to Strengthen Human Resources Capacities to Advance Green, Low Emission and Climate Resilient Development. It is piloting such efforts in Benin, the Dominican Republic, Indonesia, Malawi and Uganda (UN CC: Learn, 2012). Such a strategy allows countries to

- Take stock of relevant capacity development and learning initiatives;
- Assess existing human capacities to achieve climate change objectives;
- Identify and prioritize learning interventions in the short, medium and long term; and
- Engage educational and vocational training institutions.

Two concrete learning interventions (farmer field schools [FFS] and e-learning) for boosting technical and functional capacities for CSA are illustrated in Box 17.2.

Box 17.2
Climate change learning approaches in the Philippines

Context

The MDG-F 1656 climate change project, implemented from 2009 to 2012 by the Philippine government and various UN agencies, aimed to strengthen the institutional capacity of the Philippines to adapt to climate change. The project component 3.1, led by the Department of Agriculture and FAO used FFS as an outreach vehicle to spread the pilot projects' demonstration activities alongside other methods such as e-learning, mentoring and hands-on technical trainings.

Methodologies

FFS have a very long tradition in the Philippines as a means of capturing local knowledge and working with farmers to adapt innovative management practices to local conditions based on a sound understanding of the relevant agro-ecosystem. FFS have proved to be successful in providing effective linkages with farming communities, allowing participatory testing and experiential learning while empowering farmers. Having started as FFS for Integrated Pest Management focusing on farmer fields, in the last decade the FFS' scope expanded first into Integrated Crop Management FFS and since then also into FFS that look more broadly from farmer fields to agricultural landscapes as a whole. Thus, Sustainable Land Management (SLM) and watershed scale FFS, pastoralist FFS and climate field schools now also exist.

E-Learning also provides a powerful method for CSA capacity development. It can take various forms, from individual self-study to facilitated online courses, or blend approaches by combining 'face-to-face' workshops and e-learning. The MDG-F project in the Philippines introduced an e-learning tool on planning community-based adaptation to climate change. The tool was developed by FAO and targeted to rural agricultural extension workers. It should be noted that bringing e-learning to rural communities might be challenging if it is not carefully integrated with other learning processes. In the Philippines project, e-learning was introduced after social mobilization and good practice identification had already begun and was followed by field demonstrations that were clearly communicated and easy to understand. In this way, everyone was able to clearly relate e-learning to their own situation and experience and could easily define how to put what they had learnt into practice.

Outcomes

The advantages of combining e-learning with 'face-to-face' interaction (as compared with using either technique in isolation) were as follows:

1. 'Face-to-face' allows for better tailoring and ad-hoc adjustment of training content to specific contexts (prior knowledge of participants and country context; ability to give direct responses to individual participants' questions; embeddedness in the current status of related project activities);
2. E-learning allows participants to refer back to sessions of particular interest after the course, and course CD-ROMs can be copied and disseminated to others;
3. Particularly younger extension workers are eager to use e-learning and to improve their skills with new technology;
4. The introduction of new e-technology using 'face-to-face' methods also takes older, often computer illiterate extension workers who would otherwise have been excluded, into account and brings them on board.

For these reasons, the combination of both methods for capacity development has been a key success factor of the MDG-F1656 climate change project.

Full Report available at FAO and Republic of the Philippines, 2011

17.2 Strategies for improving policy coherence and effectiveness

Building on Module 12 on local institutions and Module 13 on mainstreaming CSA into national policies and programmes, the following two key strategies for improving policy coherence and effectiveness will be discussed: multi-stakeholder processes and efforts to link scientific assessments and decision-making in CSA.

Facilitating multi-stakeholder processes

Facilitating multi-stakeholder processes is a key strategy for improving a conducive enabling environment, including governance. Good and efficient governance of natural resources and the equitable and transparent distribution of benefits lead to the success of many policies and measures aiming for climate-smart agricultural systems. It is important to create inclusive spaces in which multi-stakeholder dialogue about CSA can take place, such as cross-ministerial roundtables, multi-stakeholder platforms for strategy development or the coordination of regional bodies, among others.

The capacity development activities for REDD+ readiness supported by the UN-REDD Programme is one such example. They focus on stakeholder consultation and participation, as well as cross-sectoral coordination in REDD+ planning and implementation in developing countries. Box 17.3 illustrates one of the many methodologies developed in this context.

Box 17.3 Facilitating multi-stakeholder processes to support improved governance—the REDD+ Participatory Governance Assessment in Indonesia

Methodology

The participatory governance assessment (PGA) provides a clear picture of a country's REDD governance situation, identifying gaps and needs through inclusive, participatory, multi-stakeholder processes. The methodology has been developed and tested by the United Nations Development Programme and relies on a partnership between government and civil society to define governance challenges and to develop performance improvement processes. The assessments aim to (i) analyze and obtain credible information; and (ii) trigger public opinion, creating a demand for accountability and thereby ensuring government leadership on improving governance. The framework develops disaggregated governance indicators that feed into a tailored information management system that reinforces domestic accountability over time.

Indonesia was the first UN-REDD country to pilot the PGA methodology. Different stakeholders' views were taken into account to develop a set of governance indicators collaboratively. The assessment looked at three areas of governance in particular: legal and policy frameworks; capacities of REDD+ actors (nationally and sub-nationally), including civil society actors and business entities; and the impact of existing laws and practices. In 2011/2012 a series of meetings were held, including national workshops and provincial consultations with representatives from governments, NGOs, academia and forest business associations. A meeting of the expert panel was also held to further refine the indicators and the methodology. It comprised of government representatives, members of civil society and of academia, as well as governance practitioners and members of the UN-REDD Programme.

Outcomes

Preliminary recommendations from the PGA in Indonesia included: (i) ensure discussions on framework, structure and measurement flow early on, (ii) apply iterative methods that allow for constant tool improvement, (iii) engage external reviewers (in addition to consultations at national and provincial level) for quality assurance. The revised indicator set will serve as a basis for collecting the data necessary to assess REDD+ governance in the Indonesian context. The PGA in Indonesia focused on the following governance issues related to REDD+: spatial and forest planning, rights regulation, forest organization, forest management, forest control, and REDD+ infrastructure.

Full Reports available at UN-REDD, 2012a and 2012b

Linking scientific assessments and decision making

Creating an interface between science, planning and policy is essential for achieving CSA. The following Box (Box 17.4) illustrates efforts to develop simple and robust scientific tools that can guide decision making of farmers on a seasonal and long-term basis.

Box 17.4
CD for farm management strategies to improve crop-water productivity using AquaCrop

Context

It is commonly acknowledged that most climate change impacts will be felt through water. The free AquaCrop software is an important tool for increasing water use efficiency in rain-fed and irrigated agricultural production systems. Developed and applied by FAO and multiple partner institutions, it is mainly intended for practitioners such as those working for extension services, governmental agencies, NGOs, and farmers associations though it is also used by scientists and for teaching. AquaCrop uses a relatively small number of simple input variables to enable easy use while maintaining accuracy and robustness. AquaCrop can serve as a benchmarking tool, comparing the attainable yields against actual yields of a field, farm or region. It can help develop irrigation schedules for different climate scenarios, assess water productivity at various scales and support decision making on water allocation and other water policy actions.

Methodology

In response to the urgent need of significantly raising the number of adequately trained water professionals, FAO, the UN Water Decade Programme on Capacity Development (UNW-DPC) and local partners organized five regional, one week "training of trainers" workshops in 2009/2010. In total, 147 participants from 58 countries and over 100 institutions were trained in the practical applications of AquaCrop, improving their skills in strategic farm management for increased crop-water productivity.

The five local host institutions (mainly research institutions or ministries) in China, Iran, Burkina Faso, Egypt and South-Africa were actively engaged in selecting the participants. The nearly 500 applications contained motivation and reference letters and proof of at least 3 years' professional experience in a related field to ensure that participants would disseminate their newly derived knowledge in their institutions and home countries. Most selected participants received scholarships. 43 percent of them came from academia, 32 percent from national research institutes, 15 percent from ministries or government agencies, 7 percent from international development organizations, 2 percent from private companies and 1 percent from NGOs. The training was delivered by means of lectures and computer-based hands-on exercises. Both the theoretical and practical sessions of these workshops were followed by the participants with high interest and active involvement. The open, interactive approach adopted for the training program was a key factor for its success. Prior to participating, trainees had to complete a questionnaire on capacity development needs in the field of water and food. This was then analyzed in order to assess the specific gaps in terms of individual, institutional and organizational capacity.

Outcomes

Six months after the last workshop, participants were invited to present case studies on their use of the software and to discuss their experiences in training others. The best cases were then presented at the International Commission on Irrigation and Drainage's Asian regional conference held in Indonesia in October 2010. Of the 19 participants that attended, 16 had trained a further 120 people. Finally, a 6th workshop was organized, inviting the strongest case studies from the previous workshops to share their experiences of using AquaCrop in different agro-climatic conditions. The workshop also analyzed the success of former workshops and identified further follow-up activities for participants to undertake within their countries.

Source: UNW-DPC, 2011

17.3 Strategies for knowledge sharing and effective learning

Knowledge sharing and effective learning comprise key components of a comprehensive and more sustainable capacity development approach. Farmers and pastoralists have been dealing with natural climate variability over millennia and have developed a wide range of coping strategies. Many of these remain valid in a climate change context, though scientists expect many to be insufficient to deal with the impacts of climate change in the long term. In addition, much of this indigenous knowledge is likely to be lost as local farming population aged and youth tend to migrate to urban areas or engage in activities other than farming. Therefore, documenting, mobilizing and sharing indigenous knowledge can be vital for safeguarding and further developing local adaptation strategies.

Below, three key strategies for knowledge sharing and effective learning will be discussed: the potential of agricultural innovation systems; the use of ICTs and ComDev approaches for improving access to information; and the role of knowledge networks.

Strengthening agricultural innovations systems to harness the innovation potential needed for CSA

As part of a broader capacity development approach, agricultural innovation systems with public and private research as well as extension and advisory services play a key role in supporting the transition towards CSA by documenting, generating, blending and sharing indigenous and scientific knowledge. Such services facilitate learning processes as well as network-based development and innovation. Knowledge networks and platforms provide a venue in which the various actors can connect. They take diverse forms depending on their target group, for example global or regional platforms for coordination, knowledge exchange or advocacy are very different from field support platforms. Aggregation—through farmer unions, cooperatives or value chains—is a key strategy to minimize transaction costs and upscale CD for CSA. Moreover, the roles, responsibilities and capabilities of both men and women need to be well understood to ensure that both men and women benefit from innovation systems supporting the transition to CSA (see Box 17.5) calling for methodologies and approaches for gender sensitive research as well as extension and advisory services on CSA.

Box 17.5
Developing capacity to understand and address the gender dimensions of climate change and agriculture

Context

A gender-sensitive approach is crucial to achieve CSA. However, little research has been undertaken to understand how men and women are adapting to climate change, mitigating emissions and maintaining food security. Methodologies and approaches for research and development planning are needed.

Methodology

As a contribution to addressing this gap, FAO's Mitigation of Climate Change in Agriculture Programme (MICCA) partnered with the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) to develop training material on "Gender and Climate Change Research in Agriculture and Food Security for Rural Development".

The objectives of the training material were to: sensitize users to the links between socio-economic and gender issues in the context of climate change in the agriculture and food security sectors; develop the capacity of users to utilize Participatory Action Research (PAR) tools in gathering socio-economic and gender-sensitive information for climate change research and development; help users understand how to analyse field research outputs in a field research setting; apply knowledge gained beyond research to promote gender-sensitive adaptation and mitigation activities in agriculture.

The guide focuses on action research in three areas: (1) the use of climate analogues to assess the possibility of farmer to farmer exchanges; (2) equitable access and use of weather information to minimize risk; and (3) catalyzing CSA.

Drawing on the network of CCAFS research sites, six researchers – two each from Bangladesh, Ghana and Uganda – were trained at FAO, Rome, to test the training materials in their home countries. The testing was followed by a debriefing workshop at which the training materials and research outcomes were discussed. The training material was subsequently revised and disseminated.

Outcomes

The process of field testing and revising the training material was found to be a critical component of developing training documents that are user-friendly and designing research methods that can be carried out under a variety of circumstances. Engaging researchers from different countries enriched the process by involving a variety of perspectives and experiences. In addition, involving researchers in the process of developing the training material was an opportunity to develop their individual capacity to train and disseminate the research methods.

The materials and methods are now being used by CCAFS' scientists to conduct research in CCAFS sites. They will serve to mainstream gender into research and analyses on agriculture and climate change.

The training material is available online at FAO, 2012c
Working papers based on the findings from the field testing are available at FAO, 2012d

Box 17.6 illustrates the role of local innovation in adapting pastoral systems to climate change in Ethiopia and Niger.

Box 17.6
Emerging responses to climate change in pastoral systems in Ethiopia and Niger

Methodology
In 2008, an exploratory study was made into the emerging responses of pastoralists in Ethiopia and Niger in the face of climate change. It examined both technical and institutional innovations developed by pastoralists in families and communities to adapt to new conditions.

Outcomes
The study indicated that pastoralist vulnerability to climate change varies within and between areas and communities. Furthermore, some of their innovations are locally specific and cannot necessarily be scaled up to apply to other areas or communities. However, they do offer starting points for joint action between pastoralists and other stakeholders (e.g. researchers, development agents and government authorities) to deal with changing conditions. Moreover, the study confirmed that pastoralists' increasing vulnerability to climate change can largely be attributed to their marginalisation in decision making about the use of resources.

In Ethiopia and Niger, a wide range of different types of innovation to address food security, sustainable resource management and improved governance within social-political units were identified. Many of these innovations rely on maintaining mobility, an important basis for pastoralist resilience. Local innovations are characterised by flexibility, multi-functionality and a high degree of integration into socio-cultural systems.

It was concluded that local innovation in adaptation to climate change needs to be assessed alongside other environmental, socio-economic and policy measures. Moreover, the focus should not be primarily on specific innovations, but rather on recognising local innovation as a process, and stimulating this process to continue interacting with other stakeholders. Rather than waiting for climate change to happen and then react, proactive ideas for already feasible innovations should be tested, in practice as well as in pastoral policy frameworks. Thus, local adaptation capacities can be strengthened through joint experimentation and other forms of investigative action led by the affected pastoralists themselves.

Source: GebreMichael *et al.*, 2011

Global attention to agriculture as one of the most climate-vulnerable sectors provides an opportunity to accelerate a much-needed reform of extension and advisory services. Extension has long played an intermediary role between farmers and technology suppliers (see Module 12 on institutions). However, the challenge of climate change requires collaboration with more actors and more complex interventions than ever before. This calls for a shift in extension systems (Wageningen University *et al.*, 2010):

- From a focus on introducing new technologies to a focus on institutional change;
- From rural engagement to national-level engagement and from public service delivery to multiple agency advisory provision;
- From practice development to more strategic policy development; and
- From communication for information diffusion to communication for network-based development and innovation and from core service delivery by experts to facilitation.

Effective adaptation involves the use of coherent technical and institutional solutions congruent with contemporary thinking on innovation studies. Today, innovation is no longer associated only with technological advances, but is understood as a successful combination of 'hardware' (i.e. new technical devices and practices), 'software' (i.e. new knowledge and modes of thinking) and 'orgware' (i.e. new social institutions and forms of organization). Climate change adaptation can also be regarded as a process of innovation (Smits, 2002; Leeuwis, 2004).

Improving access to climate and agricultural information using ICTs and ComDev

Bridging the current information and knowledge gap for more inclusive and effective decision-making within CSA is a key challenge. Smallholders are usually based in rural areas far from the traditional providers of agricultural information and advisory services. Successful adaptation to climate change by small producers is not merely a question of developing new adaptation technologies, but depends on ensuring access to them.

ICTs such as radio, television, video, internet, and media and mobile services can play a pivotal role in facilitating the assessment of expected future impacts of climate change on agricultural production systems and landscapes (e-Agriculture). ICTs are powerful tools to improve farmers' access to timely climate and agricultural information. Knowledge and advice facilitate the exchange of experiences among peers and between farmers and various stakeholders while helping to empower local stakeholder groups through increased participation in decision-making processes (Kalas and Finlay, 2009). The information provided through ICTs varies substantially, ranging from technical advice on specific CSA practices or early warning and disaster information on price and market information.

The following two boxes (Box 17.7 and 17.8) illustrate how the use of ICTs can improve access to research information for researchers, development practitioners and extension workers in the context of CSA.

Box 17.7
Advances in ICTs increase the utility of African sites for testing crop varieties

Context

The widespread use of higher-yielding and stress-resistant crop varieties throughout Africa has been frustrated by the variability of African growing conditions and the difficulty of selecting appropriate sites and growing environments to test new cultivars. Innovations may be tested, but they are often not tested in ways that make it more likely that they will be useful to farmers, meaning they are not adopted.

Methodology

To address this situation, the Africa Trial Sites portal enables national and international research organizations to pool their extensive information on trial sites electronically and provides numerous tools (based on ICT advances in bioinformatics, Geographic Information Systems [GIS], and data management) to help farmers, plant breeders, and agronomists evaluate new varieties more efficiently in the field. For some time, much of the data from field trials— representing an enormous investment of research resources over several decades—resided on the shelves of research institutions and was difficult to assemble, analyze on a large scale, and put to use. Now, users can search the portal to access data on trial sites by country, design trials to evaluate cultivars, obtain tools to manage trials (from developing a budget to estimating water stress during the growing season), analyze trial data, view results of spatial analyses, examine data on an interactive Google map, and report results online. They can also rank crop varieties and add comments about their performance at a given site. The website allows the analysis of climate data for any point in Africa as well as climate similarity comparisons between trial sites and other African areas. Finally, the portal includes links to useful resources, such as the websites of participating centres, from whose breeders and gene bank curators anyone can request seed supplies. The combination of African trial site data and interactive data analysis tools has made valuable information widely available to the agricultural research, development and extension community.

Outcomes

As results for cultivars tested in Africa have not been readily available online until now, participants' data is significantly expanding common knowledge of which particular cultivars are suited to which environments (especially those environments subject to stress from disease, pests, or environmental factors, including climate change). International agricultural research centres are beginning to use the portal to standardize their trial site information for a climate research program, drawing in national partners, and they are using Africats.org to standardize their trial site information.

Source: World Bank, 2012

ICTs are also frequently used to support regional, national or sub-regional knowledge networks and enable knowledge exchange between different stakeholders across geographic boundaries. For example, Africa-Adapt is a regional, bilingual knowledge network for climate change adaptation in Africa hosted by the NGO Environment and Development Action in the Third World, the Forum for Agricultural Research in Africa and the Intergovernmental Authority on Development Climate Prediction and Applications Centre, and funded by

Department for International Development and International Development Research Centre. The aim is to facilitate the flow of knowledge on climate change adaptation for sustainable livelihoods between researchers, policy makers, civil society organisations and vulnerable African communities. It uses the latest web-based applications, face-to-face interactions, and other media to share resources and promote learning. Online services are complemented by offline ones, such as an innovation fund offering small grants for new approaches to knowledge sharing; radio-based programming and dialogues in local languages; idea exchange workshops; and a dissemination service for network news and resources.

Box 17.8 illustrates how an information system can help connect farmers, extension services, the private sector, research institutes and NGOs and promote exchange for both for the improved adoption of existing technologies, as well as for signalling demand for new technologies to technology developers and knowledge providers.

Box 17.8
TECA exchange Groups: technologies and practical advice for smallholders

Context
Technologies and practices for small agricultural producers (TECA) (available at http://teca.fao.org/) offers a well-managed IT-based information system for documenting and sharing applied technologies and practices of agriculture for small-scale farmers. FAO technical divisions, FAO partners and FAO projects document technologies and practices successfully applied by small producers, and then share them through TECA. Users can provide comments on featured technologies online. The global TECA platform can be used for information sharing in English, French and Spanish. It allows easy searches, even for rural users with low bandwidth. TECA modules can be provided for decentralized use and local adaptation as well (in local languages, for example).

Methodology
The most recent, interactive version of TECA which hosts discussion groups has been running since 2009. There are currently two discussion groups, one with a regional focus (on Uganda) and one with a subject focus (beekeeping). An active group facilitator, one fully dedicated to the group, has been central to the success of both exchange groups. The role of the facilitator has been to increase awareness of the platform among potential users, bring individuals together and identify their common interests, initiate discussions, engage members to contribute, identify external experts or knowledge when needed, and provide technical assistance relating to the use of the platform. Another factor worth noting is that agricultural students are a very important and active group of participants; introducing them to experience-sharing with various rural actors via the internet platform is a great asset for their future work in agriculture.

Outcome
Lessons from the piloting of TECA's Uganda Exchange Group include:

<u>Promoting the adoption of improved seed varieties through TECA's Uganda Exchange Group</u>
In the Uganda Exchange Group, practitioners, experts, university students, local NGO staff, extension workers and other interested users engage in discussions about pressing issues, such as counterfeited agricultural inputs, difficulties with market access or diseases such as the cassava brown streak disease, but also exchange experiences of indigenous practices with smallholders in Uganda (FAO, 2010c). This way, relevant information and advice reaches those working in the field and ultimately small producers, enabling them to adapt better to the challenges they face.
For example, the use of quick-maturing and high-yielding seed varieties can help farmers adapt to changing weather patterns, shorter and more unpredictable rainfall. While locally adapted varieties were developed by research institutes, their multiplication and dissemination among farmers remains insufficient. This has been a re-occurring topic in the Uganda Exchange Group. In Uganda, new seed varieties developed by the National Agricultural Research Organization, one of TECA's partners, are expected to be multiplied and disseminated through seed companies, i.e. the formal seed market. However, Ugandan agronomists estimate that 95 percent of seeds are supplied through informal channels. A detailed analysis of the situation unfolded in a discussion in TECA's Uganda Exchange Group. Experiences of establishing self-sustaining informal seed systems for soybeans in six pilot districts were also shared. From this engaging exchange the vision for a novel approach emerged, combining formal and informal seed channels.

<u>Knowledge exchange through TECA requires commitment</u>
This is only one example for how sharing information and good practices can promote knowledge-based intervention and policy to improve the livelihoods of smallholders. However, the example also alerts us to the challenges TECA faces. Following and engaging in discussions as a user of TECA or uploading technologies and practices as a partner of TECA requires time and skilled human resources. This commitment to TECA crucially hinges on the understanding that knowledge exchange and joint learning is a prerequisite for the successful application and scaling up of existing technologies and practices as well as the development of new technologies for small producers.

A ComDev approach can also improve the effectiveness of local or national climate change and food security initiatives. It does so by facilitating knowledge exchange and learning among different stakeholders, improving participation and coordination, matching supply and demand for adaptation support services and contributing to mediation in conflict situations (see Box 17.9).

Box 17.9
Communication for Development Strategies and Tools in Community Based Climate Change Adaptation

Context

In 2008, FAO and the Italian Ministry for the Environment and Territory jointly launched the Communication for Sustainable Development Initiative (CSDI), an inter-regional project aimed at promoting ComDev as a means of improving adaptation to climate change, sustainable natural resource management, and food security. CSDI has developed ComDev strategies and services in Bangladesh, Bolivia, the Congo, Jamaica and the Caribbean region, focusing on strengthening rural knowledge and enhancing local institutions' capacities in this field. With the aim to strengthen and scale up related communication services, CSDI has supported the implementation of communication platforms, virtual consultations and publications to enhance dialogue and knowledge exchanges at the regional and global levels. For example, in collaboration with the Bolivian Ministry of Rural Development and Land, CSDI developed a National ComDev Plan. This supports the National Institute for Innovation in Agriculture, Livestock and Forestry (INIAF) in designing and implementing communication strategies and services for agricultural innovation and rural development.

Methodology

Three pilot areas were identified in Bolivia, based on INIAF´s priorities: Yapacaní and the Norte Integrado Region, Yacuiba and Chiquitanía. Participatory processes at the local level were based on three main components:

1. A participatory communication appraisal: this assessment identified local problems and needs, solutions and practices (opportunities) related to production, social and communication issues
2. A local innovation and communication program: strategic guidelines were developed with relevant local partners in response to the findings of the appraisal, with a medium-term projection (3-5 years).
3. Local innovation and communication plans (the Spanish acronym is PLICs): these plans supported the management and implementation of priority communication activities at the field level.

The PLICs were developed within the framework of Espacios Locales de Concertación (local areas of agreement) promoted by the INIAF as venues for dialogue and informed decision-making with the participation of farmers' organisations, small-scale producers, local governments, NGOs and media. The PLICs are operational tools that involve different communication resources and include participatory methodologies which support two-way learning processes, such as Audiovisual Pedagogy or training activities aimed at developing technical and communication capacities at the local level. A set of systematized iKnowledge and Communication Modules including videos, printed materials and audio tracks were developed based on the principles of the Audiovisual Pedagogy methodology:

- Recovery of farmers' traditional knowledge and combination with scientific knowledge;
- Direct reference to the producers' reality (using their own language);
- Practical learning designed for smallholders and rural families;
- Active participation of producers in the collective learning process;
- No interference in productive activities (trainings are carried out where producers live);
- Use of audiovisual tools to overcome literacy barriers in the transmission of knowledge; and
- Choice of technical information appropriate to the different groups.

Outcomes

At the local level, seven intensive training-of-trainers courses on the Audiovisual Pedagogy methodology and the application of Knowledge and Communication Modules were offered to technicians, communication practitioners, extensionists and community agents. A total of 162 people were trained as local innovation operators to act in turn as facilitators and use the modules to train small-scale producers in their local communities. This process involved 52 institutions in the Bolivian innovation system. At the community level, 26 training activities were implemented using the modules. The training activities conducted by the local facilitators have reached overall 489 producers from 54 rural communities.

The full report is available at FAO and CSDI, 2010a and 2010b

17.4 Conclusions

The transition towards CSA practice is a knowledge-intensive learning process involving multiple stakeholders. Realizing CSA practice thus requires a holistic and comprehensive CD approach of all stakeholders involved, based on good practices such as alignment with and driven by national priorities; incorporating the individual, organizational and enabling environment dimensions of CD; and complementing technical with functional competency to strengthen and apply good learning practices.

Due to the uncertain and dynamic nature of climate change impacts, the module illustrated that this transition towards CSA requires socio-institutional learning processes with a strategic approach to skills development at country level including strong engagement of national and local formal and informal education and training institutions.

This module further illustrated why and how the transition to CSA requires new forms of collaboration and partnerships. Strengthening agricultural innovation systems with public and private research, extension and advisory services plays a key role in generating, documenting, blending and sharing indigenous and scientific knowledge as well as facilitating learning processes and network-based development and innovation. The module further provided concrete examples for improving policy coherence and effectiveness through fostering inclusive spaces that promote multi-stakeholder dialogue and enable knowledge sharing and effective learning among a diverse group of stakeholders. The module highlighted that the need to access timely information and knowledge on climate agriculture will increase, and this need can be addressed through leveraging ICTs, participatory ComDev approaches and knowledge sharing methods directly applicable to CSA.

One area that needs more attention due to the uncertain and dynamic nature of climate change impacts and the complexity of agricultural production systems is the field of monitoring and evaluation (see Module 18 on M&E). Here various frameworks have been piloted in the context of CSA, but more studies are needed to ensure their applicability for robust decision-making and a sound M&E of complex, socio-institutional learning processes and the question of how to assess capacities and political commitment at country level.

Notes

This module was written by Claudia Hiepe (FAO) and Patrick Kalas (FAO) with contributions by Federica Matteoli (FAO), Katrin Nichterlein (FAO), Sibyl Nelson (FAO) and Janie Rioux (FAO). Box 17.1 was written by Janie Rioux (FAO). Box 17.5 was written by Sibyl Nelson (FAO). Box 17.8 was written by Karin Nichterlein and the TECA team (FAO). Box 17.9 was written by the CSDI team at FAO including Mario Acunzo, Federica Matteoli, Marzia Pafumi and Vanessa Vertiz.

Acronyms

CARE	Cooperative for Assistance and Relief Everywhere
CCAFS	Climate Change, Agriculture and Food Security (research programme)
CD	capacity development
ComDev	communication for development
CSA	climate-smart agriculture
CSDI	Communication for Sustainable Development Initiative
EADD	East Africa Dairy Development Project
FFS	farmer field schools
GIS	Geographic Information System
ICPAC	Climate Prediction and Applications Centre
ICRAF	World Agroforestry Centre
ICT	information and communication technology
INIAF	National Institute for Innovation in Agriculture, Livestock and Forestry
MCC	knowledge and communication module
M&E	monitoring and evaluation
MICCA	Mitigation of Climate Change in Agriculture
NAMA	National Appropriate Mitigation Actions
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action
NGO	non-governmental organization
PAR	Participatory Action Research
PGA	participatory governance assessment
PLIC	local innovation and communication plan
REDD	reduced emissions from deforestation and forest degradation
SLM	sustainable land management
TECA	technologies and practices for small agricultural producers (FAO led platform)
UNFCCC	United Nations Framework Convention on Climate Change
UNW-DPC	United Nations Water Decade Programme on Capacity Development

References

FAO. 2010a. *Corporate strategy on capacity development.* (available at http://www.fao.org/fileadmin/user_upload/newsroom/docs/Summary_Strategy_PR_E.pdf)

FAO. 2010b. *Capacity development guiding report for the MICCA programme in Kenya: capacity needs assessment.* Background Report No. 1. (available at http://www.fao.org/climatechange/31605-076f40e684fe6ef434d-086f29c000dbd9.pdf)

FAO. 2010c. *Uganda exchange group.* TECA. (available at http://teca.fao.org/group/uganda-exchange-group)

FAO. 2011a. *E-learning methodologies: a guide for designing and developing e-learning courses.* (available at http://www.fao.org/docrep/015/i2516e/i2516e.pdf)

FAO. 2011b. *Capacity development guiding report for the MICCA programme in the United Republic of Tanzania: capacity needs assessment.* Background Report No. 2.

FAO. 2012a. *Learning module 2: FAO approaches to capacity development in programming: processes and tools.* (available at http://www.fao.org/docs/eims/upload/299903/LM2_booklet_en_webready_FINAL.pdf)

FAO. 2012b. *Report of the FAO expert consultation on agricultural innovation systems and family farming.* Rome. (available at http://www.fao.org/docrep/015/an761e/an761e00.pdf)

FAO. 2012c. *Gender and climate change research in agriculture and food security for rural development – training guide.* MICCA. (available at http://www.fao.org/climatechange/micca/75949/en/)

FAO. 2012d. *Gender, climate change, agriculture, & food security.* (available at http://ccafs.cgiar.org/our-work/research-themes/integration-decision-making/linking-knowledge-action/gender-climate-change)

FAO. 2013a (forthcoming). *Acting on food insecurity and malnutrition: the food security commitment and capacity profile.* Methodology paper.

FAO &CSDI. 2010a. *Collaborative change: a communication framework for climate change adaptation and food security.*

FAO & CSDI. 2010b. *Advancing adaptation through communication for development.* Proceedings of the technical session on Communication. Third International Workshop on Community-Based Adaptation to Climate Change, February 2009, Dhaka, Bangladesh. (available at http://www.fao.org/docrep/012/i1553e/i1553e00.pdf)

FAO & Republic of the Philippines. 2011. *MDG-F 1656 project: strengthening the institutional capacities to address climate change in the Philippines.*

GebreMichael, Y., Bayer, W. & Waters-Bayer, A. 2011. Emerging responses to climate change in pastoral systems in Ethiopia & Niger. (available at http://www.agridea-international.ch/fileadmin/10_International/PDF/RDN/RDN_2010/RDN%20_2010_2.pdf)

Kalas, P. & Finlay, A. 2009. *Planting the knowledge seed: adapting to climate change using information and communication technoligies (ICTs).* BCO Alliance Report. (available at www.bcoalliance.org/Climate-Change)

Leeuwis, C. 2004. *Communication for rural innovation: rethinking agricultural extension, with contributions from A.* Van den Ban. Oxford, UK, Blackwell Science.

OECD. 2006. *The challenge of capacity development: working towards good practice.* (available at http://www.fao.org/fileadmin/templates/capacitybuilding/pdf/DAC_paper_final.pdf)

OECD. 2008. *Paris declaration on aid effectiveness and Accra agenda for action.* (available at http://www.oecd.org/dac/effectiveness/parisdeclarationandaccraagendaforaction.htm#Accra)

Smits, R. 2002. *Innovation studies in the 21st century: questions from a user's perspective.* Technological Forecasting and Social Change, 69: 861—883.

UN CC: Learn. 2012. *Developing a national strategy to strengthen human resources and skills to advance green, low emission and climate resilient development: a guidance note to support phase 1 of UN CC:Learn pilot projects.*

UNESCO-IHE & UN-Water Decade Programme on Capacity Development (UNW-DPC). 2009. *Capacity development for improved water management.* (available at http://www.crcpress.com/product/isbn/9780415573986)

UNW-DPC. 2011. *Capacity development for farm management strategies to improve crop-water productivity using aquacrop: lessons learned.* Knowledge Publication Series No.7. (available at www.unwater.unu.edu/file/get/222)

UN-REDD. 2012a. *Participatory governance assessments.* (available at http://www.un-redd.org/NewsCentre/Support_to_Effective_Governance/tabid/5543/Default.aspx)

UN-REDD. 2012b. *Moving ahead with Indonesia's REDD + participatory governance assessment.* (available at http://www.un-redd.org/Newsletter26/Indonesia_REDD_PGA/tabid/79443/Default.aspx)

Wageningen University & UNU-MERIT & FAO. 2010. *Facing the challenges of climate change and food security: the role of research, extension and communication institutions, by C.* Leeuwis and A. Hall. Report assignment commissioned by FAO Research and Extension Branch. Rome.

World Bank. 2012. *ICTs as enablers of agricultural innovation systems.* Module 6. ICT Sourcebook. (available at http://www.ictinagriculture.org/ictinag/sourcebook/module-6-icts-enablers-agricultural-innovation-systems)

Additional Resources

AFAAS (African Forum for Agricultural Advisory Services), University of Greenwich & Forum for Agricultural Research in Africa (FARA). 2011. *Emerging approaches for responding to climate change in African agricultural advisory services: challenges, opportunities and recommendations for an AFAAS climate change response strategy.* (available at http://www.fara-africa.org/media/uploads/library/docs/fara_publications/afaas_climate_change_ver09.pdf)

Africa Adapt. 2011. *(available at http://www.africa-adapt.net/)*

e-Agriculture: *References and resources on the use of information and communication technology (ICT) in the agricultural and rural development sectors, developed by the community of practice with support from FAO and other organizations.* (available *at http://www.e-agriculture.org/)*

FAO. 2011c. *Climate change for forest policy-makers - an approach for integrating climate change in forest programmes in support of sustainable forest management.* (available at http://www.fao.org/forestry/climatechange/64862/en/)

FAO. 2011d. *Learning module 1: enhancing FAO´s practices for supporting capacity development of member countries.* (available at http://www.fao.org/docs/eims/upload/298016/LM1_hi_res_IDWGsite.pdf)

FAO. 2011e. *Climate change for forest policy-makers: an approach for integrating climate change in forest programmes in support of sustainable forest management.* Excerpt (see separate document).

FAO. 2011f. *Climate change and food security.* Interactive Learning Course. (available at http://www.foodsec.org/DL/elcpages/food-security-courses.asp?pgLanguage=en&leftItemSelected=food-security-courses)

FAO. 2012e. *MICCA report on capacity assessment (available at http://www.fao.org/climatechange/30495-09a7077298edf4c3e9afa64237ade4f90.pdf)*

FAO. 2012f. *Learning module 3: FAO good learning practices for effective CD.* (available at http://www.fao.org/docs/eims/upload/301361/LM3_Final_en_webready_and_for_CD_9_5_12.pdf)

FAO. 2013b (forthcoming). FAO capacity development learning module: organizational analysis and development.

FAO Capacity Development Portal. (available *at http://www.fao.org/capacitydevelopment/)*

FAO Climate Change Capacity development Portal (available at *http://www.fao.org/climatechange/learning/*)

FAO Communication for Development Programme. (available *at http://www.fao.org/oek/communication-for-development/en/)*

FAO & CSDI. 2011. *The role of information and communication technologies for community-based adaptation to climate change.*

FAO & IFAD. 2012. *Innovative rural institutions good practices in building to increase food security.*

Kalas, P and Spurk, C. 2011. *Deepening participation and improving aid effectiveness through media and information and communication technologies (ICTs).* SDC Working Paper. http://siteresources.worldbank.org/EXTGOVACC/Resources/MediaandICTs.pdf

Pieron, M. 2012. *Bonding and bridging in capacity development networks to address wicked water challenges.* Delft University of Technology in cooperation with KWR Watercylce research Institute. (MA thesis)

PROLINNOVA. 2011. *Strengthening local resilience to climate change.* Policy brief. (available at http://www.prolinnova.net/sites/default/files/documents/thematic_pages/climate_change_pid/2011/prolinnova_policy_brief_climate_change_june_2011_lowres.pdf)

Stockholm Resilience Centre. 2012. *Knowledge systems and learning.* Insight Policy Brief. No. 6. (available at www.stockholmresilience.org/download/18.1fc8315a135cb03b559318/Insights-knowledge.pdf)

UNW & DPC. 2010. *Curriculum development for water and climate change.* Knowledge Publication Series No.5. (available at www.unwater.unu.edu/file/get/44)

United Nations Development Programme. 2013. *Capacity Development Programme.* (available at http://www.undp.org/content/undp/en/home/ourwork/capacitybuilding/overview/)

MODULE 18:

ASSESSMENT, MONITORING AND EVALUATION

Overview

This module looks at assessment, monitoring and evaluation frameworks that are necessary for the successful adoption of climate-smart agriculture (CSA). Focus is placed mainly at the subnational and national levels. However, some case studies address activities at the farm or project level. The module presents an overview of important climate change-related assessment, monitoring and evaluation activities in policy and programme processes and project cycles. The purposes of these activities, baselines, and associated concepts are also described. Details are provided about how to conduct assessments relating to policies and project justification and design, as well as monitoring and evaluation. In the last section, the specific challenges to assessment, monitoring and evaluation in the context of CSA are reviewed and some guiding principles for addressing them are offered.

Key messages

- Assessment, monitoring and evaluation are integral parts of CSA planning and implementation.
- Assessment, monitoring and evaluation are crucial for learning and for conducting policy reviews.
- The past and future impacts of climate change on agriculture and the vulnerability of livelihoods need to be assessed. CSA options should be assessed for their effectiveness in achieving goals related to climate change adaptation and mitigation, food security and development.
- Monitoring and evaluation activities set baselines, define indicators, measure progress and evaluate successes and setbacks in CSA interventions.
- Assessment, monitoring and evaluation need to be designed and conducted for CSA objectives. There are many general methodologies and existing data and tools to build upon.
- Assessment, monitoring and evaluation present several distinctive challenges in the context of CSA. There also is a set of emerging core principles that are important to consider.

Contents

List of Figures

List of Tables

List of Boxes

List of Case Studies

18.1 Introduction

This module provides an overview of methodologies, frameworks, and principles for assessment, monitoring and evaluation for CSA. The frameworks are intended to support:

- assessments of the impact of a changing climate on agriculture, food security, and livelihoods;
- assessments of the effectiveness of CSA interventions in enhancing adaptation, mitigation and food security; and
- monitoring and evaluation in results-based planning processes for CSA.

These frameworks are intended to serve the needs of a variety of stakeholders, including vulnerable and food insecure communities, farmers, farmers' organizations, district, regional and national offices of the Ministry of Agriculture (and other Ministries) and extension and rural service providers. The frameworks can also be used when designing and implementing national and subnational policies and programmes for agriculture, climate change and development.

This module provides guidance for translating the theories and practices of CSA into assessment, monitoring and evaluation activities. As the topics covered in CSA are very diverse and CSA practices are specific to location and context, it is not possible to prescribe one general approach for assessment, monitoring and evaluation. The ideas and methods outlined in this module represent a starting point for designing a more specific approach that is adequately focused, targets the needs and context of the proposed activity and takes into account the guiding principles. This module does not address in detail institutional aspects, policies and capacity development related to assessment, monitoring and evaluation (e.g. stakeholder analysis, institutional analysis). These important issues are addressed in Modules 12, 13, and 17. Although they do not explicitly address planning processes, assessments and monitoring and evaluation are intimately linked to planning. Planning at the landscape scale is dealt with in more detail in Module 2.

The term 'impact' is used in two different ways in this module:

- actual impact (i.e. historical, current) and potential impact (i.e. projected future) of climate change and climate variability on agriculture, livelihoods and food security; and
- impact of CSA interventions, which are designed to address the issues of climate change and climate variability (e.g. the reduction of greenhouse gas [GHG] emissions from agriculture), strengthen the agriculture sector and rural livelihoods, and contribute to food security.

The word 'assessment' is often used together with 'impact' (e.g. impact assessment, assessment of impact). In this module, the word indicates an assessment of impacts of climate on agriculture, livelihood and food security. The words 'evaluation' and 'indicator' are used in the context of project and programme implementation (e.g. evaluation of the impact of CSA measures, indicators for monitoring and evaluation). Throughout the module it is clearly indicated in which context these technical terms are used.

18.2 Defining assessment, monitoring and evaluation for CSA: scope, purposes, frameworks and concepts

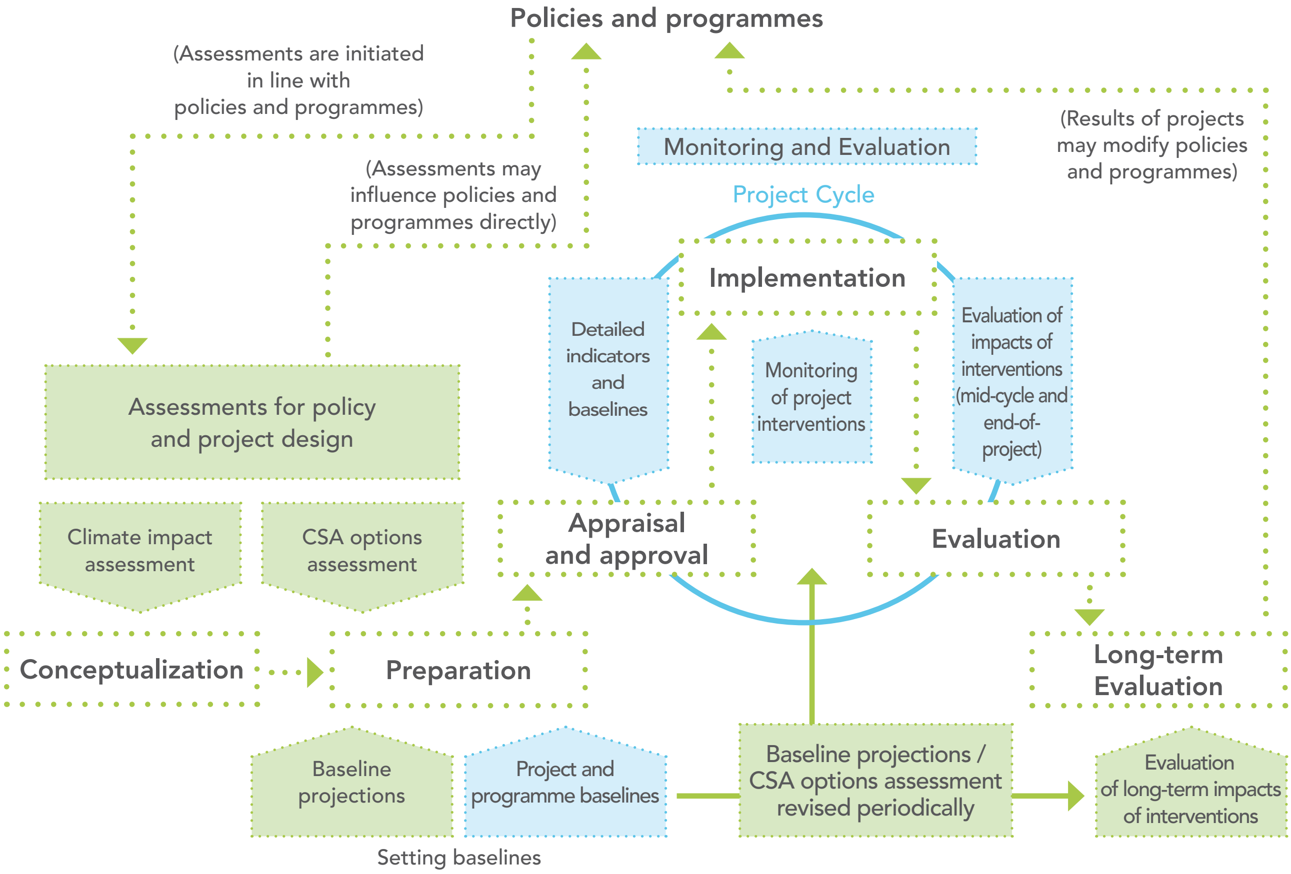
Assessments are closely related with monitoring and evaluation activities. Both are integral parts of CSA project cycles and are key to providing inputs and guidance to broader policies and programmes. Figure 18.1 shows where assessment, monitoring and evaluation activities occur through the policy and programme cycle in relation to the five steps of the planning process: conceptualization, preparation, appraisal and approval, implementation, and evaluation. The latter three steps form a project cycle in a narrow sense. The cycle is embedded in policies and programmes through assessment, monitoring and evaluation activities.

Assessments for policy and project design usually take place *ex-ante*. They are aligned with existing policies and programmes and fulfil a variety of functions, including: situation analyses; clarification of central problems and threats in terms of climate impacts and vulnerability; and the identification of effective CSA measures. Assessments are conducted mainly in the conceptualization and preparation steps of planning (climate impact assessment, CSA options assessment, and baseline projections in Figure 18.1). Based on the assessments, the CSA options to be implemented are identified. In parallel with the broader programme and policy cycle, baseline projections should be revised periodically and the long-term impacts of project interventions should be evaluated after the project ends. Assessments can also directly influence policies and programmes without going through a CSA project cycle. This can be done by using assessment reports in policy discussions, debates and advocacy.

New CSA projects are positioned within the country's development, agriculture and climate change policies and related programmes. Assessment, monitoring and evaluation start at the preparation stage (project and programme baselines in Figure 18.1), which are followed by project appraisal and approval (detailed indicators and baselines in Figure 18.1). Monitoring of project interventions takes place throughout implementation (in Figure 18.1). At the mid-project cycle and at the end of the project the evaluation of impacts of interventions becomes more important and there is more emphasis on evidence-based measurement of actual impacts of implemented activities. Evaluation of interventions' impacts at the end of a project will feed into long-term evaluation. Feedback from evaluation of projects may modify policies and programmes.

Continued evaluation beyond the lifetime of a project is recommended to measure the sustainability of the results and the long-term benefits or tradeoffs that are the expected from CSA projects. During project feedback and at the end of a project, lessons learned from evaluating the impacts of the project should be used to inform policy makers. This feedback may form the basis for a follow-up CSA project and new or suitably modified policies and programmes.

Figure 18.1
The scope of assessment, monitoring and evaluation for CSA within a project cycle and broader policies and programmes



Assessments for policy and project design (green background) and monitoring and evaluation (blue background) are color coded respectively.

The overall goal of the outlined assessments and monitoring and evaluation activities is to effectively guide the transition to CSA. Climate change is likely to hit hardest those who already are the most vulnerable and food insecure. Consequently assessments, monitoring and evaluation must pay particular attention to these vulnerable groups.

Different types of assessment, monitoring and evaluation are summarized in Table 18.1.

Table 18.1
Typology of assessment, monitoring and evaluation for CSA

1. Assessments (for policy and project design)	2. Monitoring and evaluation
1.1 Climate impact assessment (assessments of key changes in climate, climate change impact on agriculture, and vulnerability of livelihoods for strategic planning) *At conceptualization stage*	**Monitoring and evaluation** (to measure progress and identify successes and problems of CSA interventions) *Through the project cycle (implementation and evaluation stages)*
1.2 CSA options assessment (assessments of CSA options' effectiveness to achieve adaptation, mitigation, food security and development to identify best options) *At preparation stage*	

The terms in the table are used throughout the module. Assessments for policy and project design may be referred to as simply assessments where no confusion is expected. In the rest of Section 18.2 conceptual frameworks for assessments, monitoring and evaluation are explained in detail.

Assessments for CSA policy and project design

There are a number of potential practices that would improve productivity of local agricultural systems, enhance food security and support livelihoods. Implementing CSA is a very context- and location-specific process, and there are no good practices that are applicable to all situations. A careful strategic assessment needs to be made within a policy and programme to evaluate the benefits and tradeoffs in various social, economic and environmental conditions. Assessments can determine how local climate conditions and their impact on agriculture, food security, and livelihoods have been changing and are projected to change in the future. They can also determine whether certain measures are climate-smart or not in a particular context. Good CSA interventions may differ from those undertaken in more traditional agricultural development and natural resources management.

Without proper assessments it is difficult to explain why a transition to CSA is necessary and which CSA activities can achieve desired targets (e.g. increased incomes despite high vulnerability to an increasing number of droughts). Knowing which crops or livelihood activities may be more sensitive to changing climate, for example, will help practitioners choose more resilient crops and adopt more diversified livelihoods. Informing stakeholders of the changing amounts of rainfall and the spatial distribution of precipitation will help them to better allocate resources for the management of water resources.

Assessments for policy and project design identify the impact of climate change and climate variability on the agricultural sector, food security and livelihoods. Climate impact assessments characterize the effects of climate change and identify the most vulnerable locations and contexts that require adaptation actions. Climate impact assessments are typically conducted at the project's conceptualization stage, but they are also used to inform policy directly (Figure 18.1), a type of strategic planning. The main elements of climate impact assessment are: an assessment of changes in climate (historical, current, and projected future); an assessment of impacts of climate on agriculture; and an assessment of the vulnerability of livelihoods, including food security, to climate change. The relationship between climate and agriculture now and in the past can be combined with future climate projections to infer associated potential impacts on agriculture. Vulnerability is then characterized accordingly (this will be elaborated below). Baseline projections are established based on the results of climate impact assessments.

In addition, it is necessary to assess which changes in agricultural and commercial practices and in the institutional and policy environment are effective and efficient measures to achieve the CSA objectives of adaptation, mitigation, food security and development (CSA options assessment). CSA options assessments are typically conducted at the programme or project's preparation stage (Figure 18.1) and aid planners in setting project and programme baselines. CSA options for implementation are identified based on the assessments (elaborated further below).

Effective adaptation options can be explored based on historical, current and projected climatic impacts on agriculture and the vulnerability of livelihoods and food security. It is also possible to simulate the adaptation activity that is more suitable for adapting to a changing climate. Mitigating climate change can be achieved in two main ways: reducing emissions of GHGs and sequestering carbon in the biomass and the soil. Assessing the mitigation potential of project interventions is important for ensuring that there are no tradeoffs with adaptation actions. On a national scale, it is also important to monitor and assess the impact of carbon sequestration for addressing international agreements on climate change mitigation. CSA activities should also meet broader food security and development goals (see also Module 1 on rationale of CSA).

After assessing CSA options against all three CSA objectives, the best interventions would be those that promote synergies between adaptation and mitigation without compromising food security and development goals. Stakeholders are invited to review the findings of the assessment. Ideally, options that address as many CSA objectives as possible should be prioritized.

Assessments for policy and project design are initiated before the interventions are undertaken, and some of them continue throughout the project cycle. They can be climatic, biophysical and socio-economic.

Climate impact assessment

Climate impact assessments specify the changes in climate in a historic, current or future context, and establish evidence-based relationships between climate and productivity in the agriculture, forestry and fishery sectors. Climate impact assessments indicate the vulnerability of different stakeholders to a changing climate and the potential impacts of climate change on agriculture. Stakeholders targeted by vulnerability assessments include male and female smallholder farmers, landless labourers, commercial farmers and people working in the value chain. Table 18.2 gives examples of outputs from climate impact assessments.

Table 18.2
Examples of outputs from climate impact assessments of changing climate, climate impacts on agriculture and vulnerability

- Rainfall pattern, amount and area;
- Seasonality of climate (e.g. timing of monsoon, rainy and dry seasons);
- Water availability for rainfed and irrigated agriculture;
- Temperature (e.g. daytime maximum, night time minimum);
- Evapotranspiration;
- Frequency and intensity of extreme temperature events (cold spells, heat waves);
- Frequency, intensity, and duration of droughts and floods;
- Soil erosion and soil nutrient cycle;
- Snow cover;
- Pests and diseases impacted by climate;
- Changes in crop yields due to changes in climate (e.g. higher temperatures and reduced rainfall);
- Changes in market price of major commodities due to climatic factors, including climate-related disasters, such as droughts, floods and storms;

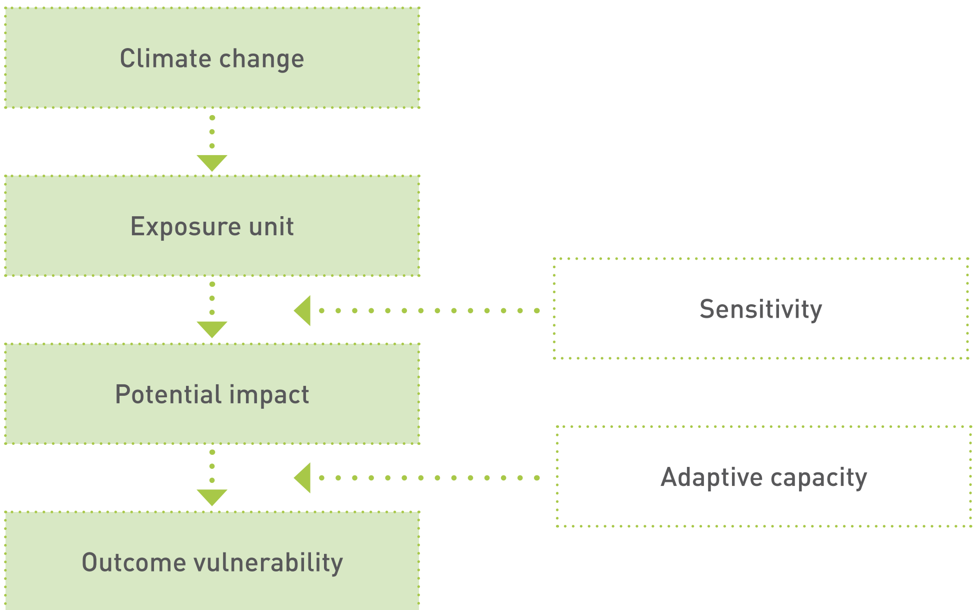
- Changes in farm household income as a result of climate variability and change;
- Number of households in areas at risk of rising sea levels and sea water intrusion;
- Accessibility to local markets due to climatic factors;
- Volatility of commodity market price due to climate variability; and
- Characterization of households or groups particularly vulnerable to climate change (e.g. income sources, crops grown, education level, male- or female-headed households, access to information, access to financial resources).

*Note: The climate impacts on agriculture are based on historical, present, and future projections under climate change

At this point it is useful to define some key concepts in climate impact assessments. 'Impact' refers to the effects of climate change on natural and anthropogenic systems. In the case of CSA, the impact will be felt in a variety of areas, including: landscapes, ecosystems, watersheds, infrastructure, farms, agricultural production and markets. The assessment of impacts considers exposure to climate effects and sensitivity to such exposure. It is done in monetary and/or non-monetary terms.

'Vulnerability' is frequently defined as a function of potential impacts (exposure and sensitivity to exposure) and adaptive capacity (Carter *et al.*, 2007; see also Module 1). Exposure is the extent to which the system is physically harmed by climate change. Sensitivity is how affected a system is after the exposure. Adaptive capacity is the system's ability to avoid potential damages, take advantage of opportunities, and cope with the consequences of damages. Assessments of impact and vulnerability (sometimes termed as outcome vulnerability) defined in this way usually adopt a top-down approach (Figure 18.2). See also Module 15 as the terms also often appear in disaster risk reduction.

Figure 18.2
Outcome vulnerability

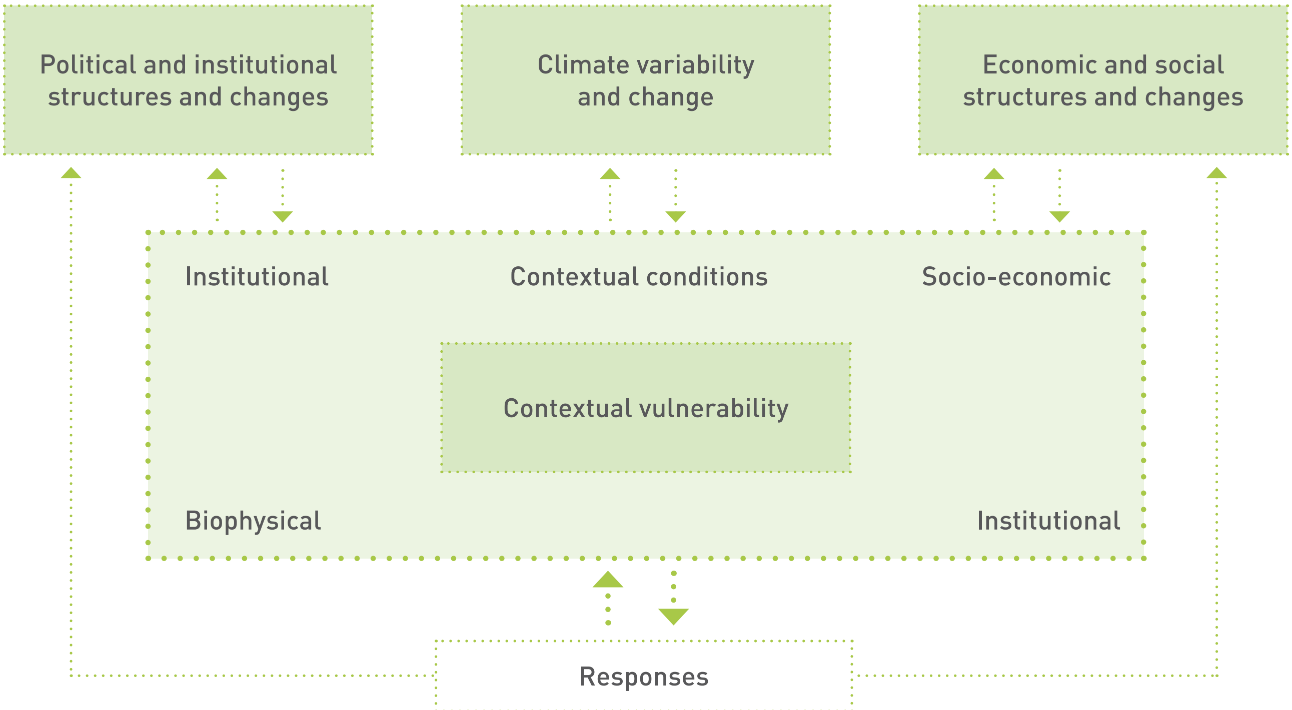


Source: adapted from O'Brien *et al.*, 2007

The top-down approach starts from global climate information and moves down the spatial scale to regional, national and subnational levels for local projections and impact analyses. Local impacts of climate change on sectors affected by CSA and vulnerability of these sectors to these impacts are derived using a sequence of different methods and tools across various levels. Uncertainties in the analyses may be inflated as they are propagated through this sequence.

The bottom-up approach, on the other hand, takes the present as the point of departure and focuses on socio-economic dimensions of vulnerability as a basis for considering future vulnerability. The emphasis is on community-based participatory assessment, rather than on the numerical models often used in top-down approaches. The vulnerability and adaptation needs of communities are put into context with reference to local non-climatic factors. Vulnerability is considered to be influenced by changing biophysical, social, economic, political, institutional and technological structures and processes. In the contextual approach, the vulnerability of social-ecological systems is determined by multiple factors and processes. The concept of contextual vulnerability provides a more holistic view in which the climate projections are only one part of the assessment of threats to social and environmental resources (Figure 18.3). The associated uncertainties will be more complex.

Figure 18.3
Contextual vulnerability



Source: adapted from O'Brien *et al.*, 2007

'Resilience' is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner (IPCC, 2012). Adaptive capacity in the resilience framework is the capacity of people in a given system to influence resilience. A system may be made more resilient in a number of ways, including: managing human and environmental components of a system in a manner that maintains the system's *status quo* (e.g. managing water resources to better cope with drought); or transforming into a new system when the current system becomes untenable (e.g. eliminating irrigation and agricultural production if drought risk is too extreme) (Engle, 2011; Walker *et al.*, 2004; Walker *et al.*, 2006; Folke, 2006; resilience is also discussed in Module 1).

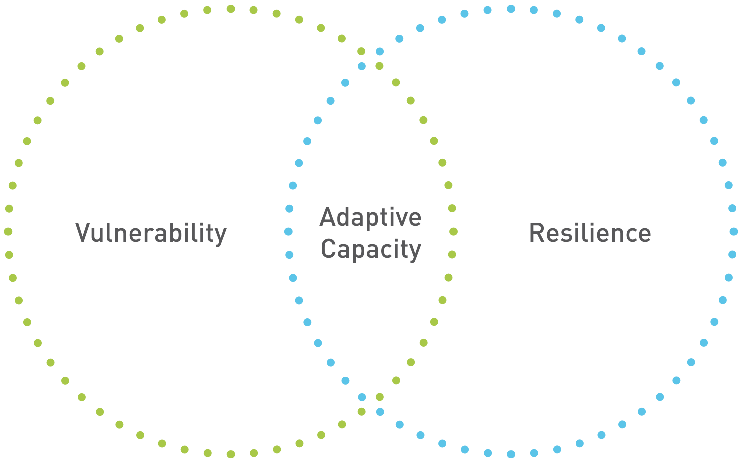
Traditionally, vulnerability and resilience frameworks are different in some key aspects (adapted from Engle, 2011). The vulnerability approach tends to:

- be oriented towards research on hazards and risks;
- be centred on people and more translatable to application and policy outcomes;
- conduct assessments for single spatial scale and 'snapshots' in time;
- be less focused on ecological and environmental aspects; and,

- assess present and future vulnerability from past information.
- The resilience approach, on the other hand, tends to:
- be oriented towards ecological sciences;
- be more focused on complex interactions, feedbacks and processes of social-ecological systems;
- be conceptual and not easily translatable into practice;
- assess one particular system and not be often generalized for wider application;
- produce more dynamic assessments (but present methodological difficulties in measuring and characterizing);
- be less focused on the social aspects of social-ecological systems; and
- assess more positively future needs by building on present assets.

These concepts have evolved over recent years and recently, the resilience framework has started to put more emphasis on the social systems (i.e. livelihood resilience) and the vulnerability framework has started to include more environmental factors. Despite their differences, the two frameworks can be connected through the concept of adaptive capacity (Figure 18.4). Adaptive capacity assessments from both a vulnerability and resilience perspective are recommended. An important common element will always be the specific identification of target groups and areas in relation to livelihoods and food security systems.

Figure18.4
Vulnerability and resilience frameworks linked through the concept of adaptive capacity



Source: adapted from Engle, 2011

Climate impact assessments provide an important interface among science, policy and the public. Better communication should be encouraged among these three different distinct communities: the climate science community, the impact assessment community and the CSA community. An effective climate impact assessment must incorporate a wide variety of stakeholders to validate the process, interpret the results and translate them into adaptation and mitigation options that support CSA outcomes.

CSA options assessment

Following climate impact assessments, CSA options assessments examine the extent to which different CSA measures may achieve the objectives of increasing productivity, enhancing climate change adaptation and mitigation, and improving food security, given the expected impacts of climate change. This helps practitioners identify effective CSA options and creates synergies for reaching multiple objectives. CSA projects can be formulated to implement the identified measures. CSA strategies should ideally be reviewed and updated periodically as new information becomes available and the baseline evolves. Complementing the information given by Table 18.2, Table 18.3 presents examples of assessed benefits of CSA practices in fostering productivity, climate change adaptation and mitigation and food security.

Table 18.3
Examples of assessed benefits of CSA practices in contributing to climate change adaptation and mitigation, and food security

- Reduced soil erosion and improved nitrogen efficiency from minimum tillage, cover crops and improved rotations;
- Improved water availability from soil and water conservation activities;
- Improved crop yield with new varieties, a change in farm management (e.g. planting date change, fertilizer, irrigation water use) or short-term weather and climate forecasts;
- Improved livestock productivity through enhanced breeding and feeding practices;
- Balance among improved productivity, market prices, and farm income through fertilizer subsidy programmes;
- Improved economic resilience from income diversification; and
- Reduced GHG emissions or increased soil carbon sequestration through better management practices.

Monitoring and evaluation for CSA programmes and projects

Monitoring and evaluation are critical for ensuring CSA interventions are implemented properly and achieve the desired outcomes. Evaluations can also identify shortcomings and lessons for future policies and programmes. The monitoring and evaluation framework and systems are designed once the assessments of climate change scenarios have been made (see above) and when the CSA intervention options and detailed project or programme plans are being formulated. Monitoring and evaluation of CSA programmes and projects use as a starting point the baseline projections regarding climatic conditions, as well as the desired CSA objectives from the policy and project design assessments. Monitoring and evaluation plans refine the indicators from the policy and project design assessments. The combination of primary data collected through various methods and analyses constitutes the evidence base that describes the start of the project baseline situation. CSA activities for the project can also be prioritized using information from CSA options assessments.

Monitoring and evaluation are initiated at the project preparation stage of the project cycle (Figure 18.1) in the interplay between assessments, monitoring and evaluation activities. Here they are intimately linked through detailed and regular planning processes. In particular, impact evaluation frameworks should also guide the preparation of project and programme baselines. Shortly after appraisal of the project proposal and approval of the project, detailed indicators, baselines and targets are set, with clearly specified beneficiaries and well-defined interventions. Commonly used indicators covering a range of important CSA aspects are given in Table 18.4. Throughout the implementation of the project, the progress of CSA interventions is monitored, as is the use of resources and delivery of outputs. At mid-cycle and at the end of the project, impacts of CSA interventions on socio-economic, environmental and livelihood indicators are evaluated based on the baseline situation and the initial expectations in terms of results. Ideally, project monitoring and evaluation should continue beyond the project cycle as some of the benefits of CSA may not be realized within the timeframe of a short project but only during a subsequent capitalization phase.

To further support CSA, it is essential during project implementation to monitor progress and identify successes and problems of CSA interventions, be they pilot initiatives, projects or programmes. This monitoring will verify whether activities are meeting the CSA objectives and project milestones in a way that satisfies efficiency standards. It will also facilitate the adjustment of activities in the face of uncertainties. Within the project or programme, monitoring and evaluation promotes accountability and the wise use of resources. Good monitoring and evaluation helps improve the design of future CSA interventions and stakeholders' decision making. They are part of a long-term learning process.

Monitoring and evaluation, together with learning, can contribute to the achievement of national mitigation goals. Detailed monitoring of GHG emissions can be part of accounting requirements within the framework of the United Nations Framework Convention on Climate Change (UNFCCC). Table 18.4 shows examples of a variety of indicators that can be considered for the monitoring and evaluation for CSA programmes and projects. The identification and selection of indicators are further discussed in section 18.4.

A common problem in the evaluation of results is the attribution challenge (i.e. To what degree is it possible to attribute results to a project intervention rather than to other external causes?). For example, from the indicators in the table below, the adoption of climate-smart forest technologies may be the result of other forest programmes, or market forces; and the proportion of people living below the poverty line may be due to migration and wider economic forces. The attribution issue is usually dealt with through robust sampling when setting baselines and making impact evaluations of project interventions (discussed further later in the module).

Table 18.4 shows examples of indicators of common outputs, outcomes and impacts in monitoring and evaluation for CSA programmes and projects. Their refinement ensures that they are measurable and will be context-specific. Disaggregating data where possible (e.g. by gender and other key target groups) is important.

Table 18.4 Examples of indicators of common outputs, outcomes and impacts in monitoring and evaluation for CSA programmes and projects

Poverty and household impacts (where possible this data should be disaggregated by gender or by male- and female-headed households)

- Percentage of population that is food insecure;
- Percentage of population below the poverty line;
- Household income, income variability and diversification;
- Gini coefficient;
- Marketing and commercialization chains that are adapted to changing conditions;
- Proportion of food and income that comes from climate-sensitive sources;
- Amount of time spent collecting firewood; and
- Amount of time spent collecting water.

Outcomes in terms of CSA-related productive change

- Agricultural productivity (e.g. tonnage of crop produced per hectare);
- Changes in land use (area);
- Reduced GHG emissions;
- Changes in productive resilience to climate variability;
- Changes in biophysical characteristics (e.g. content of soil organic matter); and
- Diversification from climate-sensitive livelihood sources.

Outcomes in terms of adoption of CSA systems

- Number of irrigation systems that raised drought prevention standards and area of farmland area covered;
- Number of soil and water conservation works;
- Area of farmland that adopted CSA technologies (e.g. reduced tillage, permanent crop cover, agroforestry);
- Forest area in which climate-smart technologies are adopted;
- Number of fisherfolk who adopted climate-smart fishery technologies, disaggregated by sex; and
- Increased access of women to land and/or productive resources.

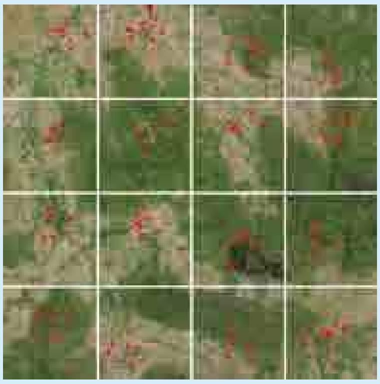
Outputs and outcomes related to capacity-building and service-related interventions

- Number of people who benefited from capacity development, disaggregated by sex;
- Number of male- and female-headed households that have gained direct household benefits from more climate-resilient agriculture infrastructure;
- Farm-gate and market price;
- Women beneficiaries constitute half of participants in capacity-development activities; and
- Number of officials trained on the inclusion of gender issues in CSA.

Institutional outputs and outcomes

- Strategy, policy and regulation formulated for CSA;
- Inclusion of climate change in agricultural policy frameworks;
- Actions identified and planned by local authorities to address significant vulnerabilities and opportunities not yet present in existing strategies and actions;
- Public commitments made to identify and manage climate-related risk;
- Proportion of budget allocated to support CSA;
- Proportion of budget allocated to agricultural research and development;
- Evidence of climate change mainstreaming in national and local agricultural development plans; and
- Increase in number of women participating in local, national and regional dialogues on CSA.

Box 18.1
Land degradation surveillance framework



The World Agroforestry Center (ICRAF)'s land degradation surveillance framework (LDSF) establishes a biophysical baseline at the plot and landscape levels. It also provides a monitoring and evaluation framework for assessing the processes of land degradation and the effectiveness of rehabilitation measures over time. The LDSF collects information on land use, vegetative cover, soil properties and topography using hierarchical field survey and sampling protocols. FAO's Mitigation of Climate Change in Agriculture (MICCA) Programme implements the LDSF in East Africa as a tool for measuring the baseline for land health in pilot projects. There are three additional primary data collection activities (GHG emissions and agricultural productivity, carbon balance, and socio-economic indicators) to monitor changes in socio-economic and environmental conditions.

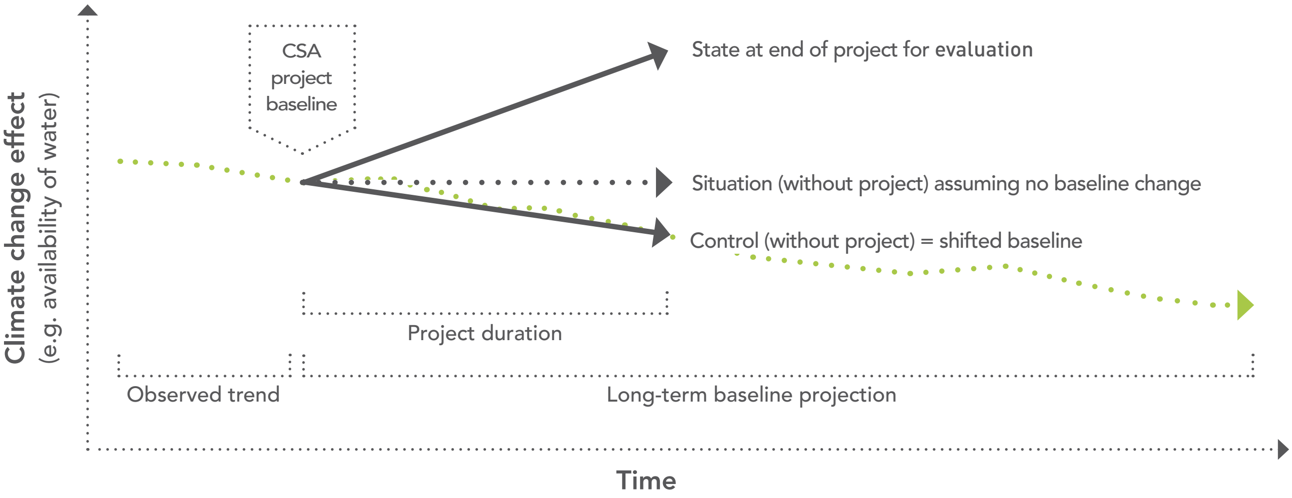
The figure below shows an example of LDSF hierarchical sampling design used to establish baseline soil and vegetation information. Ten subplots (red points) are selected at random from 16 clusters within a 10 x 10 km.

Source: Adapted from Vågen *et al.*, 2010

Baselines and baseline projections

If climate impact assessments and CSA options assessments are carried out for a given point in time or for the projected future conditions, they constitute a baseline or baseline projection that are relevant for the evaluation of impacts of a particular policy, project or programme (Figure 18.5) and for the monitoring of outputs and progress towards outcomes and impacts along the way. Examples of variables used to measure baselines are shown in Table 18.5.

Figure 18.5
Baselines and baseline projections



Based on climate impact assessments, baseline projections can be developed for expected future climate variations, associated variations in agricultural outputs and respective vulnerabilities. These are projections of the state of climate impacts, agriculture, and food security and vulnerability without the programme's or project's interventions. This 'without intervention' scenario helps to frame broader policies and programmes (see Figure 18.1). Baseline projections provide 'counterfactuals' and are used to evaluate long-term impacts of CSA and related interventions at a longer time scale than typical development projects.

More detailed CSA options assessments contribute to the development of more specific baselines of the present status against which measurements can be made to see if CSA practices improve local agriculture. These are project and programme baselines and usually refer only to the status at the beginning of an intervention. Associated with these baselines are the related indicators and targets of objectives and changes expected, which are used to frame the CSA project. Evaluation of the impacts of CSA interventions is made against these project and programme baselines at the end of a project cycle. Progress being made towards important intermediate outcomes and results is also often monitored during implementation.

However, as climate conditions evolve over the project and programme cycles, and new information about impacts of and vulnerability to climate change becomes available, baseline projections may need to be revised periodically. Adaptation processes need to be designed in response to evolving climate conditions. The carbon balance of the ecosystem is dynamic and may change over time in the absence of mitigation interventions. Project managers may need to adjust the CSA interventions according to revised baseline projections at the project's mid-cycle and evaluate the project's benefits against the new projections.

Over a short period of time, changes in baselines or baseline projections can be subtle, so they are not a great concern for shorter CSA projects (GIZ, 2011a). The use of 'control' groups when doing impact evaluations should be able to account for some of the variability in baselines (more on this in Annex 18.1 on basic tools) as well as changes in other factors, such as markets and the broader economy.

However, for longer-term projects and programmes (more than 5 years), monitoring and evaluation should take place against a 'moving' baseline or up-to-date baseline projections as well as against the typical project and programme baselines. An additional use of baseline projections is recommended for CSA practitioners to deal with the characteristics of longer-term climate change adaptation and mitigation actions.

Table 18.5 Examples of variables used for measuring baseline projections and project and programme baselines

Examples of variables used in climate change baseline projection within a specific geographic region of interest, include:

- Key climatic variables such as temperature, rainfall, and its seasonality;
- Frequency and intensity of extreme weather events;
- Water availability;
- Climate-risk prone areas;
- The number of people affected by floods or prone to flood risks;
- Agricultural productivity in terms of crop yield (without any adaptation measures); and
- GHG emissions (without any mitigation measures).

Examples of variables and indicators for setting project and programme baseline at the beginning of intervention to compare with end results include:

- Irrigation, water availability and withdrawal;
- Size of farm and land-use areas by crop (both cash crops and crops grown for household consumption) and management practices;
- Livestock numbers and management practices;
- Domestic market prices and their volatility;
- Population groups and their location categorized by poverty, food security, vulnerability and other key socio-economic factors, such as caste, class or age, disaggregated by sex; and
- Percentage of the population with access to and control over key resources for adaptation (CSA technologies, crop insurance, early warning information, seasonal climate forecasts), again disaggregated by sex and other key socio-economic factors.

Box 18.2
The CGIAR research programme on Climate Change, Agriculture and Food Security baseline

The Consultative Group for International Agricultural Research (CGIAR) Research Program on Climate Change, Agriculture and Food Security (CCAFS) baseline is being implemented on three different levels: household, village and organization. It collects indicators that describe current practices and behaviours in relation to livelihood systems and farming practices in CCAFS sites over time. These indicators also indicate changes made to agriculture and natural resources management strategies in the recent past. Other indicators help CCAFS to understand the enabling environment that allows for these practices and behaviours (e.g. natural resource conditions, policies, institutions) and the agricultural and climatic information that organizations that work at each site receive. The objective is to capture diversity across communities and households with sufficient precision to capture changes that occur over time.

The key aim of the CCAFS baseline is to provide snapshots of current behaviour at the sites using instruments that can be applied in all the CCAFS regions. The plan is to revisit the same households and communities after five years, and again in ten years, to monitor the changes that have occurred since the baseline was carried out. The same survey is being conducted in diverse locations across all CCAFS target regions. To date, close to 4 500 households have been surveyed in over 220 villages. In 16 CCAFS sites, 16 communities participated in qualitative focus group discussions, and over 160 organizations have been interviewed at these sites. This has allowed for valid and robust cross-site and cross-regional comparisons. As a result, the baselines are broad rather than deep. The intention is that complex relationships will be explored through further research in the same locations with secondary data.

The emphasis on carrying out cross-site comparisons has two costs. First, the baselines include information on the site's characteristics, but they are typically not sufficiently detailed for some activities (e.g. farming systems studies). Second, the baselines do not contain all the information needed to do *ex-post* impact assessment studies. Such studies are usually designed to evaluate specific technological or policy changes in a location and attribute the changes to particular activities carried out by specific agents. The CCAFS baseline meets the first objective of impact assessment (tracking change over time), but does not allow for the attribution of these changes to specific activities. The goal is not to attribute these changes to the programme, but to assess what kinds of changes have occurred and whether these changes are helping households adapt to, and mitigate, climate change.

All CCAFS baseline guidelines and tools for data collection, processing and analysis, as well as the data itself and the reports are being made publicly available.

For more information about CCAFS: CCAFS and CGIAR, 2013

18.3 How to conduct assessments for CSA policy and project design

Designing assessments

To draw useful information for planning CSA actions, a literature review is recommended. In this way, already available information can be gathered about the country and local areas. A literature review identifies gaps, and a customized assessment complements the literature review by collecting and analysing additional data.

Abundant information on climate change and its impact on agriculture are available at global and regional scales. Information at national and subnational scales is more scarce but can be found from a range of sources, including: the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Reports; the IPCC Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC, 2012); National Communications to the UNFCCC; UNFCCC National Adaptation Programmes of Action (NAPAs); national climate change strategy and action plans; academic papers; non peer-reviewed reports; national ministries; climate change bodies; and research institutions and universities.

Assessments of impacts and mitigation potential, particularly those done by academic scientists and economists, often do not have the user's perspective in mind. In designing assessments, the information needs of CSA practitioners should to be clearly defined at the outset.

Different stakeholders play different roles in conducting assessments. Evaluation of the roles and capacities of the stakeholders for carrying out assessments is one of the first essential activities for ensuring successful assessments for designing policies and projects.

The national climate change office, the ministry of agriculture, and other relevant ministries define the goals and transition pathways for CSA in countries. The providers of climate and agriculture information at the global and national levels are usually national institutions and universities. Scientists at either the national and subnational levels conduct assessments, but the practitioners of CSA interventions are subnational administrators, extension workers or local farmers. Identification of all stakeholders and their involvement in the design of assessments would contribute to answering basic questions:

- What is the target CSA sector? Crop, fisheries, livestock, forestry, water, pasture? What is the target system? Food production systems, landscape, ecosystem, national economy?
- What is the temporal scale? Future periods from the next few years to a hundred years?
- What is the spatial extent required by the users? National, subnational, local community or household?
- What is the spatial resolution? Metres, kilometres, hundreds of kilometres, individuals, households, community, farm or watershed?

The major steps for designing assessments can be summarized as:

- literature review;
- identification of stakeholders;
- assessment of information needs of stakeholders;
- evaluation of role and capacity of stakeholders; and
- design of assessments, including agreement on CSA objectives by stakeholders.

Conducting assessments

Once the study design is drawn up in consultation with stakeholders, choices can be made about the data, methods and tools that best meet the specified spatial and temporal scales and the other requirements of the assessments. A variety of methods, tools and databases for climate data, climate downscaling tools and vulnerability assessment tools are described in GTZ (2009), World Bank (2009b), UNDP (2009), UNDP (2010), and FAO (2012b). CSA planners should choose a method that suits the needs of the project and programme. There is no single method that is applicable to all CSA projects.

Climate impact assessment

Changes in climate

CSA is a response to historical and current changes in climate and projected climate change. Weather and climate data are key components of all CSA interventions. A correct understanding of local climatic conditions, trends and projections form a foundation for assessing climate impacts and monitoring and evaluating CSA practices. Focus should be on climatic variables that are related to agriculture, such as rainfall and the intensity, extent, and duration of droughts.

Weather observations are collected at tens of thousands of land-based weather stations across the world. They are complemented by observation by ships, radiosondes, aircraft and satellites. Some of the data are shared with the international community; other data are owned by the country. At the outset, it is advisable to inquire with the national weather service about data availability. Data availability and quality varies significantly by location, country, climatic variables and temporal frequencies. Observed climate data may be verified and complemented by local knowledge of climate trends. Future projections of climate are outputs from global climate models that typically operate at a coarse resolution of about 100 kilometres x 100 kilometres, or larger. Global data are often translated into finer spatial scales through downscaling methods. For more discussions of climate data collection and analysis, consult FAO (2012b), UNDP (2009) and UNFCCC (2010b).

Box 18.3
Climate-risk assessment to reduce the vulnerability of livelihoods

Central Guinea is dominated by the Fouta Djallon Highlands, a large plateau with altitudes ranging between 600 to 1 500 metres and an annual rainfall of 1 800 millimetres. It is the source of a significant number of important rivers on which many West African countries depend. The plateau is also threatened by a range of impacts associated with climate change. The Guinea NAPA has reported an almost constant decline in annual rainfall, the disruption in normal precipitation patterns and a general downward trend in water available from rivers. These meteorological trends have become more evident during the last decade: rivers and land are drying out; forests are having difficulty recovering; and agricultural production is being affected.

The Global Environmental Facility Fouta Djallon Highlands Integrated Natural Resources Management Project implemented in Guinea and its neighbouring countries, aims at ensuring the conservation and sustainable management of the natural resources to improve the livelihoods of rural populations directly or indirectly connected to the highlands. At the end of the first phase, the importance of reducing rural communities' vulnerability to climatic disturbances became crucial. However, a clear understanding of the current impact of climate variability was necessary for the project to ensure that the activities would have a positive impact on local resilience to climate change.

Accordingly, a climate-risk assessment of the target communities was undertaken to evaluate the impact of current climate-related hazards on local livelihoods in different agro-ecological zones. During community consultations, farmers reported observing changes in weather patterns over the last decade. These changes included: increased frequency of droughts, extreme heat, delays in the arrival of the rainy season, and scarcity and unpredictability of rains. These perceptions about the changes in the timing, intensity and frequency of climatic hazards are consistent with scientific data. These changes are reported to have significant impacts on farmers. Local perceptions on the connections between climate-livelihood and current and potential coping strategies were discussed and analysed. The appreciation of how the farmers respond to the climatic risks and the identification of resources that are both sensitive to climatic risks and crucial for implementing the coping strategies helped to incorporate climate-smart practices into the project activities. Originally planned activities were adjusted according to the way project activities could affect the availability of critical livelihood resources and the access of local communities to these resources. The purpose of the revisions was to make the project's activities resilient to current climate variability and deal with emerging climate issues.

Climate impacts on agriculture

An analysis of whether climate variability and change are having an impact (historical, current, and future) on the agriculture sector needs to take into account agricultural input markets, food demands, transportation, distribution channels and agricultural production. Impact assessment models are typically physical models (e.g. crops, hydrology, fisheries and forestry) or economic models that are highly specialized, so that experts in the field may need to be consulted. Aquacrop, for example, is a FAO crop model to simulate yield response to water of major crops. The Modeling System for Agricultural Impacts of Climate Change (MOSAICC) is an integrated package of tools for facilitating an interdisciplinary assessment of the impacts of climate change on agriculture (see Box 18.4).

A common climate impact assessment of agricultural productivity (e.g. crop yield) follows a top-down approach. It requires a good understanding of current and past impacts of climate change on CSA sectors and local perceptions of climate change as well as the collection of long-term historical data of weather and agriculture. Past climate conditions can be associated with past agricultural productivity to establish causal links and calibrate models. Global climate models can provide future climate projections, based on socio-economic and emission scenarios, and they can be downscaled using appropriate methods. The calibrated models can simulate future impacts of climate change on agriculture with projected climate as an input (see also FAO, 2012b for general methodology). UNFCCC (2010b) provides a review of available agricultural models, including: agroclimatic indices with geographic information systems (GIS); statistical models and yield functions and process-based crop models; and economic models, such as economic cross-sectional models, farm-level microeconomic models, household and village models, and macroeconomic models. All of these models may be useful for climate impacts assessment for CSA.

Box 18.4
MOSAICC – an integrated modelling system for assessing the impact of climate change on agriculture

The impacts of climate change on crop production are the result of a combination of factors, including: changes in temperature and rainfall regimes; variations in growing season starts and lengths; carbon dioxide (CO_2) fertilization; pest and disease outbreaks; and water availability for irrigation. Changes in agricultural yields will affect food production and have repercussions throughout the national economy. A multidisciplinary approach is useful for dealing with these different aspects.

MOSAICC is an initiative by FAO that integrates multidisciplinary models to capture different aspects of the impacts of climate change on agriculture. MOSAICC includes a tool for statistical downscaling of climate projections, two crop models (Aquacrop and WABAL), one precipitation-runoff model (STREAM) and one economic model (Computable General Equilibrium). All of these tools and models are incorporated into unique software architecture. A spatial database has been structured around a data typology that has been defined to link data and models. The architecture also has utilities to process the data so that it can pass from model to model, and web interfaces that can be used to manage data and simulations.

Such an integrated system offers a number of advantages. Remote access and the system's user-friendliness (users do not need to install any software on their own computer) facilitate collaborative work with experts around the world. Computing time is reduced and data conversion and reformatting are taken care of within the system. The system allows data tracking down the succession of experiments and can carry out replicable studies. In addition, the modularity of the system gives users the opportunity to substitute different models. Finally, the system runs at low cost. It does require maintenance, but all software programs are free of charge.

The whole system is installed on a central server for use by national experts in specialized institutions of developing countries. The different models within MOSAICC should be run by researchers with the relevant expertise. The experts are trained to use the models.

The system is being deployed in Guatemala, Morocco and Niger in the framework of the European Union/FAO Programme on global governance for hunger reduction, and in Peru and the Philippines in the framework of the Japan-funded Analysis and Mapping of Impacts under Climate Change for Adaptation and Food Security project.

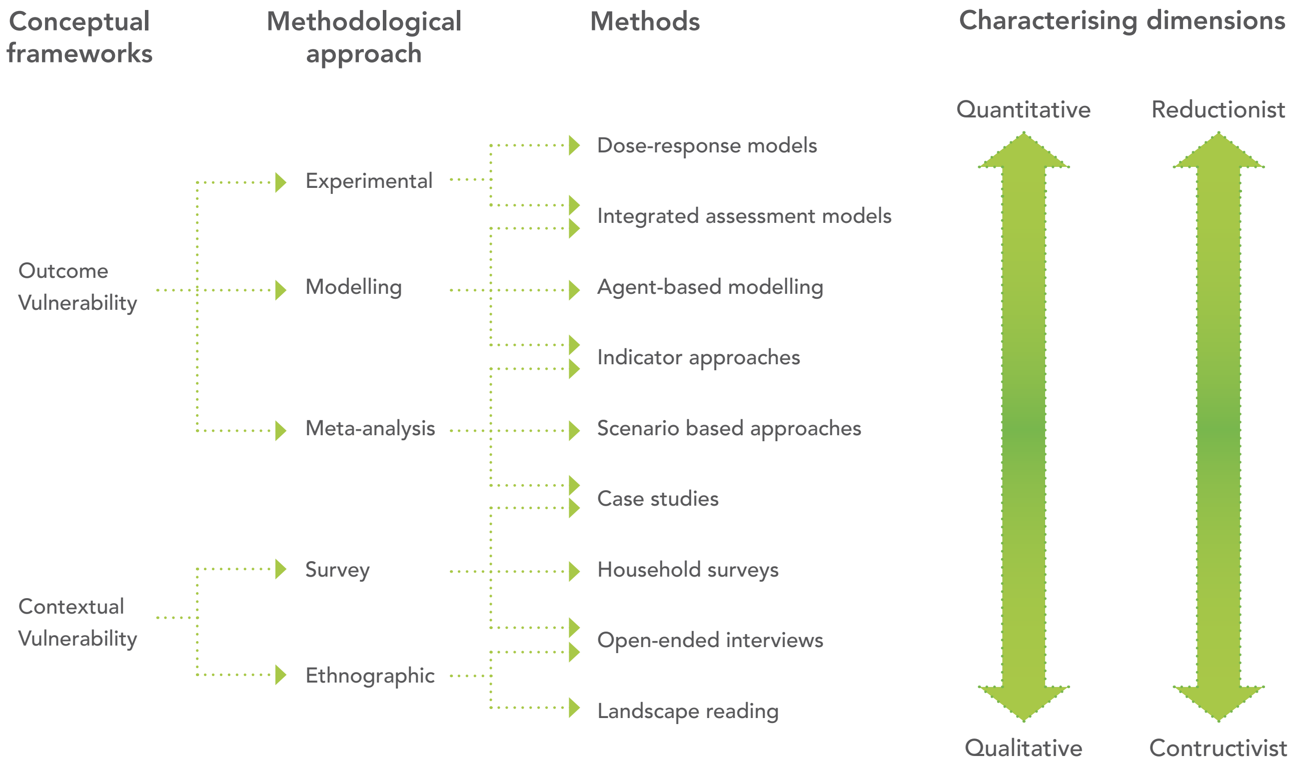
Source: FAO, 2013

Vulnerability assessment

Impacts on agricultural productivity and other aspects of the sector can lead to different repercussions in household income and food security. Vulnerability of livelihoods depends on the capacity of local communities to substitute a negatively affected production system with an alternative that could prevent losses in agricultural income, provide subsistence production, or supply food to urban markets. Vulnerability assessments characterize and identify areas, households or subpopulations that have particularly low livelihood resilience. This helps CSA planners prioritize their actions and target vulnerable communities (e.g. youth, elderly, landless people, and women). Vulnerability assessments also provide the basis for the development of strategies to increase the resilience of livelihoods to climate change.

With the potential impacts of climate change identified from previous assessments, vulnerability can be assessed by evaluating the adaptive capacity of the system in a top-down approach. The bottom-up approach, on the other hand, focuses more on collecting different indicators that would characterize the vulnerability of CSA and associated sectors to various risks, including climate change. There are a wide variety of possible indicators, including: socio-economic resources, technology, infrastructure, information and skills, institutions, biophysical conditions and equity (Desai and Hulme, 2004). Climate change and variability is considered as one of the threats to society and the environment, along with socioeconomic, political and institutional structures and changes. Contextual conditions of the society and environment clarify their adaptive capacity and vulnerability to potential threats. Some of the common methods of vulnerability assessments are categorized in Figure 18.6.

Figure 18.6
Methodologies, methods and characterizing dimensions of outcome and context vulnerability



Source: Pearson and Langridge, 2008

From the perspective of resilience and adaptive capacity, the World Bank (2009a) indicates three broad options for conducting assessments: full scope social assessment and/or extensive consultations (e.g. key informant surveys, focus group discussions, community surveys); rapid social assessments (e.g. checklists of key climate-related vulnerabilities, current coping strategies and limiting factors); and field-testing project management tools (e.g. CRiSTAL). Although not developed specifically for CSA, an empirical resilience model put forward by FAO (FAO, 2011; Alinovi *et al.*, 2010; Frankenberger *et al.*, 2012) uses structural equation modelling and factor analysis to identify the variables that contribute to household resilience. Common components (and associated indicators) that are considered in the resilience model are: income and food access, access to basic services, social safety nets, assets, adaptive capacity and stability.

CSA options assessment

Adaptation

Assessments of CSA options for adaptation effectiveness are an extension of climate impact assessments. Having gained an understanding of potential impacts of climate change and vulnerability, the best CSA practices for local conditions can be reviewed and identified. Ideally stakeholders are involved in validating the findings of the assessment and help to define and select suitable and workable adaptation options. Process-based crop growth models at the farm level could be used to suggest better management practices to improve yields. Economic models could simulate, for example, the effect of a fertilizer subsidy on productivity, market prices and farm income. A screening analysis is a simple method in which the assessor answers yes or no questions about options. Those options with the most yeses can be given the highest priority or be further assessed using more quantitative analytical methods. In multi-criteria assessments, stakeholders identify the criteria to be used in assessing adaptations. Common metrics are defined to measure the criteria. Assessors rank each adaptation option against each criterion by giving scores. In cost-effectiveness analysis, the relative costs of different adaptation options that achieve similar outcomes are compared (UNFCCC, 2010b).

A bottom-up approach in which the local community is fully engaged complements analytical assessments and is strongly encouraged. In the bottom-up approach, local men and women farmers discuss and agree on the best CSA interventions that they would be willing to adopt, given the local climatic, socio-economic and environmental conditions (community-based adaptation). This provides an opportunity to link local traditional knowledge with scientific knowledge. In addition, it gives the affected populations an opportunity to identify possible unintended consequences of CSA interventions and discusses how to resolve them. When the comparative advantage of different adaptation options is not clear, an assessment of the costs and benefits of adaptation measures can be done in an economic cost-benefit analysis or a non-economic evaluation method. In either way, some metrics of costs and benefits need to be estimated (World Bank, 2009c).

Food security

CSA practices should provide an overall strategy on how to achieve sustainable increases in productivity that enhance the food security of agricultural producers and the overall population. Additional assessment criteria that address a specific food security concern may need to be added to vulnerability and adaptation assessments. Standard literature is available on approaches for food security assessments in agriculture (e.g. FAO, 2009; IFRC, 2006; USDA, 2002).

Mitigation

An assessment of mitigation benefits simulates the dynamics of GHG emissions and carbon sequestration of CSA options, and quantifies their mitigation potentials. Assessments of mitigation potential typically assume a linear relation between the intensity of the mitigation activity and the estimated emission of a given emission and removal activity through an emission factor. The *Ex-Ante* Carbon-balance Tool (EX-ACT) (see Box 18.5) and Marginal Abatement Cost Curves (FAO, 2012a) are some of the tools that facilitate the calculation of mitigation potentials for CSA projects. Other tools include the Agriculture and Land Use National Greenhouse Gas Inventory Software (Colorado State University, 2013), the Carbon Benefits Project tool (UNEP,2013) and the Cool Farm Tool (see Box 18.7). These tools are not specific to any region and can be applied in any location.

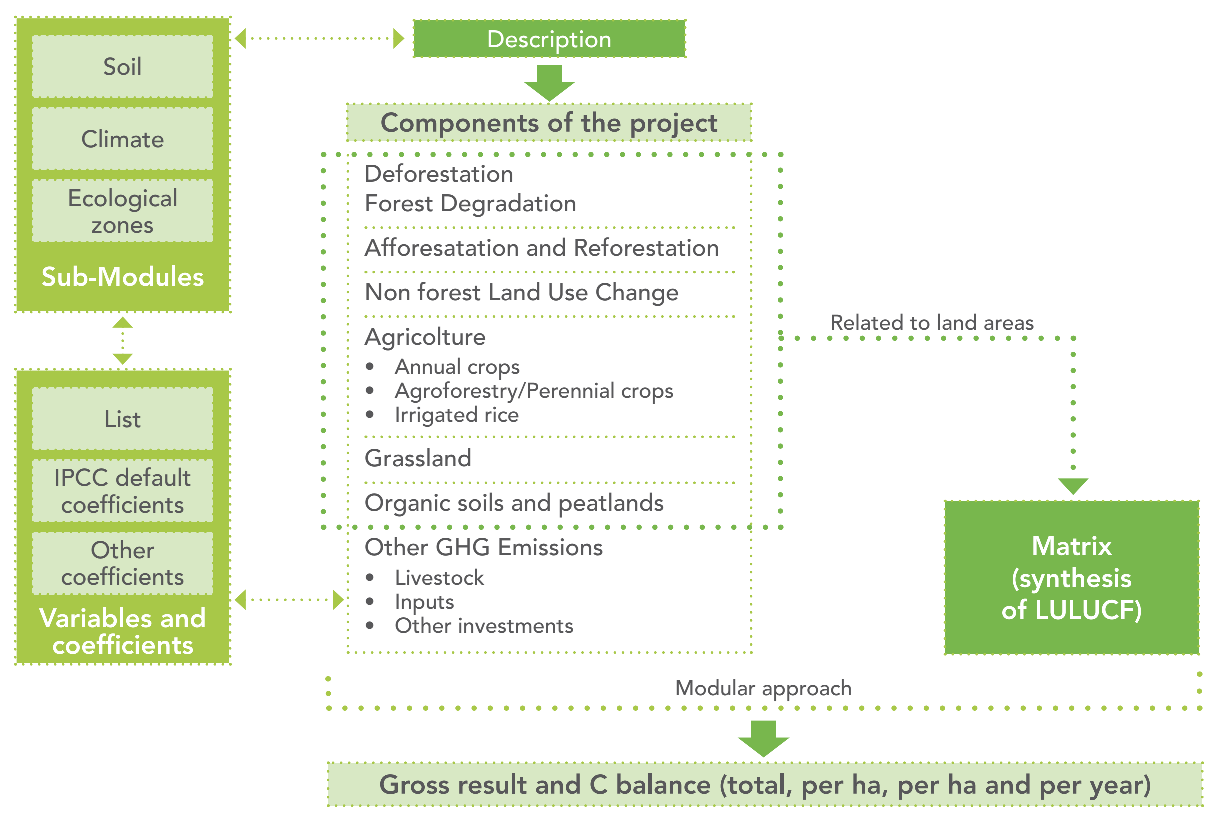
A Life Cycle Assessment (LCA) approach may be necessary to estimate the GHG emissions throughout the life cycle of a product, including production, transport of inputs (e.g. fertilizer, pesticide and feed), transport of the product, processing, packaging and distribution of the product to retailers. The LCA is widely accepted in agriculture and other industries as a method for evaluating the environmental impacts of production and identifying the resource and emission-intensive processes within a product's life cycle (see FAO, 2010a and 2012b).

Box 18.5
EX-ACT: assessing the mitigation potential in agriculture and forestry

EX-ACT provides ex-ante estimations of the impact of agriculture and forestry development projects on GHG emissions and carbon sequestration. EX-ACT is a land-based accounting system, measuring carbon stocks and stock changes per unit of land, expressed in tonnes of carbon dioxide equivalent (CO_2 eqv.) per hectare and year. The ex-ante carbon balance appraisal guides the project design process and decision making on funding aspects and complements the usual ex-ante economic analysis of investment projects. EX-ACT has the potential to support project designers in selecting project activities with higher benefits both in economic and climate change mitigation terms. EX-ACT outputs can also be used in financial and economic analysis.

EX-ACT has been developed based on the IPCC Guidelines for National Greenhouse Gas Inventories and makes use of other existing methodologies. The default values for mitigation options in the agriculture sector are mostly from IPCC (2007). EX-ACT consists of a set of linked Microsoft Excel sheets into which project designers insert basic data on land use and management practices foreseen under projects' activities. EX-ACT adopts a modular approach with each module describing a specific land use. It follows a three-step logical framework:

Figure 18.7
Modular structure and outputs of EX-ACT



1. A general description of the project (geographic area, climate and soil characteristics, duration of the project);
2. Identification of changes in land use and technologies foreseen by project components using specific modules (deforestation, forestation, forest degradation, annual and perennial crops, rice cultivation, grasslands, livestock, inputs, energy); and
3. Computation of the carbon balance with and without the project using IPCC default values and, when available, ad-hoc coefficients.

The main output of the tool consists of the carbon balance resulting from project activities. EX-ACT is an easy, cost-effective tool that requires a minimum amount of data. It includes resources (e.g. tables and maps) that can help users find the information required to run the model. While mainly used at the project level, it can easily be scaled up and be applied at the programme and sector level. It has already been applied to assess agricultural policies or value-chain driven changes in farming systems.

Further information and applications of EX-ACT can be found on the EX-ACT website at FAO, 2012c

18.4 How to implement monitoring and evaluation for CSA programmes and projects

Basic overview of the planning, monitoring, evaluation and learning cycle

For CSA, as in any other development context, monitoring and evaluation cannot be seen as separate from the programme and project planning cycle processes that define objectives and intervention actions that focus on expected results. Evaluation primarily deals with the assessment of results and impacts. Expectations for these results and impacts need to be set out clearly at the beginning of a project. Programme and project monitoring predominantly deals with tracking progress and intermediate results, and making adjustments during the project's implementation. Also, monitoring and evaluation processes should not be isolated from the learning processes. For the programme and project to remain flexible, all three processes are necessary.

A number of manuals and e-learning tools are available for in-depth monitoring and evaluation that can be applied to CSA interventions. Examples include the International Fund for Agricultural Development (IFAD) Monitoring and Evaluation Guide (IFAD, 2002); World Bank's monitoring and evaluation tools and approaches[1], with basic definitions provided by the Organisation for Economic Cooperation and Development, Development Assistance Committee (OECD DAC) (OECD DAC, 2009); and the European Commission Project Cycle Management. Any monitoring and evaluation system needs to be developed using the process enumerated in the following paragraphs. The process is elaborated in FAO (2012b) and draws on work carried out by GIZ (2011a) that specifically looks at monitoring and evaluation of climate change adaptation interventions.

1. Conceptualization. Situation analysis will build upon climate impact assessments and CSA options assessments (see Figure 18.1), together with an initial review of resources, key institutions and implementation mechanisms that form the concept for a detailed intervention, usually for a project or programme (see also Module 2);

2. Preparation and appraisal. Programme and project intervention planning and targeting sets the detailed framework within a wider programme and project cycle management. The project cycle management encompasses a wider framework of strategic planning, detailed project planning, implementation, monitoring, evaluation, learning and re-planning, and influences existing and new programmes. Detailed planning activities that are important to monitoring and evaluation include:
   - *Identifying the contribution to adaptation and/or mitigation:* this helps to identify more specific areas for engagement and contribution, such as: adaptive capacity, adaptation and/or mitigation actions, and sustained development in a changing climate.
   - *Forming an adaptation hypothesis and theory of change*: this is required to delineate in a participatory, gender-sensitive way the possible options and their expected changes and results chains between activities, expected behaviour changes, outcome and impacts. These can then be formalized in the intervention design and process, often in the form of logical frameworks that outline indicators, assumptions and risks to achieving these changes. These will help define:
     - inputs and activities (the details and resources of the actual interventions);
     - outputs (the direct results and deliverables of the interventions which are required for the outcomes);
     - purpose-level and intermediate outcomes (the expected external changes from the intervention); and
     - higher-level outcomes or impacts that interventions may contribute to, usually affecting household and individual living conditions, and changes in the environment.
   - *Developing adaptation and mitigation associated indicators*: the indicators are developed in relation to the above hypothesis and changed expectations, and reviewed on a regular basis (see Figure 18.8).

[1] For quick overview see World Bank, 2011. For more details see World Bank, 2004.

Milestones and targets help to identify the range of achievements expected in shorter- and longer-term scales. Project and programme baselines are then prepared to measure future changes.

- *Developing a results-based management*: this provides a framework whereby monitoring and evaluation is used to drive stakeholders to focus much more on results (outputs and outcomes) rather than inputs and activities.
- *Carrying out appraisals:* these appraisals review the whole design with regard to its risks, technical and social feasibility, robustness and efficiency and safeguards.

3. Implementation of the adaptation and mitigation actions, with the appropriate monitoring, evaluation and learning system, is the third element of the process. Initial emphasis is placed on monitoring with the continuous collection of data on specified indicators for implementation in relation to activity schedules, expenditure of allocated funds, and progress and achievements in relation to its objectives. Monitoring helps to inform supervision oversight and accountability.

4. Evaluation is the periodic assessment of the design, implementation, outcomes, impact and sustainability of a development intervention. It includes the review of *ex-ante* predictions of efficiency and effectiveness. The evaluation framework is set at the beginning of the intervention, both in the design of the logical framework, but also in the design and sampling of the project and the programme's baseline situation. It is also fundamentally inherent in the various stakeholders' assessment of the expectations of results, both at the beginning and at the end of a project.

Monitoring and evaluation are not completely separable, but they are two distinct things. They need to be linked to understand causes and effects. Both are concerned, to different degrees, with tracking progress and change. Both are concerned with ensuring upwards and downwards accountability of results to a range of stakeholders. They both require participation by stakeholders to generate, analyse and verify information.

Learning is a continuous process related to monitoring and evaluation mechanisms. The learning process is enhanced at the evaluation stage when important issues are identified and lessons are drawn to improve the way interventions are implemented. This process also offers lessons for future interventions and policies, and helps to build local capacities. With considerable uncertainties in CSA interventions, this learning process significantly helps adaptive management during implementation. Experience has shown that throughout this process it is important to apply participatory, gender-sensitive approaches and methods to increase the involvement of beneficiaries and stakeholders. This can be a prolonged process and can incur costs. However, if it is done well, the greater range of information gathered and the improved validation of the results usually will more than compensate for the extra time and expense. In addition, participatory approaches give stakeholders a greater sense of ownership of the results and can strengthen their adaptive capacity.

Figure 18.8 shows, using a results-based framework, how specific CSA practices are expected to be linked to intermediate variables (on the output and outcome level) and finally lead to improvements in terms of adaptation, mitigation and food security. The starting point is the implementation of specific CSA farming practices as well as CSA support activities. An evaluation has to show if and to which extent such activities translate into positive impacts in terms of climate change mitigation, adaptation and food security. Changes in biophysical, socio-economic and institutional outcomes may occur, as a result of CSA activities which in turn have been delivered by key project outputs. The outcome variables can usually be defined as changes in behaviour, agricultural systems and institutional capacity that translate into effective adaptation, mitigation and food security benefits at the impact level.

Figure 18.8
Linking activities and benefits of CSA through a results-based framework that provides an entry point for the development of indicators

CSA activities

CSA practices
- Reduced tillage
- Composting and organic manure application
- Crop residue mulching

CSA support activities
- Payment for Ecosystem Services
- Crop insurance
- Capacity development for rural producer organizations

↓

Outputs

Bio-physical variables
- Soil organic carbon levels increased
- Above and below ground biomass increased
- Soil depth increased
- Soil water retention increased

CSA support activities
- Changes in resources use (labour, mechanization, infrastructure, energy, water, etc)

Institutional processes
- Village organizations, rural producer organizations and cooperatives strengthened
- Farmers have better access to credit, extension service, weather information, marketing services

↓

Outcomes

Bio-physical variables
- GHG emissions reduced
- Carbon sequestration increased
- Increased drought resilience
- Better water and nutrient availability in soil

CSA support activities
- Climate-related yield variability is reduced
- Agricultural productivity increased
- Agricultural income increased
- Natural, physical and financial asset stocks increased
- Revenue for environmental services increased
- Income levels enhanced
- Livelihoods diversified

Institutional processes
- Better knowledge about climate impacts and CSA measures
- Enhanced institutional capacity for climate risk management
- CSA policies, strategies, and regulations strengthened
- Improved infrastructure for CSA
- Area of CSA adopted farmland increased

↓

Impacts

Contribution to climate change mitigation

Agriculture better adapted to climate

Improved food security

The steps in monitoring and evaluation of programmes and projects with CSA considerations

As noted above, monitoring and evaluation start with the design process and identification of objectives. They cannot be seen as separate activities. Before describing monitoring and evaluation indicators and tools, some important design processes need to be described. A shared process for setting objectives and determining indicators among intervention stakeholders is key to obtaining feedback, learning and restrategizing, all of which are important for CSA, which is quickly evolving.

The paragraphs below largely refer to outcomes and impacts. As they tend to be specific to climate change and agriculture, outcomes and impacts are pertinent to evaluation. On the other hand, outputs and activities to be monitored (e.g. capacity development, organizational change, infrastructure and policy support) will be highly intervention-specific and will fall within more regular planning and monitoring guidance.

Developing the basic intervention design

Much has been written about different kinds of project and programme frameworks (e.g. logical framework and results frameworks) as key tools for planning and setting monitoring and evaluation indicators. These frameworks do not need to be treated in detail here (see e.g. IFAD Monitoring and Evaluation Guide at IFAD, 2002). What needs be noted is that logical frameworks are very intervention-specific and cannot be prescriptive. There is no single model for a logical framework that can work for the very large range of CSA interventions, many of which will be nested within broader programmes and projects (FAO, 2012b provides some guidance).

Project and programme frameworks are useful in delineating the expected outputs and outcomes that result from stakeholder participation. Indicators are more easily developed and organized around such a framework.

A different organizing framework is the Driving forces - Pressure - State - Impact - Response (DPSIR) framework, which has been extensively applied in the environmental management context. This framework captures a causal chain from the causes of an environmental issue (the driving forces), to its effect (impact) and required responses. Monitoring indicators are then identified in relation to the different elements of the causal chain.

It is important to distinguish between objectives that are oriented towards processes and those that are oriented toward objectives. Even though an understanding of underlying processes is critical for CSA interventions, these processes are often neglected as they are less easy to measure. Implementing CSA cannot be done in a strictly linear way from interventions to results. With rapid changes in the environment and also to continuously address capacity for adaptation (at both the institutional and household level) it is crucial to also measure changes in processes and participation (Villanueva, 2010). For example, understanding why behavioural changes are taking place or not (Villanueva, 2010) is a process that is worthy of monitoring and evaluation. In this area, it is possible to draw on work from the broader agricultural development field (see for example FAO, 2012d) and other disciplines.

Outcome mapping, developed by Canada's International Development Research Center in a research context, has been adopted by a range of programmes for fostering institutional change. It is particularly helpful in delineating the expected outcomes among the different engaged project partners and stakeholders. Outcome mapping is suited for monitoring institutional changes, capturing changes in capacity and the resulting delivery of services.

An important complement to climate change analysis is the decision-making input from standard *ex-ante* project investment economic and financial analysis (EFA), which examines the returns to costs at the farm and project level. EFA complements tools such as EX-ACT. It assesses the feasibility of reaching objectives and indicator targets for a range of possible interventions and their required resources and costs. This analysis helps ensure expectations remain realistic.

Please refer to Annex 18.1 for a list of methods and tools for monitoring and evaluation.

Box 18.6
The GreenChoice monitoring and evaluation framework

Conservation South Africa has a monitoring and evaluation tool that farmers in commercial and small-scale sectors under the GreenChoice platform use on their farms to input information on the best practices the y are implementing based on the Farmer Field Book and Reference for Well- managed Farms. The Well-managed Farm Guide is used as a tool for developing sector-specific guidelines for best practices, such as potato industry guidelines, mohair best practice guidelines and biodiversity conservation. The field book is then used to track the implementation of the guidelines. Specific indicators used for monitoring and evaluation that are relevant to CSA are:

- yield relative to inputs (improvement in kilograms);
- the number of farmers and farm workers whose livelihoods are improved;
- land use efficiency (reduction in land use in hectares);
- biodiversity protected (increase in hectares);
- alien plant removal (number of hectares where alien species are removed to five percent density);
- soil health, soil organic matter and nutrient balance (improvement in hectares);
- water quality (improvements in kilotonnes);
- toxic chemical use (reduction in kilograms); and
- GHG footprint (reduction of atmospheric GHG emissions in tonnes).

More information can be found at Conservation South Africa, 2013

Box 18.7
PepsiCo UK and Ireland: 50 in 5

To increase its productivity in a sustainable manner, PepsiCo has increased its focus on sustainable agriculture. PepsiCo is aiming to reduce its carbon dioxide emissions and the amount of water it uses by 50 percent in 5 years (50 in 5).

PepsiCo, in partnership with Cambridge University and the University of Aberdeen, has developed farming innovations such as i-crop and the Cool Farm Tool to meet this target. I-crop is a web-based crop management system that allows producers to monitor and manage their agricultural crops for maximum yield and quality. The system enables growers to track crop inputs and outputs and allows them to accurately calculate water use and CO_2 emissions.

With the Cool Farm Tool, a carbon calculator, PepsiCo has measured the carbon footprint of different products and has analysed ways of reducing its impact upon the climate. In 2007, PepsiCo discovered, while working with the Carbon Trust, that 34 percent of its CO_2 emissions was generated during the production stage of agricultural crops, such as potatoes, oats and apples. PepsiCo, in close cooperation with farmers in the United Kingdom and with the support of the Cool Farm Tool, started reducing CO_2 emissions and decreasing water use.

For more information see PepsiCo, 2012

Developing indicators

To measure project progress and achievements, it is necessary to identify suitable indicators and clarify related baselines, targets and means of verification for each of the results at different levels. This forms the core part of the project's monitoring and evaluation framework. Indicators are extensively treated in monitoring and evaluation guides. Highlighted below are some key aspects of indicators in relation to climate change (See also Brooks *et al.,* 2011 and 2013).

Characteristics of indicators

Indicators should, wherever possible, be Simple, Measurable, Attributable, Reliable and Time bound (SMART). The somewhat expanded set of SMART criteria presented below provides a useful guide for identifying appropriate indicators (modified from CIDA, cited in GIZ, 2011a):

1. Validity: Does the indicator measure a change in climate risk or vulnerability?
2. Precise and specific meaning: Do stakeholders agree on exactly what the indicator measures in this context?
3. Practical, affordable, and simple: Are climate- and adaptation-relevant data actually available at reasonable cost and effort? Will it be realistic to collect and analyse information?
4. Reliability: Can the indicator be consistently measured against the adaptation baseline over the short, medium and long term? With regard to mitigation, are the indicators robust enough for formal auditing under measurement, reporting and verification (MRV)?
5. Sensitivity: When the respective climatic effects or adaptive behaviours change, is the indicator susceptible to those changes?
6. Clear direction: Is it certain that an increase in value is good or bad and for which particular aspect of adaptation? Is it ultimately attributable to intervention?
7. Utility: Will the information collected be useful and relevant for adaptive management, results accountability, and learning? Does it measure achievable results?
8. Owned: Do stakeholders agree that this indicator makes sense for testing the adaptation hypothesis?

Using a simplified typology, indicators can be classified into four types. Each type of indicator is important for measuring outputs, outcomes and impacts in relation to climate change interventions. The four types of indicators are:

- Quantitative (e.g. tonnes per hectare of incremental crop production, number of days a year a household has adequate meals, or number of men and women with increased income);
- Qualitative (e.g. beneficiary perception of satisfactory service delivery by intervention agency);
- Proxy indicators, which give an approximation of a desired measure, where a direct indicator is difficult to assess; and
- Indices, which are composed from other indicators to provide a more simplified aggregate measure of change.

Proxy indicators are by their nature indirect measures. In the end, most indicators have to be screened and chosen pragmatically so that they best fit specific needs. The selection process will create a shortlist of indicators, some more direct and others more indirect, that capture a wide range of possible effects. Poverty measures, for example, are the results of a range of interventions and external forces. Adoption of a particular cropping pattern may be largely due to a project intervention, but also to other explicit or unspoken choices by farmers.

In addition, as mentioned above, it is important to highlight process-based indicators as well as outcome-based indicators. Both types of indicators are important and have their own particular advantages and disadvantages. Villanueva (2010) suggests the Adaptive, Dynamic, Active, Participatory and Thorough (ADAPT) framework with indicators that are more process-oriented. It is worth emphasizing the need to look at what has been put in place to strengthen adaptation and adaptive capacity outcomes. These outcomes are important even if events to test the adaptation may not take place during the intervention period (e.g. infrequent but stronger extreme events, such as large floods and hurricanes).

Range of indicators

According to the definition of CSA, climate change adaptation and mitigation interventions in the agricultural sector should lead to increased productivity, improved resilience to climate risks, reduced GHG emissions, greater GHG uptake and enhanced achievement of national food security and development goals.

Indicators for monitoring and evaluating projects' impact should try to reflect these objectives. Some examples include:

- agricultural productivities in the project area over a multiyear period (see GDPRD *et al.*, 2008);
- monitoring changes in land use on a wider scale, which can draw on literature such as sustainable land management impact monitoring (Herweg *et al.*, 2012);
- resilience to flood and drought disasters over a multiyear period;
- total amount of annual GHG emissions reduced from the project areas over a multiyear period;
- food security rate by household or by men and women in the project areas over a multiyear period, which is especially important in development countries; and
- participation by key stakeholders, both men and women, in agricultural decision making .

(Guidance document Annex 6 in the same work as FAO, 2012b provides a more detailed description and examples)

Outcome indicators (or 'intermediary outcome indicators', depending on the terminology adopted by the donor) are mainly process indicators. In most climate change interventions, there is often a need to develop and establish outcome indicators to track, among other things:

- capacity development, including strategy and policy capacity, institutional capacity and technical capacity at different levels (see also Module 17 on capacity development), as well as the individual capacity of men and women (e.g. changes in attitude and behaviour);
- infrastructure improvement, including water infrastructure, agriculture infrastructure and rural infrastructure with attention given to who has access to this improved infrastructure; and
- technology dissemination, including technologies for climate change adaptation and mitigation in each of the agricultural sectors, and the uptake of technology by men and women.

See also Table 18.5 earlier in the module for examples of indicators of common outputs, outcomes and impacts in monitoring and evaluation for CSA programmes and projects.

Although not an easy task, it is possible to measure variables that are financial in nature, such as income and assets. It is also possible to measure the benefits of climate change mitigation (e.g. GHG emission reduction and increased soil carbon sequestration that can be translated into CO_2 eqv.). However, it is more complex to further translate reduced CO_2 eqv. emissions into economic values. This can be done using EX-ACT —which is based on some simple assumptions for estimations of CO_2 reductions— in combination with various measures used for accessing carbon funds (see Module 14 on financial instruments). Measuring the outcomes for climate change adaptation is more difficult. There is no firm consensus on a set of measurable indicators at the outcome level. Inevitably, benefits can only be measured by more than one variable, which creates a situation where there is a risk of double accounting. In addition, many adaptation benefits, which are not traded as goods and services on markets, can only be valued using techniques from environmental economics.

Of particular importance in the context of climate change is the measurement of changes in vulnerability and resilience. In this regard, there are a number of indicators and indices that have been developed by FAO, the World Food Programme (WFP), non-governmental organizations (NGOs) and others (FAO, 2011; Frankenberger *et al.*, 2012). Also, a considerable body of work exists on emergencies and disaster risk reduction and disaster risk mitigation. Twigg (2009) identified characteristics of disaster-resilient communities using indicators organized around components of resilience. These indicators are very specific to a particular group and area. In measuring outcomes, they may include specific household or community capacities to manage key natural resources and for measuring impacts, they may include key food supplies or household assets. For example, a household with savings and assets may be able to access funds in an emergency.

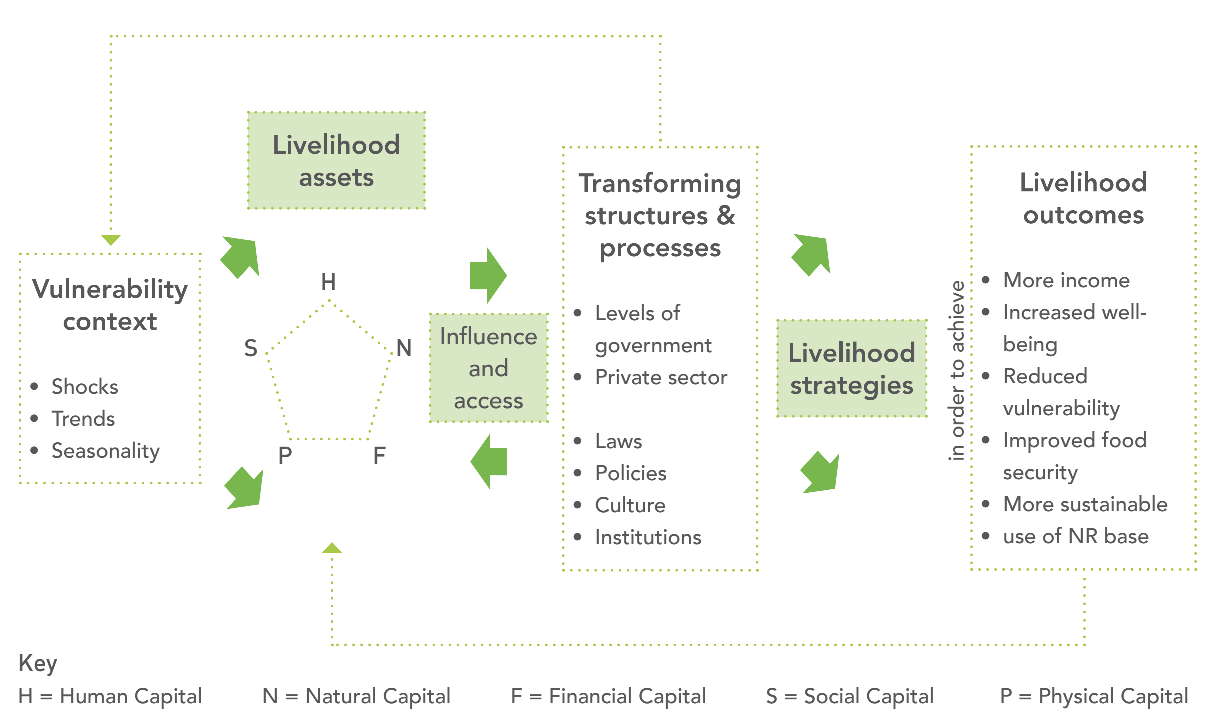
As noted, an important element will always be who decides on, and who benefits from, interventions. For example, household decision making about agricultural practices often has a strong gender dimension, with men and women taking responsibility for different spheres of influence. Sometimes, decisions made by one group affect another group that has had no say in the matter (e.g. men may choose a crop or practice that earns more income for the household, but increases the amount of time women spend weeding or watering).

In other cases, men and women take joint decisions, particularly in times of crisis. The collection of data disaggregated by sex and beneficiary groups is crucial for measuring these changes.

Box 18.8
Sustainable livelihood framework for assessing community resilience to climate change

A community's 'resilience' to climate change can be assessed using the sustainable livelihood framework. The sustainable livelihood framework shows the relationships between household assets, their vulnerability and the institutional context, which determine household livelihood strategies and their outcomes. The asset pentagon lies at the core of the sustainable livelihood framework. It visually presents information about the type and level of assets the community possesses. The pentagon consists of five different types of assets or capitals: human, social, natural, physical and financial (DFID, 1999).

Figure 18.9
The sustainable livelihoods framework



Source: DFID, 1999

In general, it can be said that households with fewer assets are more vulnerable to external shocks. However, it is not only the limited amount of assets that matter in measuring people's coping capacity. Other factors are also important, including: the quality of the assets; whether and how people have access and rights to the resources; whether and how they can use them; and whether and how the resources are or can be shared. Moreover, the institutional context, which consists of policies, institutions and processes, can also influence people's access to assets and the range of livelihood strategies available to them. Assessing changes in these assets can help to determine a household's resilience to external shocks. An Assessments of Impacts and Adaptations of Climate Change project in Sudan, for example, used the sustainable livelihood framework to measure the impact of project interventions on a community's resilience. For each type of capital, a set of criteria and indicators were developed (Elasha et al., 2005). Assessing whether CSA activities have strengthened communities' resilience to climate change can be undertaken using the sustainable livelihoods framework.

Methods for project monitoring and evaluation

Methods for measuring results of outcomes and impacts (mainly evaluation) and progress against expected targets (mainly monitoring) are very large topics that are best examined in relation to literature on specific indicators. Many indicators related to implementing CSA deal with well-established measures of change (e.g.

technology adoption, land use change, household livelihoods and institutional change) that have been dealt with extensively in development literature and through a range of methods and good practices (see Annex 18.1 and Additional Resources). Evaluation requires rigorous sampling and survey methodology with both qualitative and quantitative data and analysis. Monitoring needs to have in-built and integrated systems for tracking financial transactions, as well as expected outputs, activity targets and achievements. Monitoring also needs to incorporate feedback and learning into programme and project management. To track and manage data, many of these monitoring systems increasingly incorporate computerized management information systems. A critical element of successful monitoring and evaluation is the internalization of its importance in planning and decision making by management and other stakeholders in the CSA intervention process. Monitoring and evaluation tasks are too often merely seen as reporting for governments or donors.

A particular methodological issue noted earlier was the importance of attribution. This is the particular challenge faced when attempting to ascribe observed change and results specifically to a project while it could also be due to other external changes and interventions taking place. This is a very big concern for climate change programmes since they are potentially affected by long term and large scale climate and economic processes; hence this is specifically discussed further in section 18.5. Here in the context of projects the issue is dealt with through the design of rigorous project baselines and impact evaluation surveys, which take into account external effects (see Annex 18.1). They do so principally by including 'control' areas and households in the survey samples, against which changes in project beneficiaries' livelihoods and land use can be compared.

18.5 Challenges and guiding principles

There are numerous challenges and principles that need to be taken account of in assessment, monitoring and evaluation for agricultural development projects and programmes. This CSA sourcebook module does not discuss those general issues. Interested readers are referred to, for example, IFAD, 2002; World Bank, 2005; World Bank, 2006 and FAO, 2010b. CSA poses unique challenges for assessments, monitoring and evaluation; a set of guiding principles can be suggested to tackle them. The following discussions are intended to highlight specific problems that are particular to CSA. No concrete approaches to assessment, monitoring and evaluation are prescribed in this module, as each CSA project/programme is context specific. Instead a CSA designer is encouraged to be aware of the challenges and to follow the principles laid out in this section. Most of the challenges and principles are common to assessments for policy and project design as well as monitoring and evaluation.

Definitions and goals

"Climate-smart agriculture" is an evolving concept and there is not yet a single definition for it that is agreed by the international community (see also Module 1). CSA means different things to different countries, depending for example on the level of agricultural development. In some cases, more focus is placed on mitigation, while in others the focus is mainly on increasing productivity and enhancing resilience. Likewise, there are differing views on how to define "adaptation" to climate change, or what constitutes "successful adaptation" to climate change. The lack of consensus indicates a lack of agreed metrics to determine effectiveness of activities to achieve CSA/adaptation, which means extra challenges to monitoring and evaluation (Hedger *et al.*, 2008; UNFCCC, 2010a; Villanueva, 2010; GIZ, 2011a). Thereby, one of the first steps for successful CSA and its monitoring and evaluation is to define CSA goals with the wide participation of different stakeholders, and to develop a common understanding of what CSA's elements are.

Multi-sectoral issues and engaging stakeholders

Climate change objectives link together various sectors and stakeholders, and as an evolving concept CSA requires continuing even further dialogue and engagement of key players. A typical agricultural development project can have wide relevance from public health to migration in the context of climate change. CSA will not be successful unless relevant stakeholders are engaged at all levels and across all relevant sectors (UNFCCC, 2010a; Hedger *et al.*, 2008; Villanueva, 2010; GIZ, 2011a). The stakeholders to be consulted vary from the community level to the international level (Hedger *et al.*, 2008). In general, stakeholders must be representative of the target population, i.e. men and women and different socio-economic groups should be involved and different actors along the value chain should be consulted. Integrated frameworks of CSA across all levels will enable clear and effective feedback mechanisms throughout various levels. Table 18.6 summarizes expected levels of stakeholder involvement. Especially with regards to mitigation, national-level monitoring and evaluation may need to be linked to UNFCCC requirements of indicators (for example for greenhouse gas reporting, reduced emissions from deforestation and forest degradation [REDD+], MRV, or any other performance indicators in the future regime). At project level, monitoring and evaluation should ideally be based on a national level annual planning, monitoring, evaluation and budgeting system that provides orientation and harmonises different projects under national programmes and policies for poverty alleviation, natural resources management and agricultural development.

Table 18.6
Level of stakeholder involvement in assessment, monitoring and evaluation

Administrative Level	Stakeholders	Assessments for policy and project design	Monitoring and Evaluation
	project/programme planner	X (lead)	X (lead)
Local	Farmers (men and women)	C	X (design, collect data)
	local community	C	X (design, collect data)
	farmer association (and women's groups)		C
	local business		C
	extension workers	X (coordinate)	X (design, collect data, support)
	local government	X (provide data, coordinate)	X (design, support)
	other affected people		C
National	national government - ministry of agriculture	X (provide data, coordinate)	X (design, support)
	national government - other ministries	C	C
	national government - climate change office	X (coordinate)	X (design)
	research institutions	X (technical work)	C
	donor agencies	C	X (design)
	UN and other international organizations	C	C
	civil society, NGOs		C
	private sector		C
	national meteorological agency	X (provide data, technical work)	C
	sector-specific commissions or environmental commission	C	C
International	international climate change community	C	C

X: full involvement, C: consultation

Participatory, gender-sensitive approaches in assessment, monitoring and evaluation that recognize that local men and women are best suited to understand the conditions of local agriculture should be promoted. In these approaches, men and women contribute to assessing the impacts of climate change on their livelihoods and food security, and identifying and measuring their own indicators of change for monitoring and evaluation. This creates opportunities to develop a learning partnership that involves all the implementing partners and the participating communities. Participation in the assessment by the communities that are affected is critical. This is not only for gathering as much information as possible on the local situation by drawing on the diverse views within the community, but also for building ownership of the process by the community to increase the likelihood of successful implementation of CSA methods.

Box 18.9
Community monitoring and national MRV

The Forest Carbon Partnership Facility (FCPF) has looked at the advantages of community monitoring compared to expert monitoring for national REDD+ MRV. When communities are trained to use standard forest inventory protocols for carbon stocks using IPCC recommended procedures, their monitoring can be reliable and more economical than expert inventories. Engaging communities in monitoring activities strengthens their rights and their stake in REDD+. The ownership of the data remains with communities and this increases their motivation for supporting REDD+. Data collected by communities can also be used in stock assessments in national forest inventories and support the information gathered at basic grid points.

See more at FCPF *et al.*, 2009.

Monitoring and evaluation for CSA should be set within a broader development perspective. To avoid duplication, monitoring and evaluation systems should be built upon and integrated into existing systems, programmes and projects for agriculture, climate-responsible development and disaster risk reduction (see more in Module 15) (Hedger *et al.*, 2008; GIZ, 2011a). Within agricultural and rural development projects there are already many actions, expected results and indicators that incorporate information on climate change actions and outcomes or that can be enhanced by CSA actions with relatively lower costs (see FAO, 2012b). For guidance on participatory approaches, see FAO's Socio-economic and Gender Analysis Field Handbook (FAO, 2001).

Box 18.10
Role of ICT, Communication for Development

The role of information and communications technology (ICT) is important for implementing CSA, particularly for monitoring and evaluation. ICT is central for the collection, processing and transmission of data, and for communication among stakeholders. Global Positioning System (GPS) equipment used in project officers' cameras can automatically log the locations of the photos taken for later reference. GIS is essential in analyzing geo-referenced information. Collected information can be logged in the database for monitoring purposes using simple structured forms based on a markup language (e.g. XML) on mobile phones, mobile electronic devices and laptops.

For example, the Mobile Survey Tool, developed for the Ericsson Millennium Villages Project, is a tool that facilitates data collection for agriculture, healthcare, business, finance and government. The tool enables operators and end users to create and organize surveys and questionnaires without the need of coding or databases. The data can then be processed and used for different purposes within a village or by governments.

Participatory planning, monitoring and evaluation are recognized as important in the broader development context. They are used widely in rural community development interventions, and are particularly helpful for understanding community perspectives on CSA opportunities and constraints, dealing with fine scaled variability and empowering local communities to engage in community-based natural resources management (see Guijt, 1999 for a manual, and for an example on adaptation to drought through community groundwater monitoring see FAO, 2008). Villanueva (2010) proposes an ADAPT process to assist in organizational learning, monitor perceptions and promote organizational reflection and change.

Scales, leakage, permanency, externality and ancillary impact

Climate change interventions implicitly address longer-term and larger-scale processes. They also involve a greater number of potential tradeoffs. Unlike many projects where monitoring and evaluation addresses areas, beneficiaries and stakeholders within the project's 'boundaries' for a shorter subsequent period, CSA projects are more likely to require longer-term post-project monitoring of trends and additional comparison areas. As climate change initiatives cannot be developed or implemented in isolation, multi-criteria and multiple objective analyses can help to assess tradeoffs.

Some expected outcomes and impacts may not be able to be evaluated at the time of project monitoring and evaluation. This is particularly true for monitoring and evaluation of mitigation benefits. Increases in soil carbon content in response to improved practices cannot continue indefinitely. Eventually, soil carbon storage will approach a new equilibrium where carbon gains equal carbon losses. A default time period, usually 20 years, is assumed for this transition.

The issue of leakages and permanency is important for the monitoring and evaluation of climate change mitigation. Permanency refers to the principle that emission reductions represented by an offset should be maintained over time. In some cases, abandoning a CSA practice after only a few years will counterbalance the emissions previously avoided, and sometimes it may even surpass the emissions abated. This is why frequent monitoring is required to take into account such risks. Leakage refers to a situation where emissions abatement achieved in one location is offset by increased emissions in unregulated locations. In this regard, the difficulty lies in the choice of appropriate boundaries to conduct the appraisal.

A measure adopted for CSA may bring short-term benefits, while the same measure may lead to maladaptation over the long term and *vice versa* (Hedger *et al.*, 2008; Villanueva, 2010). The timing of monitoring and evaluation needs to be chosen to address both short- and long-term impacts. Different targets may be set for different time scales. Consideration of successful pathways for implementing CSA at different time scales will help improve the design of monitoring and evaluation systems. Ideally, additional evaluations are done after the project ends. Institutions should have good information storage and retrieval systems in place to support monitoring and evaluation (Lamhauge *et al.*, 2011; Hedger *et al.*, 2008).

Accounting for externalities and ancillary impacts should also be considered, even if they are far more difficult to evaluate than the abatement of GHGs or improvements in adaptive capacities. Virtually every CSA option will produce some positive impact (e.g. clean water or more pollinators) or negative externality and/or ancillary impact (e.g pollution or loss of biodiversity). Whether quantifiable or not, these impacts represent real costs or benefits and should be factored into the monitoring and evaluation process.

Availability of data and information

All assessment, monitoring and evaluation activities require data on a range of subjects, including: climate, agriculture, socio-economic conditions, capacities and livelihoods. The quality of data directly affects the quality of assessment, monitoring and evaluation. Analyses based on poor quality data are of very limited value.

Natural climate variability can best be described with long-term climate data that covers many decades. Anthropogenic climate change alters climate variability and mean climate. To characterize current and historical impacts of climate change on agriculture for the assessment purposes for policy and project design, good quality, continuous and long-term climate data are necessary (e.g. temperature, rainfall, wind, solar radiation, humidity, evaporation and runoff). Along with climate data, agricultural statistics describing the state of agriculture are necessary for the same time span. Such data includes crop yields and areas under cultivation, as well as fish and wood production. However, data availability and quality are often an issue in many developing countries (OECD, 2009; UNFCCC, 2010a; Lamhauge *et al.*, 2011).

Future climate projections are produced by global climate models at relatively coarse spatial resolution of 100 kilometres or larger. Downscaled climate information at finer spatial scales is usually not readily available in a format that can be easily used by researchers for assessments of policy and project design, and by practitioners for project baselines for monitoring and evaluation (OECD, 2009; UNFCCC, 2010a; Lamhauge *et al.*, 2011).

The key point is to identify the most important set of data for assessments, and to keep collecting and analysing them. National systems of data collection can be complemented by local systems and by the knowledge and observations of local people.

For monitoring and evaluation, data need to be collected throughout CSA activities and beyond. However, data collection is difficult and costly, particularly for smallholder farmers (Lamhauge *et al.*, 2011; UNFCCC, 2010a) and many local institutions. Monitoring and evaluation is already a challenging undertaking for regular development projects. It is therefore important to address data overload (e.g. too much information with too little useful analysis) by simplifying monitoring and evaluation processes and indicator sets wherever possible (see also GDPRD *et al.*, 2008) and maximizing the use of existing systems.

Again, the key point is to identify the most relevant indicators (see examples of indicators in Table 18.5) for project monitoring and evaluation purposes and broader policies and programmes (Figure 18.6) and to continue to collect data for these indicators. Some of the benefits of CSA interventions may not be realized for a long time (perhaps for decades), much longer than timelines typically associated with most projects. Supporting the collection of associated data for the purposes of evaluation beyond the project is a serious issue (Hedger *et al.,* 2008; GIZ, 2011a). Commitments to set aside resources for this should be considered as a means of providing a global public good.

Improving information and data collection and availability is a priority in many developing countries. Targeted CSA strategies and interventions need to be based on reliable user-oriented information that includes good quality data, documented vulnerabilities and accurate evidence.

Working with uncertainties

The climate system has its own natural variability that can be observed at different time scales: daily, seasonally, inter-annually, decadal, centurial. For the near future, natural climate variability may well be far larger than long-term changes in climate caused by increased atmospheric concentration of GHGs. Data collected at weather observation stations are the basis of all climate science, but these stations are few in number and the data quality is questionable, particularly in sub-Saharan Africa.

Future climate projections carry deep, multilayered uncertainties. It is not known how human activities will evolve in the coming decades and which activities will determine GHG emissions and influence climate change. Humanity's ability to adapt to future climatic conditions, the costs of adaptation and the speed at which new technologies will be adopted are not known and can only be considered in scenarios. All climate projections are based on emission scenarios that represent possible socio-economic development pathways.

Scientific understanding of the climate system is far from perfect. Even for the same emission scenario, different climate models project different future climates, even though all of the models are known to reasonably reproduce past climate conditions.

Assessments of impacts and characterizations of vulnerability (climate impact assessments) are conducted by a variety of models using climatic information as inputs. A long chain of scenarios and models will indicate the potential local impacts of climate change on agriculture and the possible adaptation responses. But each component of the chain carries its own uncertainties, which may result in a growing number of permutations and an expanding envelope of uncertainty (OECD, 2009; Hedger *et al.,* 2008, World Bank, 2010; Villanueva, 2010; GIZ, 2011a). Climatic uncertainties are an additional consideration on top of the uncertainties associated with non-climatic factors that are common in all agricultural development projects.

Uncertainty is inherent in the climate-agriculture system and cannot necessarily be reduced through scientific advances. Uncertainty is to be managed and is not to be used as an excuse for delaying action. A wise approach is to take account of uncertainties and be flexible in planning adaptation strategies that withstand unpredictable futures in a robust way. These strategies would minimize vulnerability to a range of possible risks, rather than propose an optimal policy that performs better than the others on average. When new information becomes available, adjustments may need to be made to the assessments of climate change impacts, baseline projections, CSA measures and indicators for monitoring and evaluation (GIZ, 2011a among others). This is where a project monitoring and evaluation system with strong learning mechanisms can be particularly useful.

All assumptions that are made in the assessment process and the sensitivities of these assumptions should be explicitly stated and communicated. This will help practitioners to interpret the results of assessments for policy and project design and allow them to better deal with uncertainties.

When there is no reliable information on which to base CSA decisions (even after carrying out the appropriate assessments for policy and project design, including a cost-benefit analysis), a project may adopt a general 'no-regret' approach. Such an approach brings benefits regardless of the size and direction of climate change (or even in the absence of anthropogenic climate change).

For assessments of mitigation potential, there is still a lack of suitable emission factors and coefficients, particularly in developing countries. Generic coefficients from the IPCC can be used, but they may not correctly reflect the real climatic, biophysical conditions and farming practices of the country. Given this uncertainty, being conservative in the appraisal is a desirable principle to adopt: the emissions of the baseline and baseline projection should not be overestimated and future emissions with the adoption of CSA should not be underestimated. This conservative appraisal will reinforce the credibility of the results. Sensitivity analysis to uncertainties in emission factors or alternative assumptions must also be carried out.

Attribution difficulty

As noted with projects, the attribution of impacts (e.g. adoption of technologies) can be difficult to evaluate with most monitoring and evaluation systems. This has implications for the way project impact evaluations are designed and the tools that are used (see 18.4. and Annex 18.1). Factoring in the effects of climate change makes the issue even more challenging.

Climate is variable by nature. The weather experienced daily is a combined result of natural climate variability and anthropogenic climate change. It is difficult to separate the two for the purposes of assessing impacts of climate change or the monitoring and evaluation of impacts of CSA interventions (Lamhauge *et al.*, 2011; Hedger *et al.*, 2008). It is also not easy to clearly distinguish the effects of many adaptation options from those achieved by broader sectoral development policies (UNFCCC, 2010a; Lamhauge *et al.*, 2011). The distinction is especially ambiguous when climate change adaptation interventions are not designed and implemented as stand-alone projects or components, but incorporated into various development activities. Indicators for the successful implementation of CSA that can be attributed to a specific intervention should ideally reflect achievements in addressing the additional impacts of climate change, such as the capacity to cope with increased frequency and intensity of natural disasters over the long term.

It should also be noted that climatic risks are not static. The baseline situation and baseline projections against which impacts of CSA are evaluated may change as climatic conditions change (Hedger *et al.*, 2008; Lamhauge *et al.*, 2011; OECD, 2009). Frequent updating of a 'moving' baseline with new information on climate, hazards, extreme events, and their impacts on agriculture is necessary to make the appropriate adjustments to CSA interventions and targets (Lamhauge *et al.*, 2011; Hedger *et al.*, 2008; Villanueva, 2010).

Inadequate capacity for assessment and monitoring and evaluation

Inadequate capacities (technical, human, institutional) and resources (human and financial) are often cited as barriers to successful assessment, monitoring and evaluation activities (UNFCCC, 2010a). The current trend is to use country-led systems. To make these national systems effective there is a need to strengthen human and institutional capacity through training and capacity development in the area of data collection, assessments, monitoring and evaluation for CSA (discussed in detail in Module 17 on capacity development).

In addition, monitoring and evaluation often have considerable transaction costs. Unless appreciated as a useful tool by stakeholders, monitoring and evaluation can be seen as a burden that offers little value for the effort involved in gathering an excessive amount of information.

Practicality of methods and tools

There is limited choice for appropriate analytical methods to address the specific needs and conditions of CSA projects for assessment, monitoring and evaluation. However, there is a considerable body of experience from natural resources management and rural development projects from which monitoring and evaluation activities can build upon (see Annex 18.1 on range of tools and good practices in their application).

Many of the existing tools and models are intended for highly skilled technical experts in academic institutions and may not be suited for the purposes of implementing CSA in developing countries. Further collaboration and communication between the developers of the tools and their users are necessary to ensure that simple tools that meet the needs of CSA practitioners are available. Some tools may be less sophisticated and produce less detailed scientific results but still successfully meet the needs of the CSA community. It is necessary to find the right balance between the simplicity of the tools and the reliability of the results.

Box 18.11
MRV for Kenya agricultural carbon project

Vi Agroforestry (Vi-skogen) is a Swedish development cooperation organization that works with farmers in the Lake Victoria Basin in Eastern Africa. The carbon project, which targets 60 000 smallholder farmers in 45 000 hectares in Western Kenya, plans to generate verified emission reductions through sustainable agricultural land management practices. Measurement, reporting and verification require direct, activity-based measurements that include estimates of tree carbon (measurements of diameter at breast height and allometric growth functions) and soil carbon (modelling with crop yields and land management practices data). Every year, all project participants collect core datasets. In addition, a sample of 200 farmers collect more intensive data. GPS units are used to measure farm plot size and location, but the majority of the data are collected manually with pencil and paper. The project maintains two data management systems with datasets on livelihoods and carbon. The database automatically checks the quality of manually entered data and calculates mitigation impacts. The carbon accounting methodology has been approved by the Verified Carbon Standard and is in the public domain. The project is working to develop a cost-effective way of monitoring emission reductions that minimizes transaction costs and maximizes benefits to farmers.

Source: IFC, 2012; PwC, 2012

18.6 Examples of assessment, monitoring and evaluation

In this section three case studies are presented to illustrate assessment, monitoring and evaluation in different contexts.

Case Study 18.1
Analysis of climate impacts on food security and livelihoods

Descriptive analysis of baseline vulnerability to climate risks

WFP is working with partners such as the UK Met Office Hadley Centre, the International Research Institute for Climate and Society, and the Climate Change, Agriculture and Food Security Research Theme of CGIAR (CCAFS), to develop a series of tools, methods, and services to better understand climate impacts on food security and livelihoods. The analytical methods have been tested in Ethiopia, Mali, Nepal and Senegal.

The methods include a descriptive analysis to establish a baseline against which spatial vulnerability to climate-related risks can be assessed. The aim of this component of the analysis is to identify the potential vulnerabilities of food security to climate variability through tailor-made, user-oriented outputs that can help prioritize interventions for the most vulnerable groups.

The data for the baseline vulnerability analysis are mainly taken from household surveys, such as the Comprehensive Food Security and Vulnerability Analysis or the Living Standards Surveys. For the descriptive assessment, the relevant climate-sensitive variables are identified in survey data (e.g. questionnaires, secondary data and livelihood profiles). The parameters are then selected, and their specific vulnerabilities to climate variables are described. This assessment provides information for identifying the spatial patterns of vulnerability and the factors that make regions and districts vulnerable.

Through this method, it is possible to determine the sources of food or income and then pinpoint the proportion of these factors that are climate-sensitive according to geographical region. Other vulnerability-related data, such as the consumption score, which illustrates the status of food security, and the coping strategy index, which quantifies the use of coping mechanisms during shocks (e.g. lowering food rations, lowering food quality, selling assets and migration) can also be quantified and plotted at the subnational level to identify who is the most vulnerable and prioritize interventions to support these communities.

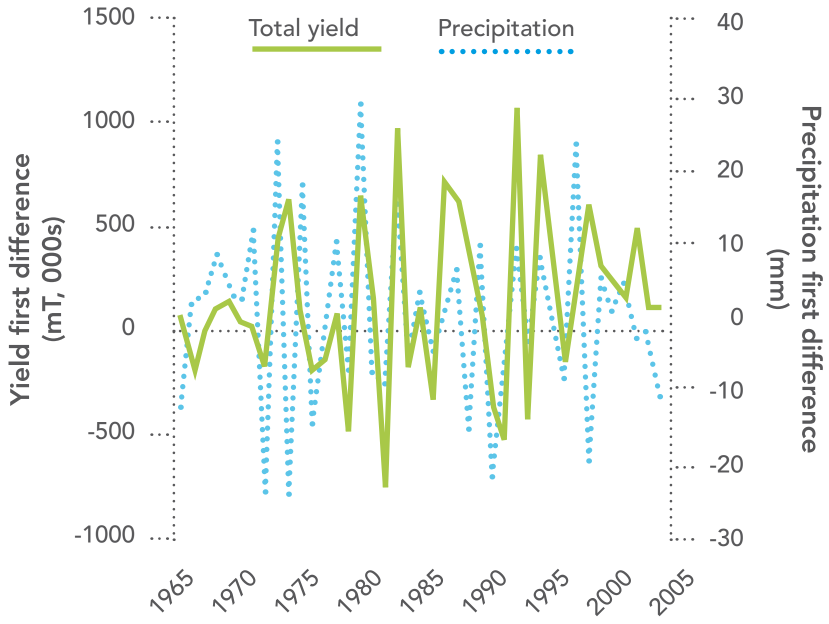
Temporal analysis of relationships between climate and food security

To complement the baseline assessment, long-term climate and food security data are also analysed. Through this analysis, it is possible to measure the impact of current and historical climate variability on food security indicators, such as crop and livestock production and food prices.

To evaluate the relationships between the time series for food security indicators and climate, the data are de-trended based on a first-difference time series (i.e. the differences in value from one year to the next). This method has been used in other studies to minimize the influence of gradual inter-annual changes associated with changes in crop management (e.g. Lobell and Field, 2007). Correlations between food security indicators (e.g. yield, food prices and livestock products) and climate variables (e.g. precipitation and temperature) are evaluated through regression analysis. A linear regression is calculated to identify the most relevant climate parameter for each crop in the different districts. Regression analyses help to identify the relative contribution of climate parameters on changes in food security indicators.

As an example, precipitation and yield correlations for the period 1965-2005 are illustrated in the figure below for Nepal.

Figure 18.10
Precipitation and yield correlations in Nepal for 1965-2005



Crop	R value
All	0.388
Paddy	0.490
Maize	-0.183
Millet	-0.197
Wheat	0.025
Barley	0.181
Potatoes	0.054
Pulses	0.086

For further information please see Box 16.2 in Module 16 on the R4 Rural Resilience Initiative (WFP)

Case Study 18.2
Drought early warning response system in Kenya with a multi-sectoral set of indicators and community-based monitoring

The Kenyan Government, with support from the World Bank, has established under the Land Resource Management Projects I and II (1996-2011), a drought early warning and response system (EWRS), which has been recognized by all stakeholders as highly successful. The first phase covered ten arid districts. In the second phase, the project's target area was extended to ten semi-arid districts. Together, the EWRS now covers about 80 percent of the country. The costs of the two projects over the 15 years of implementation has been US$ 81 million, with about US$ 20 million allocated to the EWRS.

The key characteristics of the EWRS are:

- It is multi-sectoral, combining environmental, livestock and pastoral welfare indicators.
    - The environmental indicators include rainfall and pasture conditions with the average distance to grazing areas as an important indicator for available grazing.
    - The livestock indicators include body condition and milk production.
    - The pastoral welfare indicators include:
        - livestock prices and, in particular, the grain and livestock price ratio as an important indicator for pastoral welfare (a rising ratio implies increasing stress levels); and
        - nutritional status, in particular through anthropometry measurements of children.
- It is participatory and decentralized, as the system relies on community-based local monitors (12 or more per district) who are literate members of pastoralist communities. They report to a broad based District Steering Group, which in turn reports to the Kenya Food Security Group, which includes representatives of the different ministries, NGO's and donors. To fully ensure involvement of all relevant sectors, the overall coordination is embedded in the Office of the President.
- It has a clearly defined set of stages (normal, alert, alarm and emergency) with clearly defined criteria, which greatly increases the transparency and reduces the political interference in the decision-making process.

No specific evaluations are yet available for the second phase. The first phase was subject to an in-depth audit by the World Bank's independent evaluation department. This audit reported that the early alert and response system supported by the project reduced the time between the onset of stress and response by two to three weeks. The system also helped organize response programmes to the 1999-2001 drought through aid agencies and NGOs, which saved livestock with the value of at least US$ 10 million per year. The early alert and response system is now being implemented in other countries, including Ethiopia.

Source: World Bank, 2008

Case Study 18.3
Regional silvopastoral project in Colombia, Costa Rica and Nicaragua: monitoring of carbon sequestration and biodiversity

The Regional silvopastoral project in Colombia, Costa Rica and Nicaragua was implemented between 2002-2008 with support from the Global Environment Fund, FAO's Livestock, Environment and Development Initiative and the World Bank. The total project costs came to US$ 8.7 million. The programme's main thrust is to convert degraded pastures by establishing silvopastoral systems (SPS) that combine fodder plants, such as grasses and leguminous herbs, with trees and shrubs. A total of 300 farmers participated in the project. The monitoring component (about US $ 1 million over a 5 year period) focused on land-use changes as a proxy for carbon sequestration and biodiversity enhancement. At the project start, a panel of experts estimated the carbon sequestration and biodiversity potential of the prevailing landscapes, and converted those into an index, on the basis of one point as the standard for carbon sequestration and biodiversity for primary forest. Carbon sequestration of secondary forest was estimated at ten tonnes of carbon per hectare. The index for each landscape was validated and later adjusted through field research that determined soil organic matter dynamics, and changes in bird, butterfly and mollusc populations.

Table 18.7
Environmental service indices of different landscapes in Colombia, Costa Rica and Nicaragua

Land use	Carbon index	Biodiversity index	Total
Degraded pasture	0	0	0
Live fences	0.3	0.3	0.6
Fodder banks	0.3	0.5	0.8
Natural pasture with low tree density	0.1	0.1	0.2
Improved pasture with high tree density	0.6	0.7	1.3
Secondary forest	1	1	2

In addition, water quality (biological oxygen demand) was measured to provide accurate information and understanding of the potential of intensified SPS in providing local ecological services. Table 18.7 provides the indices of some of the main land-use types.

These indices were used to develop the payment of an environmental service system. The year-to-year changes in the index of the different farm plots served as the basis for determining the amount to be paid for these services. For example, if farmers improved plot 1 (now in native pasture) to improved pasture with a high density trees (such as now in plot 2) they would have a 1.1 increase in the index, which, on the basis of US$ 7.5 per tonne of carbon would be equivalent to US$ 82.50 (1.1 index point increment, multiplied by 10 tonnes per index point, multiplied by US$ 7.5 per tonne of carbon per hectare).

The attraction of this system is that:

- It uses a landscape approach to enhance climate mitigation and adaptation.
- It is relatively easy to administer, as it is mainly GPS based. Costs per hectare for routine data collection to administer the payment of the environmental service system were about US$ 1 per hectare.
- Farmers clearly understand the system, as shown through their adoption of those strategies that were most profitable.

Overall the project was a striking example of a win-win-win:

- Farmers' income per hectare increased by 15 percent over the project period.
- Carbon sequestration over the entire project area (12 000 hectares) increased by 1.6 tonnes of carbon (or 3.5 tonne CO_2 eqv.) per hectare per year. In addition, a case study on a small number of farms indicates that silvopastoral technologies decreased emissions of methane by 21 percent and nitrous oxide by 36 percent.
- The number of bird, mollusc and butterfly species in the three pilot areas has doubled.
- Water quality improved significantly. In the one pilot area where it was measured, the biological oxygen demand declined from 11 to below 1.3.
- The inclusion of fodder shrubs enhanced climate resilience by providing high quality livestock feed in the dry season.

The project is now being scaled up in Colombia, and the SPS approach is being integrated into national systems in Costa Rica and Nicaragua.

Source: World Bank, 2008

18.7 Conclusions

Assessments for policy and project design are conducted during the conceptualization and preparation steps of a CSA project's planning. They provide situation analyses, clarify central problems and threats, and identify effective CSA measures. Monitoring and evaluation include: setting project baselines, defining indicators, measuring progress, and evaluating successes and problems of CSA interventions at the end of the project and beyond.

There are two major types of assessments for CSA policy and project design: climate impact assessments and CSA options assessments. Climate impact assessments characterize the changing local climate, the expected impacts on agriculture and the vulnerability (or resilience) of livelihoods. CSA options assessments can identify the options that will be more effective in achieving CSA objectives.

Monitoring and evaluation are initiated during the project preparation stage of the project cycle and are closely linked with the overall CSA planning. Monitoring tracks progress, checks intermediate results, and informs adjustments during the project implementation. Evaluation deals primarily with the assessment of the results and impacts of CSA interventions. The learning process identifies issues and draws lessons for future interventions and policies and should be integrated into the monitoring and evaluation process. The monitoring and evaluation framework presented in this module has six major elements: situational analysis and forecasting; intervention planning and targeting, and defining detailed indicators; implementation and monitoring; evaluation; monitoring and evaluation as closely related activities; and the importance of learning. The interventions should be designed within a results-based framework with particular emphasis on the development of appropriate indicators.

There are eight unique challenges for assessment, monitoring and evaluation for CSA: the difficulty of setting the goals and an agreed definition of CSA; the multi-sectoral nature of CSA and the involvement of various stakeholders; the issues of scale, leakage, permanency, externality and ancillary impact; the difficulty of obtaining quality data and information; the uncertainties with data, information, and methods; difficulty of attribution; inadequate capacity and resources; and the practicality of methods and tools. Most of the guiding principles for responding to these challenges are common to any assessment, monitoring and evaluation activity for CSA.

CSA practitioners are expected to use the guidance outlined in this module as a starting point for designing a more specific approach that satisfies the needs and context of a CSA plan and take into account the guiding principles.

Notes

This module was written by Hideki Kanamaru (FAO) and Jim Hancock (FAO) with contributions from Louis Bockel (FAO), Ademola Braimoh (World Bank), Elisa Distefano (IFAD), Wiebke Förch (CCAFS), Uwe Grewer (FAO), Claudia Hiepe (FAO), Madeleine Jonsson (Swedish Cooperative Centre), Krishna Krishnamurthy (WFP), Sarshen Marais (Conservation South Africa), Federica Matteoli (FAO), Katia Medeiros (FAO), Sibyl Nelson (FAO), Christina Seeberg-Elverfeldt (FAO), Philip Thornton (CCAFS), Ophelie Touchemoulin (SAUR) and Tamara Vantwout (FAO). Figure 18.8 was created by Uwe Grewer (FAO). Box 18.1 was written by Hideki Kanamaru (FAO) with material provided by Christina Seeberg-Elverfeldt (FAO). Box 18.2 was written by Wiebke Förch (CCAFS) and Philip Thornton (CCAFS). Box 18.3 was written by Elisa Distefano (IFAD). Box 18.5 was written by Uwe Grewer (FAO), Ophelie Touchemoulin (SAUR) and Louis Bockel (FAO). Box 18.6 was written by Kanamaru with material provided by Sarshen Marais (Conservation South Africa). Box 18.7 was written by Madeleine Jonsson (Swedish Cooperative Centre). Box 18.8 was written by Hideki Kanamaru (FAO) with material provided by Tamara Vantwout (FAO). Box 18.10 was written by Hideki Kanamaru (FAO) with material provided by Federica Matteoli (FAO) and Madeleine Jonsson (Swedish Cooperative Centre). Box 18.11 was written by Hideki Kanamaru (FAO) with material provided by Christina Seeberg-Elverfeldt (FAO). Case Study 18.1 was written by Krishna Krishnamurthy (WFP). Case Studies 18.2 and 18.3 were written by Ademola Braimoh (World Bank).

Acronyms

ADAPT	Adaptive, Dynamic, Active, Participatory and Thorough
CO_2	carbon dioxide
CO_2 eqv.	carbon dioxide equivalent
CCAFS	Climate Change, Agriculture and Food Security (research programme)
CGIAR	Consultative Group for International Agricultural Research
CSA	climate-smart agriculture
DFID	Department for International Development
DPSIR	Driving forces - Pressure – State – Impact – Response
EFA	economic and financial analysis
EWRS	early warning and response system
EX-ACT	Ex-Ante Carbon-balance Tool
FCPF	Forest Carbon Partnership Facility
GHG	greenhouse gas
GIS	geographic information system
GIZ	German International Development Cooperation
GPS	Global positioning system
GTZ	German Technical Cooperation
ICRAF	World Agroforestry Centre
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IFC	International Finance Corporation
IFRC	International Federation of Red Cross
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LDSF	land degradation surveillance framework
MICCA	Mitigation of Climate Change in Agriculture
MOSAICC	Modeling System for Agricultural Impacts of Climate Change
MRV	measurement, reporting and verification
NAPA	National Adaptation Programme of Action
NGO	non-governmental organization
OECD DAC	Organisation for Economic Cooperation and Development, Development Assistance Committee
PwC	PricewaterhouseCoopers
REDD+	reducing emissions from deforestation and forest degradation
SMART	simple, measurable, attributable, reliable, time bound (indicator)
SPS	silvo-pastoral system
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
WFP	World Food Programme

References

Alinovi, L., Mane, E. & Romano, D. 2010. *Measuring household resilience to food insecurity: application to Palestinian households*. In R. Benedetti, M. Bee, G. Espa and F. Piersimoni, eds. Agricultural Survey Methods. Chichester, UK, John Wiley & Sons Ltd.

Brooks, N., Anderson, S., Ayers, J., Burton, I. & Tellam, I. 2011. *Tracking adaptation and measuring development.* IIED Climate Change Working Paper No. 1.

Brooks, N., Anderson, S., Burton, I., Fisher, S., Rai, N. & Tellam, I. 2013. *An operational framework for Tracking , Adaptation and Measuring Development (TAMD).* IIED Climate Change Working Paper No. 5.

Carter, T.R., Jones, R.N., Lu, X., Bhadwal, S., Conde, C., Mearns, L.O., O'Neill, B.C., Rounsevell, M.D.A. & Zurek M.B. 2007. *New assessment methods and the characterisation of future conditions. Climate change 2007: impacts, adaptation and vulnerability*, by M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden & C.E. Hanson, eds. Contribution of Working Group II to the Fourth Assessment Report of the IPCC. pp. 133—171. Cambridge University Press, Cambridge, UK.

Climate Change, Agriculture and Food Security (CCAFS) & Consultative Group for International Agricultural Research (CGIAR). 2013. *CCAFS & CGIAR website.* (available at http://www.ccafs.cgiar.org/)

Colorado State University. 2013. *Agriculture and land use national greenhouse gas inventory software.* United States Environmental Protection Agency, United States Agency for International Development, United States Forest Service. (available at http://www.nrel.colostate.edu/projects/ALUsoftware/)

Conservation South Africa. 2013. *Greenchoice.* (available at http://www.conservation.org/global/ci_south_africa/our-initiatives/food-security-land-reform/greenchoice/pages/overview.aspx)

Department for International Development (DFID). 1999. *Sustainable livelihoods guidance sheets.*

Dessai, S. & Hulme, M. 2004. *Does climate adaptation policy need probabilities?* Climate Policy, 4(2): 107—128.

Elasha, B.O., Elhassan, N.G., Ahmed, H. & Zakieldin, S. 2005. *Sustainable livelihood approach for assessing community resilience to climate change: case studies from Sudan.* Assessment of impacts and adaptations to climate change (AIACC) Working Paper No. 17. AIACC.

Engle, N.L. 2011. *Adaptive capacity and its assessment.* Global Environmental Change, 21: 647—656.

FAO. 2001. *Socio-economic and gender analysis programme.* Field Level Handbook. (available at http://www.fao.org/docrep/012/ak214e/ak214e00.pdf)

FAO. 2008. *Andhra Pradesh farmer managed groundwater systems: evaluation report.* (available at http://www.fao.org/nr/water/apfarms/reports/GCPIND175NET-APFAMGS_eval_final.pdf)

FAO. 2009. *Joint guidelines for crop and food security assessment missions (CFSAMs).* (available at ftp://ftp.fao.org/docrep/fao/011/i0515e/i0515e.pdf)

FAO. 2010a. *Greenhouse gas emissions from the dairy sector: a life cycle assessment.*

FAO. 2010b. *The use of monitoring and evaluation in agriculture and rural development projects: findings from a review of implementation completion reports.*

FAO. 2011. *Measuring resilience: a concept note on the resilience tool.* Food security information and decision making concept note. EC-FAO Programme on Linking Information and Decision Making to Improve Food Security. (available at http://www.fao.org/docrep/013/al920e/al920e00.pdf)

FAO. 2012a. *Using marginal abatement cost curves to realize the economic appraisal of climate-smart agriculture: policy options.*

FAO. 2012b. *Annex 2: approaches to rapid assessments of impacts of climate variability and climate change on agriculture in the project area.* Incorporating climate change considerations into agricultural investment programmes: a guidance document. (available at http://www.fao.org/docrep/016/i2778e/i2778e.pdf)

FAO. 2012c. *The Ex-ante Carbon-balance Tool (EX-ACT).* (available at http://www.fao.org/tc/exact/ex-act-home/en/)

FAO. 2012d. *Learning module 2: FAO approaches to capacity development in programmes: processes and tools.* FAO Capacity Development. Office of Knowledge and Capacity for Development (OEKC), Food and Agriculture Organization. (available at http://www.fao.org/docs/eims/upload/299903/LM2_webready_interactive_final.pdf)

FAO. 2013. *Modelling System for Agricultural Impacts of Climate Change (MOSIACC).* (available at http://www.fao.org/climatechange/mosaicc)

Folke, C. 2006. *Resilience: the emergence of a perspective for social-ecological systems analyses.* Global Environmental Change, 16 (3): 253–267.

Forest Carbon Partnership Facility (FCPF), Global Environment Facility & Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autonoma de México. 2009. *Linking community monitoring to national measurement, reporting and verification for REDD+.* (available at http://www.forestcarbonpartnership.org/fcp/sites/forestcarbonpartnership.org/files/Documents/PDF/May2012/FCPF%20Durban%20Note%20-%20Community%20Monitoring%20for%20REDD%20MRV%20final_0.pdf)

Frankenberger, T., Langworthy, M., Spangler, T. & Nelson, S. 2012. *Enhancing resilience to food security shocks*. White Paper (DRAFT) May 2012. TANGO International, Inc. (available at http://www.fsnnetwork.org/sites/default/files/revised_resilience_paper_may_28.pdf)

German Technical Cooperation (GTZ). 2009. *Climate change information for effective adaptation: a practitioner's manual.*

German International Development Cooperation (GIZ). 2011a. *Making adaptation count: concepts and options for monitoring and evaluation of climate change adaptation.*

Global Donor Platform for Rural Development (GDPRD), FAO & World Bank. 2008. *Tracking results in agriculture and rural development in less-than-ideal conditions: a sourcebook of indicators for monitoring and evaluation.* (available at http://www.seachangecop.org/sites/default/files/documents/2009%2003%20World%20Bank%20-%20MandE%20indicators%20in%20agriculture.pdf)

Guijt, I. 1999. *Socio-economic methodologies for natural resources research: participatory monitoring and evaluation for natural resource management and research.* Chatham, UK, Natural Resources Institute. (available at http://www.nri.org/publications/bpg/bpg04.pdf)

Hedger, M., Mitchell, T., Leavy, J., Greeley, M., Downie, A. & Horrocks, L. 2008. *Desk review: evaluation of adaptation to climate change from a development perspective*. Institute of Development Studies.

Herweg, K., Steiner, K. & Slaats, J. 2012. *Sustainable land management impact monitoring module: a seven-step procedure for SLM-IM*. (available at http://srdis.ciesin.org/ & http://srdis.ciesin.org/pdf/slm-im.pdf)

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate change 2007: mitigation of climate change, B.* Metz, O.R. Davidson, P.R. Bosch, R. Dave & L.A. Meyer, eds. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. Cambridge, United Kingdom and New York, USA, Cambridge University Press.

International Federation of Red Cross (IFRC). 2006. *How to conduct food security assessment: a step-by-step guide for national societies in Africa.* (available at http://www.ifrc.org/Global/Publications/disasters/food_security/fs-assessment.pdf)

International Finance Corporation (IFC). 2012. *Smart lessons: more than just hot air: carbon market access and climate-smart agriculture for smallholder farmers.*

International Fund for Agricultural Development (IFAD). 2002. *Managing for impact in rural development: a guide for project monitoring and evaluation.* (available at http://www.ifad.org/evaluation/guide/index.htm)

IPCC. 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation, Field, C.B.,* V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, & P.M. Midgley, eds. A Special Report of Working Groups I and II of the IPCC. Cambridge University Press, Cambridge, UK, and New York, USA. 582 pp.

Lamhauge, N., Lanzi, E. & Agrawala, S. 2011. *Monitoring and evaluation for adaptation: lessons from development co-operation agencies.* OECD Environment Working Paper No. 38. OECD. (available at http://dx.doi.org/10.1787/5kg20mj6c2bw-en)

Lobell, D.B. & Field, C.B. 2007. *Global scale climate-crop yield relationships and the impacts of recent warming*. Environmental Research Letters, No. 2. 7 pp.

O'Brien, K., Eriksen, *S.,* Nygaard, L. P. & Schjolden, A. N. E. 2007. Why different interpretations of vulnerability matter in climate change discourses. Climate Policy, 7: 73—88.

Organisation for Economic Cooperation and Development, Development Assistance Committee (OECD DAC). 2009. *Policy guidance on integrating climate change adaptation into development co-operation.* Joint High-Level Meeting of the OECD DAC and the Environmental Policy Committee (EPOC), OECD. (available at http://www.oecd.org/document/40/0,3746,en_2649_34421_42580264_1_1_1_1,00.html)

Pearson, L. & Langridge, J. 2008. *Climate change vulnerability assessment: review of agricultural productivity.* CSIRO Climate Adaptation Flagship Working paper No.1. (available at http://www.csiro.au/resources/CAF-Working-Papers)

PepsiCo. 2012. *Agriculture.* (available at http://www.pepsico.com/Purpose/Environmental-Sustainability/Agriculture.html)

PricewaterhouseCoopers (PwC). 2012. *MRV and data management for CSA mitigation: climate-smart agriculture in Sub-Saharan Africa project.* (available at https://www.pwc.co.uk/assets/pdf/mrv-date-management-for-csa-mitigation.pdf)

Prowse, M. & Snilstveit, B. 2009. *Impact evaluation and interventions to address climate change: a scoping study.* International Initiative for Impact Evaluation (3ie).

Twigg, J. 2009. *Characteristics of a disaster-resilient community: a guidance note.* Version 2. Disaster Risk Reduction Interagency Group.

United Nations Development Programme (UNDP). 2009. *Applying climate information for adaptation decision-making.*

UNDP. 2010. *Screening tools and guidelines to mainstream climate change adaptation into development assistance: a stocktaking report.*

United Nations Environment Programme (UNEP). 2013. *Carbon benefits project: modelling, measurement and monitoring.* (available at http://www.unep.org/climatechange/carbon-benefits/Home/tabid/3502/Default.aspx)

United Nations Framework Convention on Climate Change (UNFCCC). 2010a. *Synthesis report on efforts undertaken to monitor and evaluate the implementation of adaptation projects, policies and programmes and the costs and effectiveness of completed projects, policies and programmes, and views on lessons learned, good practices, gaps and needs.* Note by the secretariat.

UNFCCC. 2010b. *Handbook on vulnerability and adaptation assessment.* Consultative group of experts on national communications from parties not included in Annex I to the Convention.

United States Department of Agriculture (USDA). 2002. *Community food security assessment toolkit.* (available at http://www.ers.usda.gov/media/327699/efan02013_1_.pdf)

Vågen, T-G., Winowiecki, L., Desta, L.T. & Tondoh, J.E. 2010. *The land degradation surveillance framework (LDSF) field guide.* ICRAF.

Villanueva, P.S. 2010. *Learning to ADAPT: monitoring and evaluation approaches in climate change adaptation and disaster risk reduction – challenges, gaps and ways forward.* Strengthening Climate Resilence (SCR) Discussion Paper No. 9. SRC. (available at http://community.eldis.org/.59d49a16/Learning-to-ADAPT.pdf)

Walker, B., Gunderson, L., Kinzig, A., Folke, C., Carpenter, S. & Schultz, L. 2006. *A handful of heuristics and some propositions for understanding resilience in social-ecological systems*. Ecology and Society, 11 (1). (available at http://www.ecologyandsociety.org/vol11/iss1/art13/)

Walker, B., Holling, C.S., Carpenter, S.R. & Kinzig, A. 2004. *Resilience, adaptability and transformability in social-ecological systems*. Ecology and Society, 9 (2). (available at http://www.ecologyandsociety.org/vol9/iss2/art5)

World Bank. 2004. *Ten steps to a results-based monitoring and evaluation system, by K.* J & R. Rist. (available at http://www.oecd.org/derec/worldbank/35281194.pdf)

World Bank. 2005. *Monitoring and evaluation for World Bank agricultural research and extension projects: a good practice note.* Agriculture and Rural Development Discussion Paper No. 20. World Bank, Washington, D.C.

World Bank. 2006. *Module 12: scaling up agricultural investments in the bank's changing internal environment.* Agricultural Investment Sourcebook. Washington D.C.

World Bank. 2008. *Implementation completion and results report.* (available at http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2008/11/25/000333037_20081125224142/Rendered/PDF/ICR00008750ICR1isclosed0Nov02502008.pdf)

World Bank. 2009a. *Note 2: assessing communities' resilience to climate change.* Mainstreaming adaptation to climate change in agriculture and natural resources management projects. (available at http://climatechange.worldbank.org/content/note-2-assessing-communities%E2%80%99-resilience-climate-change)

World Bank. 2009b. *Note 3: assessing climate risk.* Guidance Notes Mainstreaming Adaptation to Climate Change in Agriculture and Natural Resources Management Projects.(available at http://climatechange.worldbank.org/content/note-3-assessing-climate-risk)

World Bank. 2009c. *Note 7: evaluate adaptation via economic analysis.* Guidance Notes Mainstreaming Adaptation to Climate Change in Agriculture and Natural Resources Management Projects. (available at http://climatechange.worldbank.org/content/note-7-evaluate-adaptation-economic-analysis)

World Bank. 2010. *Note 8: monitoring and evaluation of adaptation activities.* Guidance Notes Mainstreaming Adaptation to Climate Change in Agriculture and Natural Resources Management Projects. Climate Change Team, Environment Department, World Bank.

World Bank. 2011. *Monitoring and evaluation tools, methods and approaches.* (available at http://go.worldbank.org/1K0M1NHOQ0)

Additional Resources

Aerts, J., Lasage, R. & Droogers, P. 2003. ADAPT: *A framework for evaluating adaptation strategies.* Report No. 3. Institute for Environmental Studies.

CCAFS & CGIAR. 2012. *Baseline surveys.* (available at http://ccafs.cgiar.org/resources/baseline-surveys)

Ecoagriculture partner site for Landscape Measures Resource Center (LMRC). (available at http://treadwell.cce.cornell.edu/ecoag1a/)

GIZ. 2011b. *Integrating climate change adaptation into development planning: a practice-oriented training based on an OECD policy guidance.* Handouts.

Sustainable land management toolkit module. (available *at* http://srdis.ciesin.columbia.edu/pdf/toolkit.pdf*)*

UNDP. Online *guidance for monitoring and evaluation for community-based adaptation is available from the UNDP Web site.* (available at http://www.undp-adaptation.org/projects/Websites/index.php?option=com_content&task=view&id=344)

Annex

A.18.1 Methods and tools for monitoring and evaluation

Basic tools

Most of the tools necessary for measuring the indicators and processes for the monitoring and evaluation of climate change related interventions are standard monitoring and evaluation tools, the most prominent of which are worth noting:

Participatory poverty assessment: helps to assess who are the most vulnerable in the community as defined by community members' own criteria. This helps to identify key intervention target groups.

Project and programme baseline assessments: done through surveys of intervention and control areas, measuring food security, incomes, basic household assets and services, as well as environmental parameters.

Regular project monitoring: gathering of activity and output progress data, financial management information, and signalling emerging issues or good practices.

Management information Systems: web-based support systems increasingly managed through remote devices, linked to financial management and GIS systems.

Agriculture and natural resource management monitoring: measured at frequencies and scales significant enough to provide meaningful information. The measurements can be done by a range of methods from structured crop to participatory transect walks.

Process monitoring: often done in support of regular monitoring to assess project process and institutional changes and relationships – to rapidly identify management responses.

Participatory monitoring and evaluation methods: a wide range of methods engaging communities, not just enhancing information gathering but also increasing ownership and project adaptation.

Impact evaluation methodology: Impact evaluation assesses the impact of an intervention using counterfactual analysis. The estimated impact of the intervention is calculated as the difference in mean outcomes between a 'treatment group' (those receiving the intervention) and a 'control group' (those who don't). This is done through randomization (experimental design), pipeline and matching. While it has been used little in climate change context so far, and faces some challenges there, due to the scales and externalities and process orientation, impact evaluation is increasingly advocated to understand attribution, has been applied to mitigation programs, and is often applied in agricultural and rural development and natural resource management projects. (Prowse and Snilstveit, 2009)

Stakeholder, Institutional and legal assessments: To assess changes in capacity, human resources, organizational systems, coordination, as well as laws and policies.

Economic and Financial analysis (EFA): using mainly agricultural, environmental and socio-economic data, as well as detailed market, labour and trade information, analyses are made of the economic and financial returns at household, farm and system levels.

Supporting good practices in monitoring and evaluation methods

Experience has shown the above tools by themselves may be implemented mechanically without great usefulness for decision making. Some useful practices in relation to strengthening monitoring and evaluation have been noted:

1. Use of triangulation and mixed methods: No one tool will provide all the information and complementary use of tools, quantitative and qualitative methods will be important. There can also be difficulty due to resource and ethical reasons to apply a strictly experimental design.
2. Getting management and stakeholder ownership and engagement in the monitoring and evaluation process. Often monitoring and evaluation is seen as a standalone reporting task. There is a need to internalize project management and staff responsibilities more.
3. There is a need to build capacity across the board on planning and monitoring and evaluation, and create a learning culture. CSA projects are often experiments, and need to maximize lesson learning for potential scaling up.
4. Networks and shared learning between projects and programmes is critical in rapidly sharing practical knowledge on monitoring and evaluation (examples of networks on monitoring and evaluation are www.3ieimpact.org, http://mande.co.uk, etc.) and similar sharing networks have considerable potential for monitoring and evaluation for CSA.

Glossary

Glossary

Adaptation (to climate change): Adjustments to current or expected climate variability and changing average climate conditions. This can serve to moderate harm and exploit beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

Adaptive assessment: The practice of identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility.

Adaptation benefits: Avoided damage costs or accrued benefits following the adoption and implementation of adaptation measures.

Adaptive capacity: The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

Afforestation: The conversion from other land uses into forest, or the increase of the canopy cover to above the 10 percent threshold.

Ageing of soils: Deposition of polysaccharides and other organic cementing agents by microbial activity in soil.

Agricultural Innovation System: A system of individuals, organizations, and enterprises focused on bringing new products, processes and forms of organization into social and economic use to achieve food and nutrition security, economic development, and sustainable natural resource management.

Agro-ecology: An ecological approach to agriculture that views agricultural areas as ecosystems and is concerned with the ecological impact of agricultural practices.

Agro-ecosystem: The organisms and environment of an agricultural area considered as an ecosystem.

Anaerobic digestion: Anaerobic Digestion is a natural process in which micro-organisms break down organic matter, in the absence of oxygen, into biogas (a mixture of carbon dioxide and methane) and digestate (a nitrogen-rich fertiliser).

Annex I countries: The group of countries included in Annex I (as amended in 1998) to the Framework Convention on Climate Change, including all the OECD countries and economies in transition. Under Articles 4.2 (a) and 4.2 (b) of the Convention, Annex I countries committed themselves specifically to the aim of returning individually or jointly to their 1990 levels of greenhouse gas emissions by the year 2000. By default, the other countries are referred to as Non-Annex I countries.

Agricultural biodiversity (agrobiodiversity): It is the result of natural selection processes and the careful selection and inventive developments of farmers, herders and fishers over millennia. Agrobiodiversity is a vital sub-set of biodiversity.

Aquifer: A water bearing stratum of permeable rock, sand or gravel.

Bagasse: Residues consisting of the fibrous portion of the sugar cane after the juice has been extracted. Used as fuel in sugar mills, as animal feed and in paper production.

Biodiversity: The total diversity of all organisms and ecosystems at various spatial scales (from genes to entire biomass).

Capacity Development (CD): The process whereby individuals, organizations and society as a whole unleash, strengthen, create, adapt and maintain capacity to set and achieve their own development objectives over time.

Carbon dioxide (CO_2): A naturally occurring gas, and also a by-product of burning fossil fuels and biomass, as well as land-use changes and other industrial processes.

Carbon finance (carbon market financing): Resources provided to projects generating (or expected to generate) greenhouse gas (or carbon) emission reductions in the form of the purchase of such emission reductions.

Carbon sequestration: The process of increasing the carbon content of a reservoir or pool other than the atmosphere.

Climate change: Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes.

Climate extreme (extreme weather or climate event): The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes.'

Climate-proofing: Ensuring that climate risks are reduced to acceptable levels through long-lasting and environmentally sound, economically viable and socially acceptable changes implemented at one or more of the stages in the project cycle.

Climate-smart agriculture (CSA): Agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes greenhouse gases (mitigation), and enhances the achievement of national food security and development goals.

Climate variability: Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Co-benefits: Multiple benefits in different fields resulting from one policy, strategy, or action plan.

Communication for Development (ComDev): ComDev is a social process based on dialogue using a broad range of tools and methods. ComDev is about seeking change at different levels including listening, establishing trust, sharing knowledge and skills, building policies, debating and learning for sustained and meaningful change.

Conditional transfers: Feature the provision of transfers in exchange of certain actions by beneficiaries, such as sending children to school or attending health clinics. Transfers include food, cash (i.e. 'conditional cash transfers') or vouchers.

Conditional cash transfers: Conditional cash transfers seek to break the cycle of poverty by developing human capital. Cash is provided upon the recipient's fulfilment of specific criteria, including enrolling children in school, regularly visiting the doctor, or receiving vaccinations.

Conservation agriculture (CA): Conservation Agriculture is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. It is characterized by three linked principles, namely, continuous minimum mechanical soil disturbance; permanent organic soil cover; and diversification of crop species grown in sequences and/or associations.

Controlled traffic: Restriction of all heavy wheel traffic to permanent traffic lanes.

Coping capacity: The ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters.

Crop diversification: Species diversification through varied crop associations and/or rotations (involving annual and/or perennial crops including trees).

Cross breeding: Crossbreeding refers to the process of breeding an animal or plant with purebred parents of two different breeds, often with the intention to create offspring or seedlings that share the traits of both parent lineages, or producing an animal or plant with hybrid vigor.

Deficit irrigation: An irrigation practice whereby water supply is reduced below maximum levels and mild stress is allowed with minimal effects on yield.

Deforestation: The conversion of forest to another land use or the long-term reduction of tree canopy cover below the 10 percent threshold.

Disaster: A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.

Disaster risk reduction (DRR): The concept and practice of reducing disaster risks through systematic efforts to analyse and manage the causal factors of disasters, including through reduced exposure to hazards, lessened vulnerability of people and property, wise management of land and the environment and improved preparedness for adverse events.

Disaster risk management (DRM): The systematic process of using administrative directives, organizations, and operational skills and capacities to implement strategies, policies and improved coping capacities in order to lessen the adverse impacts of hazards and the possibility of disaster.

Drought: The phenomenon that exists when precipitation is significantly below normal recorded levels, causing serious hydrological imbalances that often adversely affect land resources and production systems.

Drylands: Areas characterized by lack of water, which constrains their two major interlinked services of primary production and nutrient cycling.

Dry spell: Short period of water stress during critical crop growth stages and which can occur with high frequency but with minor impacts compared with droughts.

Ecosystem: The interactive system formed from all living organisms and their abiotic (physical and chemical) environment within a given area. Ecosystems cover a hierarchy of spatial scales and can comprise the entire globe, biomes at the continental scale or small, well-circumscribed systems such as a small pond.

Ecosystem functioning: Builds on the processes shaped by interactions among biological communities of both wild and domesticated species, biophysical processes such as water regulation, and nutrient recycling.

Ecosystem services: Ecological processes or functions that have monetary or non-monetary value to individuals or society at large. There are: supporting services such as productivity or biodiversity maintenance; provisioning services such as food, fibre, or fish; regulating services such as climate regulation or carbon sequestration; and cultural services such as tourism or spiritual and aesthetic appreciation.

Ecosystem resilience: The capacity of an ecosystem to absorb external pressure or perturbations through change and re-organisation, but still retain the same basic structure and ways of functioning.

E-learning (electronic learning): Term covering a wide set of applications and processes, such as Web-based learning, computer-based learning, virtual classrooms, and digital collaboration. It includes the delivery of content via Internet, intranet/extranet (LAN/WAN), audio- and videotape, satellite broadcast, interactive TV, CD-ROM, and more.

Energy efficiency: Ratio of energy output of a conversion process or of a system to its energy input.

Enteric fermentation: Enteric fermentation is a natural part of the digestive process for many ruminant animals where anaerobic microbes, called methanogens, decompose and ferment food present in the digestive tract producing compounds that are then absorbed by the host animal. A resulting byproduct of this process is methane.

Enteric methane: Methane emitted as a natural by-products of microbial fermentation of carbohydrates and, to a lesser extent, amino acids in the rumen and the hindgut of farm animals.

Erosion: The process of removal and transport of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, winds and underground water.

Evaporation: The amount of water that leaves the basin or country as vapor. Evaporation can be beneficial or non-beneficial. Non-beneficial (Enb) includes evaporation from open water bodies (reservoirs, canals) and from bare soil.

Evapotranspiration: It is the sum of evaporation and plant transpiration. It is the water lost from an area through the combined effects of evaporation from the ground surface and transpiration from the vegetation.

Ex-situ conservation: The maintenance of genetic material outside of the 'normal' environment where the species has evolved and aims to maintain the genetic integrity of the material at the time of collecting. Gene banks, botanical gardens and zoos are typical examples of ex-situ conservation activities.

Exposure: The nature and degree to which a system is exposed to significant climatic variations.

Extension: Rural or agricultural extension services refer to the transfer of research and new practices through farmer training. Successful extension does not merely facilitate the use of new technology or crop alternatives, but empowers farmers to make farm management decisions based on knowledge of options available to them.

Externalities: Situations when the effect of production or consumption of goods and services imposes costs or benefits on others which are not reflected in the prices charged for the goods and services being provided.

Farmer Field School (FFS): The FFS approach is an innovative, participatory and interactive learning approach that emphasizes problem solving and discovery based learning. FFS aims to build farmers' capacity to analyze their production systems, identify problems, test possible solutions, and eventually encourage the participants to adopt the practices most suitable to their farming systems.

Food losses: decrease in edible food mass available for human consumption throughout the different segments of the supply chain. In addition to quantitative losses, food products can also face a deterioration of quality, leading to a loss of economic and nutritional value.

Food and nutrition security: This exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Food system: Involves all processes and activities related to the production, distribution and consumption of food that can feed a population and affects human nutrition and health. It operates within an infrastructure (roads, rivers, ports, energy and communication networks, etc.) and is influenced by political, social, economic and environmental aspects.

Food value chain: The full range of farms and firms and their successive coordinated value-adding activities that transform raw agricultural materials into food products that are sold to final consumers and disposed after use.

Food waste: Food losses resulting from decisions to discard food that still has value. Food waste is most often associated with the behavior of retailers, the food service sector and consumers, but food waste and losses take place all along food supply chains.

Genetic resources (for food and agriculture): This includes any material of plant, animal, microbial or other origin containing functional units of heredity that is of actual or potential value for food and agriculture. Genetic resources for food and agriculture includes the diversity present in agricultural, pastoral, forest and aquatic production systems or of importance to them: the variety and variability of animals, plants and micro-organisms at the genetic, species and ecosystem levels that sustain the structure, functions and processes of production systems. This diversity is often the result of the work of farmers, pastoralists, forest dwellers and fisherfolk over many hundreds of generations and reflects the diversity of both human activities and natural processes.

Global circulation model: Numerical models that represent physical processes in the atmosphere, ocean, cryosphere and land surface, and are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations.

Green economy: An economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.

Green growth: Economic growth that is environmentally sustainable: green in that it is efficient in use of natural resources; clean, in that it minimizes pollution and environmental impacts; and resilient in accounting for natural hazards and the role of environmental management and natural capital in preventing physical disasters.

Greenhouse gases: Those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. This property causes the greenhouse effect. Water vapor (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O) methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine and bromine-containing substances, dealt with under the Montreal Protocol. Besides CO_2, N_2O, and CH_4, the Kyoto Protocol deals with the greenhouse gases sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

Hazard: A dangerous phenomenon, substance, human activity or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

High regret options: They are options valid for future climate but not necessarily for the current climate situation, and would therefore represent costs and have possible negative consequences under current climate, and therefore require careful consideration in terms of risk analysis.

Hydrological cycle: The process of evaporation, transpiration, vertical and horizontal transport of vapor, condensation, precipitation, interception, runoff, infiltration, percolation, storage, the flow of water from continents to oceans, and return.

Impact assessment (of climate change): The practice of identifying and evaluating, in monetary and/or non-monetary terms, the effects of climate change on natural and human systems. Potential impacts: all impacts that may occur given a projected change in climate, without considering adaptation. Residual impacts: the impacts of climate change that would occur after adaptation.

In-situ conservation: implies the maintenance and recovery of viable populations of species in their natural surroundings and – in the case of domesticated or cultivated species on farm – in the surrounding where they have developed their distinctive properties. This method preserves both the population and the evolutionary processes that enable the population to adapt by managing organisms in their natural state or within their normal range.

In-vitro conservation (of animal genetic resources): Conservation by cryopreservation of a breed's genetic material (usually semen, embryos or somatic cells), so that live animals can, if necessary, be regenerated in the future.

In-vivo conservation (of animal genetic resources): Conservation of a breed through maintenance of live animal populations, which encompasses both in-situ conservation of animals in their typical production environment and ex-situ in-vivo conservation, in non-typical surroundings, such as a research farm.

Inclusiveness: Agri-food systems and related agri-food value chains that enable ample participation by commercial input suppliers, farmers, traders, wholesalers, retailers and consumers as well as commonly marginalized groups (the poor, disabled, youth and women) in economic activities. Its focus is on wider social participation in agri-food systems and creating positive benefits to communities; it enables and involves even the smallest of participants in the overall agri-food system and others in a community that may not be involved in commercial activities; fair returns to all participants involved in activities; and fair, equal and safe employment conditions.

Information and Communication Technologies (ICTs): Technologies designed to access, process and transmit information. ICTs encompass a full range of technologies – from traditional, widely used devices such as radios, telephones or TV, to more sophisticated tools like computers, mobile phones or the Internet.

Institutions: Encompasses formal organizations and contracts as well as informal social and cultural norms and conventions that operate within and between organizations and individuals.

Integrated landscape management: An umbrella term for natural resource management systems that recognize the value of various ecosystem services to multiple stakeholders, and how this leads them to pursue different land use objectives or livelihood strategies.

Integrated pest management: An ecosystem approach to crop production and protection that combines different management strategies and practices to grow healthy crops and minimize the use of pesticides.

Joint Implementation (JI): Market-based implementation mechanism defined in Article 6 of the Kyoto Protocol, allowing Annex I countries or companies from these countries to implement projects jointly that limit or reduce emissions or enhance sinks, and to share the Emissions Reduction Units. JI activity is also permitted in Article 4.2(a) of the Framework Convention on Climate Change.

Kyoto protocol: The Kyoto Protocol to the Framework Convention on Climate Change () was adopted at the Third Session of the Conference of the Parties (COP) in 1997 in Kyoto. It contains legally binding commitments, in addition to those included in the UNFCCC. Annex B countries agreed to reduce their anthropogenic GHG emissions (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by at least 5 percent below 1990 levels in the commitment period 2008-2012. The Kyoto Protocol came into force on 16 February 2005.

Land grabbing: Controversial large-scale land acquisitions by domestic and transnational companies, governments, or individuals, which result in the disenfranchisement of the poor. The term has gained currency since the large-scale land acquisitions following the 2007-2008 world food price crisis.

Landscape: Agricultural landscapes can be described in terms of the three elements: (i) structure – the interaction between environmental features, land use patterns and man-made objects; (ii) functions – the provision of landscape functions for farmers and for society (environmental services); and (iii) value – concerning the value the society places on agricultural landscape and the costs of maintaining and enhancing landscape provisions by agriculture. Because the underlying human and natural processes are subject to change and evolution, landscapes are dynamic systems.

Landscape approach: Landscape approach means the management of production systems and natural resources in an area large enough to produce vital ecosystem services and small enough to be managed by the people using the land and producing those services.

Low regret options: see no regret options

Maladaptation: Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead.

Microfinance: The provision of credit and other financial services to small businesses which typically do not have access to such services, aiming to foster economic development.

Mitigation (in relation to climate change): Technological change and substitution that reduces resource inputs and emissions per unit of output. Although several social, economic and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHG emissions and enhance sinks.

Mitigation (in relation to hazard): The limiting or lessening of the adverse impacts of hazards and related disasters.

National Adaptation Programmes of Action (NAPAs): Documents prepared by least developed countries (LDCs) that identify the activities to address urgent and immediate needs for adapting to climate change.

Nationally Appropriate Mitigation Actions (NAMAs): A set of government prioritized actions aimed at reducing or limiting greenhouse gas emissions.

National platform for disaster risk reduction: A generic term for national mechanisms for coordination and policy guidance on disaster risk reduction that are multi-sectoral and inter-disciplinary in nature, with public, private and civil society participation involving all concerned entities within a country.

Natural hazard: Natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.

Networks: Networks can be vast repositories of data and/or affiliations of expert contacts on particular issues. Networks allow for knowledge to be shared and managed within and across institutions, thereby facilitating collaboration and research. Networks can also take up an advocacy role.

No regret options: options that are valid whether climate change will occur as expected or not. In general, they are aimed at increasing the resilience of rural population and reducing their vulnerability to water-related shocks.

Ocean acidification: Increased concentrations of CO_2 in sea water causing a measurable increase in acidity (i.e. a reduction in ocean pH). This may lead to reduced calcification rates of calcifying organisms such as corals, molluscs, algae and crustaceans.

Paludiculture: The process of transforming land into a wetland such as a marsh, a swamp or a bog.

Partnership brokers: Skilled communicators who support interactive collaboration between different types of stakeholders (e.g. public-private partnerships). Partnership brokering should minimize asymmetries of power between actors, ensuring that all stakeholders are heard and their expertise shared appropriately. Depending on the local context, the capacities and legitimacy available, a brokering role can be played by local government, extension services, civil society organizations or national agricultural research systems.

Payment for Environmental services (PES): An economic instrument designed to provide positive incentives to users of agricultural land and those involved in coastal or marine management. These incentives are expected to result in continued or improved provision of ecosystem services, which, in turn, will benefit society as a whole.

Peatlands: Peatlands or organic soils are soils with a substantial layer of organic matter near or at the surface.

Peri-urban agriculture: An agricultural system developed around cities to take advantage of local markets for high value crops (fruits, vegetables, dairy products, etc.).

Permaculture: Permaculture (permanent+agriculture) is the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems. It is a land use and community building movement which strives for the harmonious integration of human dwellings, microclimate, annual and perennial plants, animals, soils, and water into stable, productive communities.

Private sector: The part of an economy, industry, etc., which is privately owned and free from direct state control.

Public good: A good with benefits for the broader economy and society, or which generates benefits in a different location from where the activity takes place.

Public sector: The part of a country's economy which is controlled by the state.

Rainfed agriculture: Agricultural practice relying exclusively on rainfall as its source of water.

Reduce, Reuse, Recycle: The '3 R's'' of waste management. Reduction refers to minimizing the amount of waste generated from a given operation or process. Reuse refers to using the waste material "as is"— such as using waste oil for fuel. Recycling refers to reclaiming materials from the waste product or transforming the waste product into new products.

Reduced Emissions from Deforestation and Forest Degradation (REDD): REDD is a mechanism to create an incentive for developing countries to protect, better manage and wisely use their forest resources, contributing to the global fight against climate change. REDD strategies aim to make forests more valuable standing than they would be cut down by creating a financial value for the carbon stored in trees. Once this carbon is assessed and quantified, the final phase of REDD involves developed countries paying developing countries carbon offsets for their standing forests. REDD is a cutting-edge forestry initiative that aims at tipping the economic balance in favour of sustainable management of forests so that their formidable economic, environmental and social goods and services benefit countries, communities, biodiversity and forest users while also contributing to important reductions in greenhouse gas emissions.

Reduced Emissions from Deforestation and Forest Degradation Plus (REDD+): REDD+ strategies go beyond deforestation and forest degradation, and include the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in reducing emissions.

Reforestation: The re-establishment of forest formations after a temporary condition with less than 10 percent of canopy cover due to human-induced or natural perturbations. (FAO, 2000a)

Residual feed intake: The difference between an animal's actual feed intake and its expected feed requirements for maintenance and growth.

Resilience: The ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a hazardous event in a timely and efficient manner.

Riparian: Relating to land adjoining a stream or river.

Risk: The combination of the probability of an event and its negative consequences.

Risk assessment: A methodology to determine the nature and extent of risk by analysing potential hazards and evaluating existing conditions of vulnerability that together could potentially harm exposed people, property, services, livelihoods and the environment on which they depend.

Safety nets: A sub-set of broader social protection systems. Safety nets mostly include non-contributory transfers, such as in-kind food, cash or vouchers; they can be provided conditionally or unconditionally, and can be targeted or universal in coverage. Safety nets may also include other interventions to improve access to food and basic essentials, such as price subsidies. The terms safety nets, social safety nets, social transfers and social assistance are often used interchangeably.

Salinisation: The accumulation of salts in soils.

Sensitivity (to climate variability or change): Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. The effect may be direct (e.g. a change in crop yield in response to a change in the mean, range or variability of temperature) or indirect (e.g. damages caused by an increase in the frequency of coastal flooding due to sea-level rise).

Smallholder: The definition of smallholders differs between countries and between agro-ecological zones. In favourable areas of smallholder subsistence agriculture with high population densities, smallholders often cultivate less than one hectare of land, whereas they may cultivate ten hectares or more in semi-arid areas, or manage up to ten head of livestock.

Social protection: initiatives that: (1) provide income (cash) or consumption (food) transfers to the poor; (2) protect the vulnerable against livelihood risks; and (3) enhance the social status and rights of the excluded and marginalised".

Soil health: The capacity of soil to function as a living system.

Soil organic matter (SOM): Soil organic matter is any material produced originally by living organisms (plant or animal) that is returned to the soil and goes through the decomposition process. At any given time, it consists of a range of materials from the intact original tissues of plants and animals to the substantially decomposed mixture of materials known as humus.

Soil structure: Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. Single particles when assembled are called aggregates. Aggregation of soil particles can occur in different patterns, resulting in different soil structures.

Soil texture: Texture indicates the relative content of particles of various sizes, such as sand, silt and clay in the soil.

Subsoiling or Ripping: Soil preparation treatment done with tined implements to break up hardpans without turning the soil upside down.

Supplementary irrigation: The process of providing additional water to stabilise or increase yields under site conditions where a crop can normally be grown under direct rainfall, the additional water being insufficient to produce a crop. The concept consists in making up rainfall deficits during critical stages of the crops in order to increase yields.

Supply chain: The full range of activities, which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final customers, and final disposal after use.

Sustainability (Economic): A situation whereby: (1) the value added resulting from upgrading in the value chain (additional profits, wages, taxes, consumer value) is positive for each stakeholder in the extended value chain whose behavior (in terms of upgrading) is expected to change in order to create the additional value; and (2) the generation of added value sets in motion, or speeds up, a process of growth and structural transformation.

Sustainability (Environmental): Meeting the needs of the present without compromising the ability of future generations to meet their needs.

Sustainable and inclusive value chain development: The full range of farms and firms and their successive co-ordinated value-adding activities that transform raw agricultural materials into food products that are sold to final consumers and disposed after use, in a manner that is profitable throughout the chain, has broad-based benefits for society and does not permanently deplete natural resources.

Sustainable use of genetic resources: The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

Triple bottom line: The intersection of social, environmental and financial performance.

Unconditional transfers: Transfers that do not require reciprocal actions by beneficiaries (such as sending children to school) in order to access program transfers.

Vulnerability: The propensity or predisposition to be adversely affected; a function of potential impacts (exposure and sensitivity to exposure) and adaptive capacity.

Watershed: A topographically delineated area that is drained by a stream system, i.e. the total land area that drains to some point on a stream or river. The watershed is a hydrologic unit that has been described and used as a physical-biological unit and a socio-economic-political unit for planning and managing of natural resources.

Water scarcity: The point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be fully satisfied.

Weather-index insurance: A class of insurance products that can allow weather-related risk to be insured in developing countries where traditional agricultural insurance may not always be feasible, thereby helping to increase farmers' ability (and willingness) to invest in measures that might increase their productivity.

ISBN 978-92-5-107720-7

9 789251 077207

I3325E/1/05.13

www.fao.org/climatechange/climatesmart

Climate-Smart@fao.org