Adaptation Measures in Agricultural Systems

Messages to SBSTA 44 agriculture workshops

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Abstract

This working paper synthesizes knowledge within CGIAR on adaptation measures in agricultural systems, for the benefit of parties and observers preparing submissions to the UNFCCC SBSTA. Experience from CGIAR and partners indicate that adaptation measures covering policy, technological, financial, institutional, and research interventions are being tested and applied in agricultural systems in low-income and middle-income countries. Lessons include the need to ensure context-specificity when designing adaptation measures, engaging farmers in decision-making, and combining indigenous and scientific knowledge. Adaptation measures in agricultural systems are able to generate various added benefits in addition to adaptation benefits. These include enhanced food security, environmental benefits including mitigation of greenhouse gas emissions, and positive outcomes for gender and social inclusion. However, good design and implementation of these measures is important, for which capacity enhancement and technology transfer are essential functions.

Keywords

Climate change adaptation; agricultural systems; adaptation measures

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Acronyms

AWD	Alternate Wetting and Drying
CATIE	The Tropical Agricultural Research and Higher Education Center
CCAFS	CGIAR Research Program on Climate Change, Agriculture, and Food Security
CEDECO	Ecumenical Committee for Community Economic Development
CH_4	Methane
CIAT	International Center for Tropical Agriculture
CIDP	Country Integrated Development Plans
CIMMYT	International Maize and Wheat Improvement Center
CSA	Climate-Smart Agriculture
CSA-PF	Climate-Smart Agriculture Prioritization Framework
CSV	Climate-Smart Village
DACC	Sustainable Management of Natural Resources and Climate Change
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GHG	Greenhouse Gas
ICRAF	World Agroforestry Centre
IITA	International Institute for Tropical Agriculture
ICT	Information and Communication Technology
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change

IRRI	International Rice Research Institute
LAPA	Local Adaptation Plan for Action
LDCF	Least Developed Countries Fund
MADR	Ministry of Agriculture and Rural Development
MAFF	Ministry of Agriculture, Forestry and Fisheries
N_2O	Nitrous Oxide
NAMAs	Nationally Appropriate Mitigation Actions
NCCAP	National Climate Change Action Plan
NCCRS	National Climate Change Response Strategy
NEPAD	The New Partnership for Africa's Development
NGA	National Growers Associations
NICADAPTA	Adapting to Markets and Climate Change Project in Nicaragua
PAR	Participatory Action Research
PASCAFEN	Sustainable Agriculture in Coffee Plantations in Nicaragua
PLUP-CC	Participatory Land Use Planning for Climate Change
PRODECOOP	The Promoter of Cooperative Development in the Segovias
SBSTA	Subsidiary Body for Scientific and Technological Advice
SMAM	Sub Mission on Agricultural Mechanization
SNIA	National Agricultural Information System
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

Introduction

In 2014 the United Nations Framework Convention on Climate Change (UNFCCC) Subsidiary Body for Scientific and Technological Advice (SBSTA), as part of its mandate to consider issues related to agriculture, invited submissions from parties and observers covering four topics in 2015 and 2016. Of the two topics for consideration in 2016 one relates to *"Identification of adaptation measures, taking into account the diversity of the agricultural systems, indigenous knowledge systems and the differences in scale as well as possible co-benefits and sharing experiences in research and development and on the ground activities, including socioeconomic, environmental and gender aspects"*. In this context, CGIAR scientists have endeavoured to provide the knowledge base for parties and observers preparing submissions to the SBSTA and participating in in-session workshops during SBSTA44 in May 2016. We examine adaptation measures in agricultural systems from research within CGIAR, and provide key considerations for implementing these within diverse agricultural systems in low-income and middle-income countries. We also examine the role of indigenous knowledge systems in implementation, as well achieving scale in various contexts. Opportunities to achieve co-benefits, provision of adequate finance and capacity building have also been considered. Finally, we highlight opportunities to realize improved outcomes for gender and social inclusion through adaptation measures in agriculture. We adopt an approach of sharing successful programmes, pilots, methods, tools, and success stories and these case studies are embedded within the text to provide readers with practical understanding of how scientific research maybe applied in practice.

Adaptation measures refer to the wide range of actions and institutions that raise the adaptive capacity of agricultural systems. Here we consider the set of public sector and private sector measures that have particular potential to raise adaptive capacity among smallholder farmers in low-income and middle-income countries. Measures are generally applied at a higher level than practices and technologies that underpin them. In agricultural systems, we have identified the following adaptation measures: (1) governance, policy frameworks and readiness; (2) national planning; (3) local planning; (4) finance, economic incentives and value chain interventions; (6) research, extension, capacity building and knowledge systems; and (7) foresight, models and scenarios. In implementing these adaptation measures, we have examined how gender equality, social inclusion, and mitigation outcomes can be achieved as co-benefits. Underpinning these adaptation measures are various agricultural practices and technologies. Specific agricultural practices and technologies that enhance food security, resilience and productivity in a sustainable manner are presented in CCAFS Working Paper 146. These practices and technologies can be scaled up from farm level to national agricultural systems, and are categorized as: soil management, crop management, livestock management, forestry and agroforestry, fisheries and aquaculture, water management, energy management in agriculture, climate information services, and crop and livestock weather insurance.

1. Governance, policy frameworks and readiness

It is well recognized that if livelihoods and food security of farmers are to be improved in the face of climate change challenges, adaptation measures at massive scale will be needed. This will require an enabling environment to catalyse the positive behavioural changes that will be needed to move towards climate resilient food systems. Here we consider the foundations of that enabling environment: governance, policy frameworks and country readiness. Governance refers to the set of processes for decision-making and resource allocation at all levels from local to global, including both formal and informal processes, within and beyond governments. Features of "good governance" (that brings equitable and sustainable outcomes) are typically thought to be participation (i.e. clear mechanisms for stakeholders, especially more marginalized groups, to have a meaningful voice), transparency and accountability. Policy frameworks refer more specifically to statements of intent, including mechanisms for investment and action, made by the public sector, private sector or multi-stakeholder groups. Country readiness refers to the degree of preparedness of a nation state to deliver on policy frameworks, particularly where this delivery involves investment of finance (loans, grants, guarantees, etc.) from banks or development agencies.

Governance and policy frameworks: Coherence between climate and agriculture in international governance has grown tremendously in recent years. The Paris Agreement recognizes "the fundamental priority of safeguarding food security and ending hunger, and the particular vulnerabilities of food production systems to the adverse impacts of climate change". Agriculture is prominent in the 2015 and 2016 agendas of SBSTA. Of 113 Parties that included adaptation in their Intended Nationally Determined Contributions (INDCs) submitted ahead of the Paris COP, 102 (90%) include agriculture among their adaptation priorities, while 80% of INDCs included agriculture as a key sector for mitigation of greenhouse gas emissions (Richards et al. 2015). Similarly, agriculture is included in about 80% of plans on mitigation and adaptation (Action Aid 2011; Wilkes et al. 2013).

Climate adaptation is also being incorporated into mainstream agricultural planning and policy-making; a recent example is Nigeria's National Agricultural Resilience Framework (case study 1.1). In Southeast Asia, the Association of South East Asian Nations (ASEAN) member states have endorsed regional guidelines for promoting climate-resilience in the agricultural sector, and have mandated the ASEAN Climate Resilience Network to support implementation and scaling up of these efforts.

Momentum among multiple governmental and non-governmental stakeholders supports the transformation of agriculture systems towards long-term adaptive capacity in the face of climate change, especially in developing countries. For example, the African Union New Partnership for Africa's Development (NEPAD) has established Vision 25x25 aiming to have 25 million farmers practicing climate-smart agriculture by 2025 in response to the Malabo Declaration of 2014 (NEPAD 2015). The Global Alliance on Climate Smart Agriculture similarly brings interested stakeholders together for learning and exchange at the global level.

Country readiness: As climate finance becomes available for adaptation in agriculture, more attention is turning to country readiness, that is the capacity at national level to manage plan, implement, and monitor climate finance and activities related to climate change (Wollenberg et al. 2015). Key national-level capabilities that build country readiness for adaptation actions and adaptation finance are summarized in the table below.

Table 1. Dimensions of country readiness for climate change adaptation actions and finance (adapted from Wollenberg et al. 2015)

Effective governance and stakeholder engagement	Transparency, inclusiveness and effectiveness in national and local governance increased. The government engages civil society – including vulnerable and affected groups such as indigenous people and women – and the private sector in national and sub-national decision-making, strategy development and implementation.
Knowledge base and information services	Knowledge for planning and assessing the impacts of interventions exists, supported by extension services and targeted communication products.
Strategy and implementation framework	Food security, livelihood and climate change benefits are realized in climate- smart agriculture strategies and actions.
National and sub-national capabilities to develop sustainable infrastructure and investment strategies and practices	National and subnational programmes have inputs, technical capacities, and dependable funding necessary to implement adaptation and co-benefits.
National information system for monitoring and accounting in agriculture	Systems and capacities to develop and implement information and monitoring systems are established and operating.

Benefits

A key principle in designing appropriate policy frameworks is to build adaptive capacity across the agricultural system, rather than simply providing the enabling conditions for directional change. This is because future climate change trends and impacts are – for most localities and countries – fairly uncertain. Therefore governance arrangements, such as mechanisms for allocating global climate funds, and policy frameworks need to avoid trapping agricultural development in adaptation pathways aimed at climate futures that do not materialize. In some cases – for particular crops and countries – robust projections about future conditions can be made despite climatic uncertainty. For example, for coffee in Nicaragua and other Latin American countries, there is broad agreement that lowland coffee farming will not remain viable for much longer, given rising temperatures. The appropriate adaptation response in this case is a policy framework that combines enabling conditions both for *incremental* changes in coffee farming systems (e.g. better disease management) but also *transformative* changes towards a future agricultural economy based on alternative crops and value chains (case study 1.2).

Policy frameworks within agriculture, and in other key sectors such as forestry and agroforestry (case study 1.3), may be needed to support farmers in making the most efficient use of resources such as fertilizers, pesticides, and water, along with pricing policies that can promote diversified agricultural production systems, for example. Governance arrangements are especially important in managing risk, particularly as climate variability increases through time and the probabilities of extreme events, droughts and floods change. This makes it difficult for individual farmers to make appropriate decisions based on their own recent experience. Institutional interventions can either support farmers' own strategies at the local level, or improve the wider governance of food systems to dampen the negative effects of climatic shocks on food security. For example, to transfer risk across time, farmers may store water, food, and natural capital including livestock and trees; higher-level governance arrangements that can contribute may revolve around incentives for affordable private sector innovation, knowledge systems for pests and diseases, and food safety interventions (Agrawal and Perrin 2008). In livestock-based systems, risk may be transferred through market exchange, via improved market access and livestock insurance schemes, supported by market information networks and subsidized index-based insurance schemes (Chantarat et al. 2012). Many of these kinds of interventions require investment, and public and private institutions are needed to make finance available to smallholders on viable terms. Governance arrangements can also facilitate flows of the information and non-financial resources needed for farmers to increase the overall efficiency and resilience of their crop, fisheries and livestock production systems in the face of climate change.

Outlook

Smallholders will need a great deal of policy support if they are to adapt successfully, which in turn will entail evidence and analysis to support agricultural policy reforms. Various tools such as agricultural sector models can help analyse the possible effects of proposed changes in policy under climate change related to agricultural investment and technology and pricing patterns, for example (Nelson and Shively 2014). One issue is that there are large gaps in our knowledge of the relative costs and benefits of adaptation at different scales, whether associated with increasing on-farm resilience, insurance, safety nets or disaster risk management, for example. Another issue is the need to engage future uncertainty together with research to enhance the effectiveness of adaptation planning. Inclusion of multiple stakeholders in policy formulation and implementation, as in Kenya's National Climate Change Action Plan (case study 1.4), may be important to secure sustainable broad-based adaptive capacity. Tools that assist multi-stakeholder processes under climate uncertainty include scenarios that explore multiple plausible futures together with key stakeholders, allowing diverse actors to share and combine perspectives (Vervoort et al. 2014).

There is considerable research activity underway to understand the institutional environment and governance systems in which climate resilient food systems can be taken to scale, going beyond regional and global policy processes to consider other institutions and actors that shape discourse and power relations. A key challenge in emerging policy frameworks on climate adaptation in agriculture is an absence of provisions to assure gender equity (Vermeulen 2015). As Colombia demonstrates, collaborative work between policy-makers and researchers can enable adaptation programmes and investments to be better targeted towards specific stakeholders, and can improve information flows (case study 1.5).

Public sources of climate finance will play an increasingly important role in meeting the adaptation investment gap. Increasing volumes of international financing are becoming available, and accessing these will require developing countries to prioritize actions, evaluate their adaptation and mitigation benefits, and develop institutional capacity for monitoring and verifying the benefits. At the same time, better-targeted public sector finance is needed to leverage and incentivize private sector investments, particularly those that can generate the highest returns to food and nutrition security. Readiness frameworks will be increasingly important in enabling countries to qualify for, access and fast-track finance (Wollenberg et al. 2015).

Case studies

Case study 1.1: National Agricultural Resilience Framework (NARF) in Nigeria

Nigeria is particularly vulnerable to the impacts of climate change, as over 70% of the population relies on agriculture to support their livelihoods (Adegoke et al. 2014). In 2012, Nigeria's Federal Ministry of Agriculture and Rural Development (FMARD) set the goal of adding over 20 million metric tonnes of food to the country's food supply, reducing food import-dependency, increasing agricultural exports and creating 3.5 million jobs in food and agriculture. But these plans for rural development and national food security are vulnerable to climate change. Nigeria's National Agricultural Resilience Framework (NARF) is a key initiative in meeting this goal, aiming to develop a CSA programme for the country. The NARF was initiated by FMARD, drawing upon consultations with the Advisory Committee on Agricultural Resilience in Nigeria (ACARN), which convenes national and external experts on climate change, agriculture and food security. The implementation strategy includes a combination of both sector-specific innovations in agricultural production to boost productivity, and risk management mechanisms to enhance agricultural resilience. NARF seeks to strengthen the capacity of both small and large-scale producers, by improving their productivity and incomes, enabling them to thrive in the face of climate change and other constraints.

Case study 1.2: Transforming the agriculture sector: Adapting to Markets and Climate Change Project in Nicaragua

Coffee is the mainstay of the Nicaraguan economy, representing 20%-25% of the country's export revenues. However, CIAT's research showed that the sector is highly sensitive to climate change – threatening to take 80% of current coffee growing areas out of production within the next few decades. By 2050 coffee growing areas will move approximately 300 meters up the altitudinal gradient and push farmers at lower altitudes out of coffee production, increase pressure on forests and natural resources in higher altitudes and jeopardize the actors along the coffee supply chain. This requires transformative change in the Nicaraguan economy. The NICADAPTA Project (Adapting to Markets and Climate Change Project), launched by the Government of Nicaragua with support from the International Fund for Agricultural Development (IFAD)'s Adaptation for Smallholder Agriculture Programme (ASAP), is addressing sectoral change, including a transition from coffee to cocoa for affected lowland farmers and regions. The project facilitates crop diversification from coffee to cocoa, improves dissemination of agro-climatic information, raises market access, improves water efficiency and builds capacity of producer organizations and public institutions through training. The project intends to increase both the incomes and productivity of families belonging to cooperatives with investment plans in place by 20%. It is expected that 20,000 families will make investment decisions and adopt management practices that improve their resilience to climate change impacts. In addition, the project intends to incorporate diversified agricultural practices in over 25,000 hectares, to increase resilience and reduce climate risk.

Case study 1.3: National agroforestry policy of India

Of the 118 million farmers in India, over 80% are rainfed smallholders, who cultivate on two hectares of land or less. The dependence on seasonal rainfall as well as the small size of landholdings makes them highly vulnerable to climate change impacts. Agroforestry (incorporating trees and shrubs into farmlands and rural landscape) is a useful strategy for such farmers to increase the productivity from their land as well as to increase the resilience to climate change impacts (Chavan et al. 2015). In this context, the World Agroforestry Centre (ICRAF) and partners have promoted the approach in India. Taking cognizance of the multiple benefits of agroforestry, the Government of India launched an ambitious National Agroforestry Policy in 2014, to mainstream tree growing on farms (Government of India 2014). The policy aims to create convergence between various programmes, schemes and agencies containing agroforestry elements, in order to enhance the productivity, income and livelihoods of smallholder farmers. The policy also helps meet the increasing demand for agroforestry products such as timber, food, fuel, etc., protecting the environment and natural forests, and minimizing the risk during extreme climatic events. Since the policy was adopted in 2014, grants have been provided to six states and will cover approximately 70,000 ha in agroforestry (Dinesh et al. 2015).

Case study 1.4: Putting Kenya's National Climate Change Action Plan (NCCAP) into action

In 2013, Kenya launched its 2013-2017 National Climate Change Action Plan (NCCAP), taking the first step in an iterative process to bring the country towards a low carbon, climate resilient, and people-centred development pathway, merging climate change measures with wider development goals. The NCCAP brings into fruition ambitions for a Kenyan Action Plan dating back to 2009, during COP15 in Copenhagen, where the country presented its National Climate Change Response Strategy (NCCRS). The NCCAP is thus an operationalisation of the NCCRS, supporting the attainment of Kenya's Vision 2030 goals, which have the focus of transforming the country to an environmentally secure, middle-income economy. To put the NCCAP in motion, a National Adaptation Planning meeting for the agricultural sector took place in September 2013, comprised of 47 priority stakeholders including government ministries, farmers, NGOs, and the private sector. The purpose of the meeting was primarily to build consensus on the highest priority actions for agriculture in the short-, medium- and long-term perspectives. Prioritized actions identified include: drought-resistant crops, agroforestry, sustainable land management, improved water management, better use of fertilizers, and livestock breeding to increase resilience and more efficient resource use.

Case study 1.5: Climate and the Colombian Agriculture Sector: Adaptation for a Productive Sustainability

In 2013, an agreement was signed between the Colombian Ministry of Agriculture and Rural Development (MADR), the International Center for Tropical Agriculture (CIAT) and the National Growers Associations (NGA). The agreement seeks to enhance the competitiveness of the Colombian agricultural sector through the implementation of policy instruments, strengthening the investment into research, technological development and innovation. This collaboration consists of four actions that seek to strengthen the resilience of agriculture to climate change and improve efficiency: i) modelling and forecasts to support farmer decision making processes; ii) climate-site specific management as a tool to determine the most limiting factors, in order to increase productivity; iii) technological options for adaptation in priority crops as one of the adaptation measures in terms of developing new and more resistant varieties to climate change; and iv) environmentally sustainable production systems seeking to reduce negative impacts on natural resources while increasing productivity. Thanks to a capacity building plan established with researchers and partners, different kind of events were designed and facilitated in order to empower actors within the NGA. One of the key strategies is to disseminate agro-climatic information through agro-climatic newsletters by MADR. Currently the initiative reaches about 500,000 growers through Agronet, a platform for information management and knowledge. About 2,000 farmers are currently implementing these practices, mostly based on best varieties and planting dates at site-specific level.

2. National planning

Adaptation measures have varying impacts and environmental and economic costs, which change depending on place and time. Tools and approaches have been developed to assist national decision-makers in channelling adaptation investment in efficient, effective and equitable ways to address existing and future agricultural challenges. The objective is often to provide new analytical findings and/or help decision-making processes that use these results (Smit and Wandel 2006; Bours et al. 2014).

Adaptation decision-support approaches aim to guide decision-makers towards best-bet measures to be implemented over time, creating adaptation pathways towards sectoral transformation, which can be done by filtering down long lists of possible measures to adaptation portfolios (Hallegatte 2009; Corner-Dolloff et al. 2014). Other approaches also recognize along with selection of best-bet measures, adaptation itself can also be a process (Crane et al. 2011). Within this broader goal, tools have generally aimed to provide guidance on the following sub-questions:

1. What regions, production systems, and users should adaptation measures be prioritized for?
2. What ongoing and promising adaptation measures should be assessed for investment?
3. What criteria should be used to evaluate and prioritize measures, e.g. ability to build resilience, achieve co-benefits such as mitigation, economic costs and benefit?
4. What barriers to adoption exist and how can these be overcome for investment to have impact at scale?
5. What are the optimal policy options to support adaptation and transformation across spatial and temporal scales?

Tools can differ considerably in their approach to addressing these questions. Some are highly reliant on quantitative information (Stoorvogel et al. 2004; Hillier et al. 2011; Groot et al. 2012; Dunnett et al. 2015; Rosenstock et al. 2015) while others can utilize qualitative assessments, often by technical experts, or mix these approaches (Fussel 2007; Sanneh et al.

2014; Herrero et al. 2014a). Analytic processes can range from producing specific set outputs whereas others are more open to being co-designed, and analyses can target specific spatial and temporal scales or be modifiable to work across levels and time horizons. Co-development of tools with users, or at least the selection of tools that meet the specific needs of decision-makers, as well as co-design of the adaptation options being analysed, allows for existing realities, including capacity, timing, and funding (Andrieu et al. 2012, Meynard et al. 2012; Tittonell et al. 2012; Conway and Mustelin 2014), to be taken into account. Alignment with existing planning and policy cycles can also help in uptake of processes and results, and potentially in the iterative use of decision-support tools throughout implementation of programmes.

Investment in adaptation is needed at multiple levels of governance from agricultural management practices at the farm level to climate services or market interventions at subnational levels to programme and policy initiatives at the national, regional and global levels. These investments will be over different time-scales (short-, medium- and long-term). Portfolios of adaptation measures can be put together as packages of practices that act synergistically in the same spatially explicit area, that complement each other although conducted at different levels (e.g. climate services, efficient use of fertilizer, and early planting), or that can be conducted independently throughout a landscape based on localized context (e.g. fish ponds in low-lying areas and contour planting on slopes). While not all tools will be able to address these various types of adaptation measures, system level planning can integrate multiple investment allocation tools. Ultimately, if linked with institutionalized investment planning pathways, the use of these tools can facilitate increased evidence-based decision-making in both short- and long-term adaptation planning, resulting in improved decisions under existing and future uncertainties (case studies 2.2 and 2.3 provide examples of CSA-Plan).

Benefits

Investment allocation decisions are made by exploring trade-offs, and specifically maximizing positive desired outcomes over time. Tools often explore the trade-offs that exist between various outcomes, such as food security, resilience, or low-emissions development, and between the specific costs and benefits of adaptation measures. The potential performance of interventions changes given different future scenarios. Decision-makers need guidance towards robust investment decisions under existing and future risk and uncertainty (Vermeulen et al. 2013). Given the highly complex and multidisciplinary nature of adaptation, numerous variables can be considered, and mapping all trade-offs between potential changes that farmers will experience can be difficult to achieve. Some tools distil these trade-offs into singular scores used for ranking measures while others maintain the diversity presented through multi-criteria analyses (Dixit and McGray 2013; Prabhakar 2014). Visualization of trade-offs in ways accessible to decision-makers, allowing them to compare adaptation portfolios, should allow for more transparent and intentional investment decisions related to who and what benefits when and where (see case study 2.4 on optimizing benefits from "natural infrastructure" to improve climate resilience).

Climate change and agricultural planning processes, as well as decision-making and funding around adaptation and mitigation, should be linked to take into account the reality that adaptation measures impact all dimensions of agricultural systems simultaneously. Tools that promote integrated analyses and decision-making on cross-sectoral challenges can allow for improved planning towards transformation of agricultural systems. Improved planning will ultimately result from both cross-sectoral assessments and improved understanding of trade-offs.

Incorporating diversity of agricultural systems into adaptation investment allocation decisions

Adaptation measures are context-specific, and must be selected to suit the economic, environmental and social contexts. Performance of adaptation measures also differs given the context, depending on such factors as varying climate impacts, soil and water conditions, and household adaptive capacity and resource availability (Frelat et al. 2016). Potential adaptation measures should match the context in question and can draw heavily from local knowledge of ongoing adaptation practices that link with future threats and vulnerabilities (see case study 2.1 for example of prioritization in Mali). Systems typologies can also be used to identify differentiated recommendations as needed, for example varying portfolios based on production systems, agro-ecological zones, or different farmer groups (see case study 2.3 for example on CSA country profiles).

Incorporating indigenous/existing knowledge systems, gender equality, and social inclusion in adaptation investment allocation decisions

Stakeholder engagement is critical for appropriately contextualizing investment decisions, capturing existing knowledge, and identifying criteria for prioritization. Investment allocation tools and framework programmes are often used by higher-level decision makers who have access to funding streams. Perspectives of end-users and beneficiaries should also be included in the design and use of investment prioritization tools to improve links with locally desired outcomes of adaptation actions and perceptions of the feasibility of suggested measures, as well as, ultimately, the adoption of suggested measures at scale. Given adaptation interventions can have differentiated outcomes for different groups within society, analyses would ideally outline trade-offs for different beneficiaries prior to prioritizing adaptation investment decisions (see example of devolving climate change planning to local levels in case study 3.5).

Outlook

Given the urgent need for adaptation action, there is interest in tools that assist with rapid decision-making (see case study 2.6). While lack of data often limits the ability to conduct full quantitative analyses of all trade-offs between practices, decision-support tools provide opportunities to use available information, often expert knowledge, to make robust best-bet decisions and to identify gaps for research and development investment. Through monitoring evaluation and learning systems accompanying the scaling out of adaptation measures, new data can be gathered and included in future iterations of investment prioritisation. And regardless of the analyses provided, it must be recognized that investments are not made in a vacuum. Planners face a variety of constraints and political realities surrounding what to prioritize, and tools seen as useful often allow them to improve their decisions within these realities instead of attempting to provide prescriptive advice.

Scaling out adaptation measures on the ground also requires the assessments of the enabling environment, which can either promote or hinder the scaling up and out of adaptation measures. Effective adaptation investments focus both on the agricultural sector and beyond in order to address bottlenecks and barriers to adoption. Some common challenges to mainstreaming adaptation are limited extension services, poor access among farmers to inputs and markets, and weak access and capacity to utilize information services. Identifying barriers is critical to ensure particularly vulnerable groups, including women, the very poor and young people, are receiving development benefits from investment allocation. Some barriers can be overcome in the short-term while others will require longer-term investment, so identifying timelines for rolling out actions based on existing and future entry points for different priority adaptation measures can assist in investment creating pathways towards adaptation.

Capacity building

The process of co-designing and using investment allocation decision tools in and of itself is often a capacity building exercise. Stakeholders gain a better understanding of the adaptation concept, technical methods for data assessment and interpretation, and systematic processes for assessing measures and planning for impact. At the same time, stakeholder involvement may inform the tool design and help improve the tool. If conducted in inclusive participatory ways decision-makers may find themselves empowered to take on more holistic and integrated planning processes in the future.

Implementation of adaptation measures on the ground many require investment in additional capacity building of actors along the implementation pathway. This could include establishment of cross-sectoral partnerships and information sharing, technology transfer to extension systems and farmers, and establishment of monitoring, evaluation and learning systems that feel into iterative planning (see case study 2.5). These enablers for achieving adaptation measures can also be considered in investment allocation decisions, because without the capacity to enact the priority measures on the ground mainstreaming will be stalled.

Case studies

Case study 2.1: Climate-Smart Agriculture Prioritization Framework in Mali

Malian decision-makers have come together to identify and scale out priority adaptation actions for the agriculture sector given the overall susceptibility of the national economy to climate change, especially with highly erratic rainfall and dry years, and 50% of Gross Domestic Product (GDP) coming from the agriculture sector. In an effort to find solutions, the Malian Association of Awareness of Sustainable Development (AMEDD), a local NGO, in collaboration with the Agency of Environment and Sustainable Development, and with the support of CIAT and CCAFS, led the participatory use and development of the Climate-Smart Agriculture Prioritization Framework (CSA-PF) (Corner-Dolloff et al. 2015; Loboguerrero and Corner-Dolloff 2016). The CSA-PF began in September 2014 in Mali with the identification of vulnerable regions and production systems of Mali to focus investment in the country. A Steering Committee of national agricultural experts led the delineation of three priority regions and the selection of 23 potential adaptation measures related to regional production systems. The measures were evaluated for the impact they were expected to have on productivity, adaptation, and mitigation using eleven indicators that were selected by the Steering Committee and other regional stakeholders. Prioritization of a shortlist of high-interest measures was based on criteria set by the stakeholders, which included the evaluation of impact and links between practices and specific climate threats. The shortlist of measures was then fed into a more detailed cost-benefit analysis, and from there portfolios of adaptation measures were selected for investment and scaling out.

Case study 2.2: CSA-Plan: A guide for operationalizing planning and implementation of adaptation measures in agricultural systems

CSA-Plan provides a four-step planning guide along with specific tools to operationalize adaptation measures. These are:

Situation Analysis involves stocktaking and provides an understanding of the climate risks, vulnerabilities and institutional readiness for mainstreaming adaptation in agricultural development. For example the Climate-Smart Agriculture (CSA) Country Profiles developed by the CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS), International Center for Tropical Agriculture (CIAT), the Tropical Agricultural Research and Higher Education Center (CATIE) and the World Bank originally in Latin America and now being scaled out globally (see case study 2.3).

Targeting and Prioritizing provides an understanding of trade-offs and value for money of potential investment portfolios. For example, the CCAFS CSA-PF (highlighted in case study 2.1) facilitates governments, donors, and other development partners to establish agricultural investment portfolios that reduce trade-offs between productivity, adaptation, and mitigation outcomes.

Programme design provides training curricula, extension materials, and implementation plans that enable the development and delivery of systems and information to scale adaptation interventions by turning knowledge into action. This provides a means for operationalizing adaptation measures in terms of practical on-the-ground implementation, institutional structures, and financing. CCAFS, the Food and Agriculture Organization of the United Nations (FAO), The New Partnership for Africa's Development (NEPAD) and partners are developing a CSA Practical Guide for implementation.

Monitoring, evaluation and learning using an evidence-based results framework that develops strategies and tools to track progress of implementation and evaluate impact across scales. This involves identification of metrics and indicators, which have been selected and evaluated to be simple, measureable, accurate, reliable and time-bound (‘SMART’).

Case study 2.3: Latin American country profiles for Climate-Smart Agriculture

With support from the World Bank, climate scientists from CIAT and CATIE launched an initiative to kick-start CSA across Latin America and the Caribbean, with the goal of improving food security while enhancing agriculture's climate change resilience and mitigating GHG emissions. The first output of this partnership is an assortment of seven country (and two sub-national) profiles, including Argentina, Colombia, Costa Rica, El Salvador, Grenada, Mexico, and Peru (CIAT, 2014). The CSA profiles were developed in collaboration with government agencies, civil society, and the private sector. The profiles describe the overall context of climate change and agriculture in each country, and contain an inventory of existing CSA technologies and practices, the institutional and policy context, financing opportunities, as well as a selection of case studies for the most promising initiatives. The country profiles raise awareness among governments and financing institutions on successful practices, and help identify specific entry points for investment and scale up.

Case study 2.4: Optimizing benefits from "Natural Infrastructure" to improve climate resilience

Many of the most significant impacts of climate change on agriculture will be felt through changes in the water cycle. More productive and resilient agriculture requires changes in the management of natural resources and greater efficiency in the use of those resources, including water. "WISE-UP to climate", is a project that demonstrates how natural ecosystems (conceived as natural infrastructure in landscapes) and the ecosystem services they provide, can contribute to climate change adaptation and sustainable development. The objective of the project is to determine how to optimize the benefits from combinations of built water infrastructure (e.g. dams, levees, irrigation channels) and natural infrastructure (e.g. wetlands, floodplains, watersheds) for poverty reduction, water-energy-food security, biodiversity conservation, and climate resilience. The project, led by IUCN with contributions from IWMI and many other partners, is funded by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Germany. Research is being conducted in the Tana River basin in Kenya and the Volta River basin in West Africa. In both basins agriculture dominates water use, is vital for the livelihoods of many millions of people and is likely to be significantly affected by climate change. The project will generate knowledge that improves understanding of: i) of how ecosystem services support the functions of built infrastructure; ii) how ecosystems services are changing because of changes in climate; and iii) how the data and tools needed to incorporate ecosystem services into water resources development and climate change adaptation can be made available to policy makers and water resource managers.

Case study 2.5: Uruguay: Sustainable Management of Natural Resources and Climate Change (DACC)

To support the long-term vision of Uruguay on sustainable intensification, the Ministry of Agriculture, Livestock, and Fisheries (MGAP) worked together with the World Bank to design the Sustainable Management of Natural Resources and Climate Change (DACC) project. The DACC project targets family farmers and medium sized producers, providing technical assistance and financial incentives, on a matching grant basis, to approximately 4,000 family farmers and medium-size producers to invest in measures that improve their resilience to extreme climatic events. One of the notable achievements of the DACC project is the establishment of a National Agricultural Information System (SNIA) and the required preparation of soil management plans, to increase productivity, promote climate resilience, and reduce the emissions of key crop systems. The SNIA, centralises and analyses agricultural, economic and climate data and information from 25 national agencies to support better decision-making on agricultural and investments policy frameworks. It also provides oversight to the soil-use and soil-management plans produced by farmers for government use, and offers tools to increase farmers' access to information, an agrochemical control system, rural risk assessments, soil and land-use plans, and water studies for irrigation. As a consequence of these, among other adaptation measures, the country has quadrupled its agricultural production within a decade, while increasing the resilience and adaptation of their productive systems to climate change, and significantly reducing GHG emission associated with food production (current technologies are estimated to reduce carbon emissions by about 8.8 million tonnes CO_2 per annum).

Case study 2.6: Application of Climate-Smart Agriculture Prioritization (CSAP) tool for investment planning

A Climate-Smart Agriculture Prioritization Toolkit has been developed and tested by the CCAFS South Asia team together with CGIAR centres and local partners in the region (CCAFS 2014). This toolkit employs a dynamic, spatially-explicit optimization model to explore a range of sectoral growth pathways coupled with climate-adaptation strategies. The modelling framework consists of three major components: (i) land evaluation including assessment of resource availability, land suitability, yield and input-output estimation for all promising crop production practices and technologies for key agro-ecological unit; (ii) formulation of scenarios based on policy views and development plans and (iii) land-use optimization in the form of linear programming models. Integrating detailed bottom-up biophysical, climate impact and agricultural-emissions models, CSAP is capable of supporting multi-objective analysis of agricultural production goals in relation to food self-sufficiency, incomes, employment and mitigation targets thus supporting a wide range of analyses ranging from food security assessment to preparation of climate-smart development plans (Dunnett and Shirsath 2013). One case study had been completed for Bihar State of India. The investment required to climate-proof Bihar agricultural development is explicitly identified – providing valuable bottom-up evidence to support top-down estimates of the costs of climate change adaptation. Through application of the model to a range of constrained growth pathways it has been able to demonstrate the potential of the model to identify priorities for investment in: (i) Crops best suited to delivering target growth under impacts of climate change on yields; (ii) Technologies to deliver targeted increases in growth based on potential yield increases and efficient use of resources; and (iii) Locations for priority investment given existing surplus productive capacity, further, the investment required to climate-proof agricultural development is explicitly identified – providing valuable bottom-up evidence to support top-down estimates of the costs of climate change adaptation. Further case studies are going on in Bangladesh, Nepal and other states of India.

3. Local planning

Climate change impacts are location specific and variable within national boundaries. Thus, the granularity of adaptation measures is important to ensure that these measures are relevant to the local context (Smith 2015). Adaptation planning in some countries is taking cognizance of these needs, for example both Nepal and Pakistan have Local Adaptation Plan for Action (LAPA) initiatives which aim to identify local needs, and allocate resources based on these needs (Chaudhury et al. 2014). In Kenya, the National Climate Change Action Plan (NCCAP) is being operationalized through County Integrated Development Plans (CIDPs) (see case study 3.5). However, provision of greater decision-making authority to decentralized levels should be done together with efforts to increase capacity for planning and implementation (Kissinger and Lee 2013), as well as the availability and access to financial resources at local level.

Local planning can be mainstreamed within adaptation planning in two different ways, either through 'bottom up' or 'top down' approaches (Wright et al. 2014). In a top down approach, Government agencies responsible for planning ensure that local planning is mainstreamed within national programmes (Wright et al. 2014). On the other hand, in a bottom up approach, planning is usually scaled up or out from local community-driven autonomous adaptations (Wright et al. 2014). Both top-down and bottom-up approaches to local planning are equally important and help take into account local adaptation needs and coping mechanisms (Niang-Diop and Bosch 2005).

Success factors

Wright et al. (2014) has identified the key success factors to ensure that local planning processes realize adaptation outcomes. These include:

- participatory and locally driven vulnerability assessments (see case study 3.1 on participatory diagnosis in Burkina Faso);
- tailoring of adaptation technologies to local contexts (see case study 3.2 on participatory land-use planning in Vietnam and case study 3.4 on Climate-Smart Villages in South Asia);

- working in partnership with local institutions (see case study 3.3 on joint efforts by international, national, and local institutions).

Outlook

While local planning is extremely important in terms of addressing the granular nature of climate change impacts, some challenges need to be addressed to ensure that such adaptation measures are successful. These challenges arise from weak governance, gaps in in the regulatory and policy environment, high opportunity costs, low literacy and underdeveloped markets (Wright et al. 2014). Capacity building efforts can play an important role in helping overcome these challenges.

Case studies

Case study 3.1: Participatory diagnosis and planning approach for Climate-Smart Villages in West Africa: Evidence from Yatenga, Burkina Faso

Participatory diagnosis of climate change adaptation issues in Yatenga was conducted by the International Union for Conservation of Nature (IUCN) and its partners to monitor and evaluate the local adaptive capacity to climate change (Somda et al. 2011). The participatory diagnosis led to the identification of potential solutions to improve present living conditions in the area, which was translated into a programme of activities for Tibtenga (2012 to 2014). The work plan was focused on addressing three main issues: higher tree mortality, decrease in crop productivity and limited access to technical information. The actions were about building up soil and water conservation (SWC) techniques, farmers managed natural regeneration and tree planting, and introducing improved varieties of crops. These actions achieved a number of outcomes including strengthening of the social organization in the village, building of farmers' capacity, the strengthening of collaboration between farmers and the technical services, and the development of partnership in the village. The use of improved varieties and *zaï* techniques improved the yield of cowpea and sesame. The use of climate information contributed to increased cowpea yield by 24% and gross margin by 66% (Ouédraogo et al. 2015). Natural regeneration and tree planting based on *Adansonia digitata* and *Cacia tora* contributed to improving the vegetation cover in farmers' field and increased food productivity and incomes particularly for women.

Case study 3.2: Participatory land-use planning in Climate-Smart Villages in Vietnam: Linking community land- use plans with wider-scale land-use plans

In Southeast Asia, a Climate-Smart Village (CSV) comprises a community and the immediate surrounding landscape that contains natural and human elements (e.g. climate, environment, local community) and interactions among these elements. In this small landscape, one of the initial activities in supporting the local community adapt to climate change is the development of a community land-use plan. For this purpose, CCAFS Southeast Asia developed a Participatory Land Use Planning for Climate Change adaptation strategies (PLUP-CC) approach for CSVs, that integrates community knowledge of limitations and potentials of natural resources, including climate-related risks, in developing land-use plans. In Vietnam, PLUP-CC has been implemented in 3 CSVs from September to November 2015 as part of the social preparation and community mobilisation activities. The process has been done in partnership with IRRI, CIAT, ICRAF, Can Tho University and the Department of Agriculture and Rural Development of Bac Lieu province and of Vinh Loi district (in Mekong River Delta), farmers' unions (in the Central part of Vietnam) and the northern Mountainous Agriculture and Forestry Science Institute (in the northern Uplands of Vietnam). The CSV land-use plans were actively analysed and discussed by participants at consultation meetings and farmers re-organized land-use pattern in the village and specified appropriate areas for cultivation, livestock and agroforestry.

Case study 3.3: Participatory planning and investment in Guatemala and Nicaragua

To realize their ambition to establish a local biofertilizer processing plant in Esteli, Nicaragua, the cooperative Promoter of Cooperative Development in the Segovias (PRODECOOP) developed an investment plan named Sustainable Agriculture in Coffee Plantations in Nicaragua (PASCAFEN) in collaboration with Hivos and the Ecumenical Committee for Community Economic Development (CEDECO), with the aim of attracting investors (CEDECO 2015). With such an investment 2,300 affiliated organic coffee farmers can get access to affordable organic fertilizer to improve soil and nutrient conditions, and enhance coffee productivity and disease resistance under climate change. A multi-disciplinary team consisting of Bioversity, Hivos, ICRAF, CEDECO and UVM started with support of CCAFS and Hivos developed a participatory approach that helps farmer cooperatives identify agro-ecological practices for investment. The approach is being tested with the cooperative PRODECOOP in Nicaragua and with Barillense Farmers Association (ASOBAGRI) in Guatemala where 1,000 Maya farmer families are affiliated. The PASCAFEN case study will help understanding how cooperatives can develop investment plans and attract investors. Researchers are carrying out activities with women and men at community, cooperative and national level to prioritize agro-ecological practices for planning and investment following established PAR concepts (Schattman et al. 2015). Both cooperatives are experimenting with support of this project with online survey development and mobile data collection to include indicators in their internal systems for monitoring and evaluation.

Case study 3.4: Adaptation through Climate-Smart Villages in South Asia

Climate-Smart Villages (CSVs) are a unique initiative started by CCAFS which is extensively piloting and scaling up/out in South Asia. The CSV approach enhances climate literacy of farmers and local stakeholders and develops climate resilient agricultural systems through linking existing government's village development schemes and investments (Aggarwal et al. 2013). The model also puts emphasis on the involvement of existing community groups consisting of farmers, village officials, civil society organizations, local government officials, community based organizations (e.g. water user groups, forest user groups, and micro-finance institutions), private sector and researchers from the national agricultural research systems (NARS) in designing, implementation and monitoring of climate-smart interventions in the villages. International organizations, national and state governments have shown keen interest to invest and scale out the CSV approach in various locations. In India, CSVs are currently being piloted in more than 100 villages in Haryana, Punjab, Andhra Pradesh, Karnataka and Bihar (CIMMYT/CCAFS 2014). These include interventions related to tillage, planting methods, diversification, and water and nitrogen management individually or in various combinations based on farmer's choice. Based on the evidence created, it is planned to implement the CSV approach in Maharashtra tribal regions (1000 villages) and Haryana (500 villages) with seed money grant from the state Government (Jat et al. 2015). The encouraging results are now being replicated at large scale in Nepal through a funding support from IFC, ICOMOD and CDKN in collaboration with government of Nepal (Gautam and Chhetri 2015; Agrawal 2015). WorldFish is also piloting CSVs in two coastal districts in Bangladesh and evaluating the potential of scaling out CSVs in the country.

Case study 3.5: Adaptation planning in Kenya: Devolving Kenya's National Climate Change Action Plan

In order to strengthen and focus national actions towards climate change adaptation and mitigation, Kenya developed a National Climate Change Response Strategy (NCCRS) in 2010. In order to operationalize and take forward the implementation of the NCCRS, a National Climate Change Action Plan 2013-2017 (NCCAP) was developed in 2012 through a comprehensive stakeholder engagement process. NCCAP is expected to inform national development and policy decisions in all sectors of the economy. NCCAP identifies and prioritizes a range of immediate, medium and long-term adaptation actions in the context of a low carbon climate resilient development pathway. CSA and agroforestry are among the "big wins" identified within the NCCAP, with the agricultural sector offering great potential for synergies among the multiple objectives of food security, poverty reduction, adaptation and mitigation. Many of the CSA practices identified in NCCAP also reduce GHG emissions and improve agricultural productivity.

Under Kenya's constitution, governance and services delivery have been devolved to County Governments, providing an excellent opportunity for implementation of NCCAP priority adaptation actions at local level. Specific actions at county level include developing county adaptation plans to provide information on the impacts of climate change in the county, existing and proposed adaptation activities, including financing, monitoring and evaluation; mainstreaming adaptation priorities and actions into the 5-year County Integrated Development Plans in line with the NCCAP and integrating low carbon climate resilience considerations into county planning and programmes. Already, some of the county governments such as Isiolo and Garissa counties are piloting LAPAs, working with the government and CARE, respectively.

4. Finance, economic incentives and value chain interventions

Climate finance refers to the flow of funds that aim *"at reducing emissions, and enhancing sinks of greenhouse gases and aims at reducing vulnerability of, and maintaining and increasing the resilience of, human and ecological systems to negative climate change impacts"* (UNFCCC 2014 p. 5). The amount of climate finance invested globally in 2014, from both public and private sources, is estimated to be USD 391 billion, of which 38% comes from public sources and 62% from private sources (Buchner et al. 2015). Mitigation actions account for 93% of total climate finance flows in 2014, while adaptation accounts for 6% and joint actions comprise the remaining 1% (Ibid.). The total amount of investments in 2014 land-use mitigation and/or adaptation reached USD 7 billion on average (USD 6-8 billion) (Ibid.). The total public mitigation finance directed to agriculture, forestry and land use is estimated at approximately USD 3 billion, whereas the total adaptation finance directed to the same sector is also estimated at approximately USD 3 billion (Ibid.).

Most of this chapter discusses climate finance, but also recognizes the necessity of linking with economic incentives and value chain interventions. Economic incentives are financial policy instruments, such as tax exemption, minimum prices, assured purchase, grants and soft rural credits programmes, tradable certification and green markets in value chains, payment or compensation for environmental services (FAO 2013). Value chain interventions refer to institutional innovations that bring value chain participants together to deliver better outcomes from the value chain, such as greater efficiency or greater resilience to climate change. Examples of value chain interventions include commodity roundtables, retailer-supplier agreements, supply chain standards and certification, and ethical investment (often labelled impact investment or social investment).

Benefits

Increased access to public and private climate finance has the potential to support governments, agri-businesses, and farmers to adopt improved agricultural practices, manage risks better in the short-term and adapt to the adverse effects of climate change in the medium-term, while becoming more productive and resilient in their agricultural systems. For instance, as a result of these improved practices and the increased adaptive capacity, farmers might be able to sustain or increase their productivity, and subsequently their incomes and food security, better protect their assets base, and also reduce their vulnerability to external shocks and climate hazards. Moreover, agri-businesses may use this support to better manage their risks while developing more resilient supply chains that can also produce mitigation co-benefits. Finally, governments might use these increased resources to design and implement more appropriate adaptation and mitigation strategies, and to improve or develop policy frameworks that create more conducive and less risky investment environments to efficiently use public climate finance to attract and leverage private investments (see case study 4.1).

For these investments to achieve meaningful impact, both public and private climate finance need to ensure that financial flows are directed to those geographic locations, ecosystems and local communities that are most vulnerable to climate change, while aligning with nationally set priorities and taking into consideration context-specific needs, existing capacities and trade-offs. While the constraints that smallholder farmers often face to engage in formal markets might be a deterrent to private sector investments, climate finance presents an excellent opportunity to support farmers to access improved and increased technical assistance as well as existing and additional public and private sources of finance to overcome these challenges and further engage in formal and more developed markets.

Economic incentives can provide the basis for ensuring that climate finance targets adaptation and mitigation opportunities most effectively, and reaches poor smallholders who are most in need, without creating an unsupportable risk burden on investors. For example, subsidies to farmers can enable them to overcome barriers to investment in farm machinery and other capital that increases resilience to climate change (see case study 4.2). Working with already established value chain interventions can enable benefits to reach scale much more quickly. For example, climate change adaptations are being built into existing voluntary certification networks in the coffee and cocoa sectors, allowing scaling up to 30% of global cocoa producers and 15% of global coffee producers (see case study 4.3).

Outlook

The developing countries that are most vulnerable to the adverse effects of climate change, more specifically Least Developed Countries, Small Islands Developing States, and sub-Saharan African countries, face significant challenges and barriers to access both public and private sources of climate finance, which significantly limits their capacity to develop climate-resilient agricultural systems. These barriers are context-specific. Coupled to these, the amount of funds available for this purpose is still insufficient, as only 17% (USD 25 billion) of the total volume of all public climate finance in 2014 was allocated to adaptation activities, directing on average 12% (USD 3 billion) of the total adaptation finance to the agriculture, forestry and land-use sector (Buchner et al. 2015). Furthermore, the lack of common definitions and activity boundaries at country level, coupled with data gaps and different approaches to tracking and reporting climate finance investments, limit the ability of policy makers, donors and investors to understand the current climate finance landscape and address the investment gaps.

In addition to these barriers, potential recipients also face challenges to access finance for adaptation due to insufficient understanding of the adverse effects of climate change (particularly the granularity of impacts) and the potential positive impact of adopting appropriate adaptation strategies. Furthermore, some countries experience difficulties to understand and meet some of the complex fund procedures and criteria, which coupled with the limited number of funds that allow direct access to finance, add another layer of complexity to their insufficient resources and institutional capacity to design and implement effective adaptation interventions. Last but not least, there is need to assist these counties to access and develop relevant climate information, as well as invest in more conducive policy environments and regulatory frameworks to attract public and private climate investment.

However, climate finance for adaptation represents an excellent opportunity to address the challenges faced by countries in reducing and overcoming climate change risks, developing low-carbon economies and fostering climate-resilient development (see case study 4.1). For instance, public climate finance coupled with economic incentives has a vital role to play in meeting the essential adaptation needs of vulnerable countries to build resilience against climate shocks and livelihoods stresses, by supporting policy frameworks and providing incentives for behaviour change (see case study 4.2). Public climate finance can enable adoption of appropriate adaptation strategies, disaster risk reduction and early warning systems, and basic infrastructure to access markets. Furthermore, public finance has the potential to catalyse private climate finance by encouraging the development of public-private partnerships, bridging viability gaps and improving the risk-return profile of climate-related investments.

Finally, private climate finance is critical to achieve the scale needed in adapting to the adverse effects of climate change. It can do so by generating new sources of finance, through both debt and equity, to fill the gap in the current climate finance system, scaling up existing business and market opportunities, attracting additional investors (see case study 4.3 on scaling adaptation through voluntary certification networks), providing risk management services such as insurance schemes, building more resilient supply chains in their agricultural food production systems and designing, developing and supplying goods and services that can help end users to better adapt to a changing climate. For example, the ongoing development of climate bonds has the potential to leverage billions of dollars even if only a tiny fraction of the total climate bond market, estimated at roughly USD 600 billion (CBI 2015) can be directed toward investments in land. The Agriculture, Forestry and Other Land Use (AFOLU) standard of the Climate Bonds Initiative is being developed to help public and private investors identify investment opportunities that follow high-quality standards to lower the perceived investment risks.

Another way to leverage public and private sector climate finance for adaptation is to access the greater sum of finance available for mitigation, for example through the carbon market. For example, in an agroforestry mitigation project, although the investment is made primarily to offset emissions, for the farmers the benefits of increased tree cover on farms and in managed landscapes is a tangible livelihood improvement due to the diversification of products derived from the trees, reduced exposure to climate hazards and, above all, the high value of the timber, some of which can be sold on local markets (in essence the trees become biological savings accounts that can be monetized in times of need). In the Sustainable Agriculture in a Changing Climate (SACC) project, the value of the trees was estimated to be 70 times higher than the value of the carbon (Foster et al. 2013; Foster and Neufeldt 2014). Hence, biocarbon projects can provide important livelihood and adaptation benefits to smallholder farmers while providing mitigation co-benefits to international carbon markets.

The World Agroforestry Centre (ICRAF) is currently testing this approach through its BIODEV project in Burkina Faso (ICRAF 2015).

Case studies

Case study 4.1: Climate finance for agricultural adaptation in sub-Saharan Africa

Sub-Saharan Africa faces the conundrum of being the region least responsible climate change (4% of global emissions), while being most vulnerable to its impacts. Additionally, current climate finance streams to the region are unlikely to meet the need for adaptation, particularly for the most climate vulnerable populations who are reliant on agricultural livelihoods. A fundamental barrier is the difficulty of designing and implementing projects that are both viable and replicable. Therefore, public sector grants will continue to play an important role. Twenty climate funds are currently active in sub-Saharan Africa, including the Clean Technology Fund which has approved USD 466 million for four large projects, and the Least Developed Country Fund (LDCF), bringing over USD 458 million to 126 projects. The LDCF is involved in implementing the most urgent adaptation activities, which have been identified by the country's NAPAs. One key challenge is the fact that only 45% of the approved climate funding in sub-Saharan Africa is being directed towards adaptation measures, meaning that the region's demonstrated need for USD 18 billion per year in adaptation finance is currently not being met. Although it is beneficial to assist countries in sub-Saharan Africa in improving mitigation, their vulnerability to climate change may require further a reprioritization of funding towards adaptation measures (Barnard et al. 2014).

Case study 4.2: Economic incentives to increase resilience of Indian agriculture

Making agriculture resilient to climate change is a policy priority for the Government of India. Among schemes promoting climate-resilience is the Sub Mission on Agricultural Mechanisation (SMAM) which is one of the four major components of the National Mission on Agricultural Extension and Technology (NMAET). The SMAM was launched in 2014 with budget allocation of USD 2.11 billion to achieve inclusive growth of farm mechanisation in the country in the next five years in terms of farm power availability, human resource development, and productivity and quality assurance of agricultural machinery. SMAM relies heavily on economic incentives to achieve its objectives. It provides farmers subsidies of 25-50% on purchase of new machines for zero-tilling, seed drilling and laser land levelling. While all farmers are entitled to avail themselves of capital subsidies, small-scale and marginal farmers, women farmers and farmers in areas with lower farm power availability get priority. Half of the subsidy is reserved for small-scale and marginal farmers and 30% is earmarked for women farmers. Apart from individual farmers, SMAM also provides subsidy on capital and operational costs to agencies (private, cooperative or not-for-profit) to establish custom hiring centres on the condition that such centres will provide rental services to farmers at affordable rates. In fact, 40% of subsidies on machines under SMAM are earmarked to set up farm machinery banks for custom hiring.

Case study 4.3: Scaling adaptation measures through value chains: coffee and cocoa

CIAT and IITA are collaborating with the Rainforest Alliance, Root Capital and the Sustainable Food Lab in Ghana, Nicaragua and Peru to develop appropriate adaptation measures with farmers and other value chain actors in cash and food crop value chains. The project leverages existing smallholder value chain interventions to translate climate science into actionable strategies for farmers and supporting actors. This novel combination adds value to existing work with the goal of achieving adoption at scale for locally relevant adaptation measures, while engaging multiple actors to understand site-specific projections of climate impacts and develop suitable responses. By partnering with existing voluntary certification networks that cover 30% of global cocoa producers and 15% of global coffee producers, as well as with impact investing firms that provide approximately USD 500m of investments into producer organizations annually, this project will be able to build site specific adaptation measures into existing certification, training and extension networks with multiple public, NGO and private service providers.

5. Research, extension, capacity building and knowledge systems

Adaptation in agriculture is highly knowledge-intensive. The uncertain and dynamic nature of climate change impacts means that we need to build capacity to deal with constant change on a proactive basis, as opposed to implementing one-time step changes in agricultural systems. This in turn requires a comprehensive capacity development approach of all stakeholders that builds on sound assessments of needs across multiple levels of capacity: individual, organizational and enabling environment (Hiepe and Kalas 2013). Strong engagement will be needed with education and extension agencies of all descriptions: public and private, national and local, formal and informal. Indeed, after several years of declining investment, the urgent need for climate adaptation provides an opportunity to revivify extension services – to "make extension sexy again" (Daniel Jimenez, CIAT, personal communication). Modern communications technologies, particularly mobile phone applications, are increasingly offering a powerful, cost-effective way to revitalize extension services – but also to provide a platform for peer-to-peer learning among farmers, and for large numbers of farmers to inform research and policy decisions.

Research and associated knowledge systems are, similarly, critical adaptation measures. As climates change, consistent long-term investment in research at national level – and collaboratively across countries – will pay off for adaptation at farm, agriculture sector and national food security levels. Experience shows that research works best as an integral component of shared agricultural innovation systems – when the process brings farmers and researchers together for shared agenda-setting, field trials and interpretation of results and options. More generally, agricultural research for development is likely to have greater positive impacts when it works directly with policy makers and practitioners throughout the policy cycle (Vermeulen and Campbell 2015). The ideal knowledge systems under climate change are agricultural innovation systems that link public and private research, extension and advisory services to generate, manage, blend and share indigenous and scientific knowledge, while facilitating learning processes and network-based innovation (Hiepe and Kalas 2013).

Relevant areas of research include:

1. Vulnerability, targeting and social institutions: Integrating climate resilience into farmer-led development agendas (see case studies 5.1 and 5.2 on farmer research platforms in Ethiopia, Tanzania and Kenya). Building climate interventions on local and national capacities. Targeting and tailoring interventions effectively to different user groups, particularly by gender. Mechanisms for bringing successful pilots to scale, including finance, capacity building and technology transfer.

2. Agricultural management systems: Development of improved management systems for agriculture, livestock and fisheries that can lead to higher outputs despite prevailing adverse environmental conditions, and improving efficiency wherever possible. Development of institutions and technologies that save water, energy and other inputs (e.g. labour, fertilizer).

3. Supporting services and risk management: Development of early warning systems, climate information services for farmers, weather insurance and innovative credit systems to support farmers' adaptations.

4. Breeding for future climates: Development of improved crop cultivars and animal breeds that are more resilient and resource-use efficient, and thus can cope with the direct and indirect consequences of climate change. Participatory testing and selection of improved varieties with farmers.

5. Post-harvest management: Development of improved technologies and practices for energy and water use efficiency in processing, storage and transport of food and other agricultural products. Research on incentives and practices for reducing post-harvest losses, particularly on-farm, linked to value chain development. Addressing dietary patterns as a promising adaptation option.

6. Landscapes and ecosystems: Integrated management of soils, water resources, biodiversity, forests, rangelands, wetlands and bioenergy to support resilience.. Maximizing co-benefits to mitigation via reduced deforestation.

7. Policies, markets and governance: Testing options to enable adaptation via programmes, regulations, economic incentives, value chain coordination, community-based planning,

and other policy and governance measures. Multi-stakeholder analyses of plausible future scenarios under climate change.

8. Climate data and knowledge systems: Improving use of climate and weather information in agricultural research and in communicating forecasts to farmers. Continuous assessment of climate change impacts on agriculture. Coupling climate models with socio-economic and biophysical models, linked to bottom-up analyses of vulnerability and capacity.

Combining traditional means of communication and information sharing with modern methods can help reach people – often women – with lower literacy; extension programmes can be targeted explicitly, using rural radio and television (see case study 5.3 on Shamba Shape Up), for example. Another innovative model to support technology transfer is a project aimed at increasing youth employment in Malawi and Tanzania, involving the public and private sectors in training young people in climate-resilient agricultural practices, who then sensitize their peers to innovations learned through the programme. The model offers facilitated access to markets for young people's products through networks of producers' organizations, while young people receive a fair negotiated price for their produce and a voice in local associations (FAO 2013). Similarly, under the CCAFS infomediary programme in the Philippines, high schools students learn agriculture practices in schools and take the knowledge back to their families and communities.

Benefits

Agricultural innovation systems that bring farmers, researchers, private sector and government together have demonstrated ability to speed up the rate of learning, innovation, knowledge exchange and adoption. Participatory plant breeding is a clear example – barley breeding that involves both farmers and researchers has been shown to be 5-28% cheaper than conventional methods, mainly because it produces equivalent genetic material three years earlier (Mangione et al. 2006). The effectiveness and value for money of research on adaptation in agriculture are proven; for example, studies on the impact of the work of CCAFS (2015b) and its partners show how adaptation research can increase farmers' incomes by several percentage points in the space of a few years, while also improving outcomes for the environment and wider rural development. Gender and social inclusion are critical areas of research to ensure equitable benefits: research shows that women and men have different priorities for insurance products, which can help target products and maximize outcomes for people's resilience (Greatrex et al. 2015; Huyer et al 2015).

Outlook

Some immediate concrete opportunities for scaling up benefits from research, extension, capacity building and knowledge systems include:

1. Sustained investment in national public sector research, extension and innovation systems, that build inter-disciplinarity across social sciences, agricultural sciences and climate sciences, and bring together indigenous, scientific and other knowledge systems (see case study 5.6).

2. Revitalization of extension services, including through use of ICTs and other novel, low-cost means of large-scale knowledge transfer from farmers to service agencies and researchers, and vice versa (case study 5.4 on new approaches to extension in India).

3. Collaboration in international knowledge initiatives and platforms that address adaptation in agriculture, such as the Coordinated Regional Downscaling Experiment (CORDEX), Agricultural Model Intercomparison and Improvement Project (AgMIP), Global Alliance for Climate-Smart Agriculture (GACSA), CGIAR-CCAFS, AgTrials (see case study 5.5 on CGIAR-CCAFS).

4. Incentives for private sector R&D on adaptation that provides broad-based benefits to food security, such as public-private R&D partnerships (see case study 5.6 on public-private sector collaboration on climate-ready germplasm).

5. Cross-country knowledge exchanges at all levels (linking policy, indigenous and scientific knowledge) – (see case study 5.7 on exchange between Senegal and Colombia).

6. Participation in international capacity development programmes, such as West African Science Service Center on Climate Change and Adapted Land Use (WASCAL), Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA), Global Change System for Analysis, Research & Training (START) (see case study 5.8 on CLIFF, the Climate Food and Farming Network).

7. Improving institutional contexts for cross-country technology transfer, particularly around germplasm and at the regional level (see case study 5.6).

Case Studies

Case study 5.1: Farmer citizen science to face climate change: the ClimMob platform

The ICT-based ClimMob platform helps farmers identify adaptation measures faster. Current farmer-participatory approaches to identify locally appropriate technologies often require much effort in organizing farmers' groups, establishing dialogues between scientists and farmers, and organizing joint experiments. Without obviating the need for group activities, the ClimMob platform makes it possible to organize experiments in which farmers participate on an individual basis and use ICT to communicate results. Farmers each receive three different technologies to test and report their observations and preferences in a simple format using mobile phone technology. As different farmers test different combinations of technologies, they can jointly test a pool of 10-20 technologies. The platform combines the farmer trial data with weather data to analyse the results, making it possible to take full advantage of the environmental variation of an area to explore climate adaptation. Development of ClimMob has been led by Bioversity International and was funded by CCAFS and USAID since 2013. A rapidly increasing number of farmers have tested adaptation measures options through ClimMob. About 30,000 farmers participated in 2015, a number that is quickly growing. In parts of the Indo-Gangetic Plain of India, this work has injected a large number of rice and wheat varieties with climate adaptation traits into local farming and raised productivity by 10-30%. The ClimMob platform is also being used to identify drought-resistant common bean cultivars in Central America, and hardy cultivars of a wide range of crops in Ethiopia, Kenya, and Tanzania.

Case study 5.2: Integrating indigenous and scientific climate knowledge to support smallholder agricultural decision-making and planning in Lushoto, northern Tanzania

Local communities from the Lushoto District of northern Tanzania must adapt to climate change and its variability. The wealth of indigenous weather knowledge, passed verbally from generation to generation, is being lost with the passage of time. Furthermore, this knowledge is confronted with the complexity of climate change (in terms of uncertainty, magnitude and frequency), which limits its use and application in addressing climate risks across spatial and temporal scales. To address the above problem, local communities, scientists and agro-advisory agents are partnering in integrating indigenous and scientific knowledge that can help farmers make decisions on resource allocation and type of agricultural enterprises. Multi-stakeholder partners that include the local community, Tanzania Meteorological Agency (TMA), Lushoto District Council, Selian Agricultural Research Institute (SARI) and Sokoine University of Agriculture (SUA) are forming (i) a district weather forecasting team to improve the accuracy of weather forecasts and (ii) a climate information dissemination network that provides information to all farmers in Lushoto District to manage climate-related risks and guide farm-level decision making. The team integrates indigenous knowledge with scientific forecasts and provides comprehensive and accurate downscaled location-specific forecast that is reliable, timely, and user-friendly. They also produce seasonal weather forecast before and after the season. To ensure that the weather forecast is easily understood by all farmers and other users, it is translated into the local language (Usambaa) and national languages (Kiswahili and English).

Case study 5.3: Shamba Shape Up

Shamba Shape Up is an East African TV show with 9 million average viewers every month (CCAFS 2015a). The show helps viewers, mainly smallholder farmers to 'make over' their farms by adopting new practices and approaches, thereby improving livelihoods. In view of recurrent challenges such as water shortages, pests and diseases, market access etc., CGIAR centres and various development partners have been providing scientific inputs into the show's content, with a focus on interventions which allow farmers to increase resilience and adapt to climate change, increase productivity and improve livelihoods, and mitigate greenhouse gases where possible. Currently, such interventions make up nearly 35% of the programme time, and nearly 42% of the viewers were adopting these practices (CCAFS 2015a). It was estimated that adoption of these practices boosted Kenya's GDP by over USD 24 million in the maize and dairy sectors (CCAFS 2015a). Shamba Shape Up provides an innovative model for dissemination of agricultural practices and technologies for adaptation to climate change. The show has now expanded its scope and launched an SMS service as well as a Facebook page to disseminate information.

Case study 5.4: New approaches to extension in Haryana, India

Despite significant institutional efforts to scale up adaptation innovations in India's northern breadbasket, large-scale adoption is sluggish. Scaling up knowledge-intense technologies and practices has turned out to be more difficult than were 'green revolution' methods like new seeds, fertilizers and irrigation. One major bottleneck centres on the increasing average age of farmers, lingering traditional mind-sets, and the loss of young people who move out of farming. Discussing with communities ways to break the impasse, CIMMYT decided to undertake technology development with young farmers in the belief that engaging them in a community-based approach will facilitate adaptation and adoption of new technologies. The other benefit was to evolve institutional mechanisms for buying and sharing assets such as expensive farm machinery, for real-time decision-making, and for using resources more effectively at community-level. CIMMYT decided to interact with a group of young farmers from Taraori village, in the Karnal district of Haryana state. The response was overwhelming: farmer groups showed a keen interest in new-generation technologies to help with problems: such as sowing rice with less labour; surface levelling to save irrigation water; residue management for more healthy soil; eliminating burning and tillage to save fuel, energy and water; more efficient use of nutrients; and general adaptation to climatic risks. The enthusiasm was so great that a group of 20 young people formed the 'Society for Conservation of Natural Resources and Empowering Rural Youth'. A community-based movement led by young farmers was born. Now more than 4000 people including senior policy makers have visited these innovative farmers to learn more about resource-efficient, climate-smart and profitable technologies. Through capacity building, different climate-smart technologies were demonstrated to large number of farmers locally and from other areas. Five more young-farmer cooperatives have subsequently developed, copying this model

Source: Vermeulen and Wynter 2014

Case study 5.5: CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS)

After a successful 5-year first phase of policy-relevant research, CCAFS will start Phase 2 in 2017. The research program includes multiple partners at national level (e.g. government departments, national research organisations, NGOs) and at regional and global level (e.g. Future Earth, development agencies and development banks). Priority research themes for Phase 2 are: practices and portfolios that deliver adaptation benefits for smallholder farmers and food security, climate risk management through climate information services and climate-informed safety nets, low emissions development and priorities and policies for agriculture under climate change. Research is global, with about 80% of effort in countries in five regions (Latin America, West Africa, East Africa, South Asia and Southeast Asia). Gender and social inclusion are central to the research agenda, which covers both technical and institutional aspects of responding to climate change in agriculture and food security. The research program aims to be as demand-led as possible, responding to the needs of governments, development agencies, farmers' organisations and civil society organisations in setting research priorities and developing usable results. For more information or to get involved see http://ccafs.cgiar.org.

Case study 5.6: Public-private R&D partnerships for climate-resilient seed

The Drought Tolerant Maize for Africa, a project led by the International Maize and Wheat Improvement Centre (CIMMYT) is developing high-yielding maize cultivars to mitigate drought and diseases in maize production in 13 African counties. These drought-tolerant maize cultivars also produce approximately 20–50% higher yields under drought than do other maize cultivars. Such initiatives are able to address yield gaps that could arise due to the change in climate (Varshney et al. 2011). In this project, Monsanto provides proprietary germplasm, advanced breeding tools and expertise, and drought-tolerant transgenes developed in collaboration with BASF, a private chemical company. This partnership has the potential to benefit 30-40 million people and provide added grain worth USD 160-200 million each year in drought-affected areas. Similarly, the Stress Tolerant Rice in Africa and South Asia (STRASA) project, led by the International Rice Research Institute (IRRI) and Africa Rice, is working with Pioneer to develop rice varieties that are tolerant of abiotic stresses (i.e. flooding, drought, increase in salinity) and distributes the seeds through small private seed companies. Such tolerant, improved seeds that are currently being planted on 1.4 million hectares are expected to increase yields by 50%. Sub1 varieties are already reaching over 3.8 million farmers in India, Bangladesh and Nepal. These seeds have helped farmers protect their natural assets in light of droughts and floods, helping to build their adaptive capacity. Increases in yields per unit of input, including land, can potentially also deliver co-benefits for mitigation.

Case study 5.7: Farmers in Colombia combine scientific and local knowledge to manage agro-climatic risk

Since 2013, Senegal and Colombia have been exchanging knowledge and experiences on tailored climate services for smallholder farmers. As a result, today, in four regions of Colombia, local agricultural sector institutions and technicians are tailoring agro-climatic forecasts based on context-specific conditions as an input to make recommendations to farmers every month at the Local Technical Agro-climatic Committees meetings. By the end of 2014, two Committees were established in Córdoba and Cauca regions by CCAFS jointly with the Ministry of Agriculture and Rural Development of Colombia and other partners, with the purpose of creating a dialogue that could bring together scientific knowledge with local knowledge. The purpose of this dialogue is to develop tailored recommendations for farmers in terms of when to plant, and what management practices to use, disseminated through monthly Local Agro-climatic Bulletins. These offer probable scenarios to farmers based on agro-climatic forecasts for the next two weeks to six months. Currently, through this initiative, over 1,500 farmers receive agro-climatic information and implement measures such as early warning systems, farm planning, scaled crops, varieties resistant to drought/flood, native varieties conservation, crop calendars, water harvesting, optimisation of fertilizer use and flexible planting dates to support their decision-making process, prevent negative impacts due to climate variability, and generate mitigation co-benefits.

Case study 5.8: Climate Food and Farming Research Network (CLIFF)

The Climate Food and Farming Research Network (CLIFF) is an international research network established by CCAFS in partnership with the Universities of Copenhagen and Aarhus. The network aims to enhance the capacity of young researchers working on climate change mitigation in smallholder farming. The network provides doctoral students the opportunity to be hosted by CGIAR centres within their home regions participate in the Standard Assessment of Mitigation Potential and Livelihoods in Smallholder Systems (SAMPLES) project. The network has supported 35 students from over 20 countries, in carrying out research in low and middle income countries.

6. Foresight, models and scenarios

Foresight' is a field of approaches that are used to help gain better understanding of future uncertainties (Bourgeois et al. 2012). Foresight methods are becoming increasingly popular as governments and institutions start to explore the future of food systems in a rapidly changing world. Most foresight approaches focus on the development of future scenarios. Scenarios are plausible stories of the future that can be told in words, numbers, images, or through other formats (Van Notten 2003). A set of scenarios represents a diverse set of futures with each exploring a qualitatively different direction in which key drivers of change, such as water and environmental degradation, conflicts, market structures or governance issues, may develop and interact. Scenarios can be used at all levels, from local to global, or even in processes that connect people, ideas and plans across levels (Zurek and Henrichs 2007).

The scenarios are not meant to allow decision makers to predict the future, but offer a way to test plans and investments under widely different future conditions. Each future may offer very different challenges and opportunities to a plan, strategy or policy. In a good scenario process, the plan can then be modified to be able to deal with these different futures, either by going for "robust" options that work in all futures, by having a portfolio of options to adapt to different eventualities, or both (Vervoort et al. 2014).

To develop scenarios, multi-stakeholder processes supported by simulation modelling are often used (Alcamo 2008). Firstly, multi-stakeholder processes are used for bringing in diverse perspectives in a well-facilitated process. The involvement of diverse stakeholders in scenario processes around societal challenges such as climate change is crucial for a number of reasons (Gibbons 1999; Dryzek 2009; van der Sluijs 2012):

- Knowledge: Since there are strong individual and organizational biases related to the future, it becomes very important to use scenarios to question limiting dominant frames of understanding – in order to avoid dangerous blind spots in strategies. Diverse actors bring different understandings and perspectives, rooted in diverse sectors, operating levels and cultural backgrounds, to attempts to explore the future.

- Legitimacy: Those people who will be affected by the futures that are explored, and the plans associated with them, should be involved in scenario processes to ensure their voices are heard and their challenges understood.
- Action: Those who are in positions to take action on plans and policies to help shape better futures should be involved in scenario processes, to help ensure their impact. The most clearly impactful scenario processes are typically those that focus on the development of specific plans and policies in close collaboration with those responsible for them (see case studies 6.1 and 6.2).

Scenario process participants identify the relevant scope of a set of scenarios themselves. Scenarios are typically developed by outlining, with participants, what future drivers of change are considered important and uncertain, and then investigating how these drivers might interact and develop, resulting in diverse futures. Participants help to create integrated narratives for these futures.

In the context of scenarios, simulation models are often used to help explore plausible futures – examples are climate models (Shongwe et al. 2010), crop models that incorporate climate change (Tao et al. 2009), agricultural economic models that in turn link to crop models (Rosegrant et al. 2012, Havlík et al. 2014, Palazzo et al. 2014), integrated assessment models (van Vuuren et al. 2012, O'Neill et al. 2014) and land-use change models (Kok et al. 2001, Verburg et al. 2006). Using simulation models has a number of benefits:

- Where multi-stakeholder processes can draw on the combined practical and theoretical expertise of many societal actors, simulation models can offer the complementary benefit of formalized, consistent, data-driven and tested knowledge generation.
- Simulation models can offer insights into processes that are difficult to intuitively imagine without such tools, such as crop responses to climate, or land-use change. Because of this, they can produce counter-intuitive results that can challenge the thinking of participants in scenario processes.
- Simulation models can offer a level of detail and data richness and concreteness that is often impossible to attain through stakeholder processes – for instance producing grid-based land-use change or vulnerability maps. They offer detailed information against which policies and plans can be tested.

However, with regard to uncertain futures such as the impacts of climate change in the context of other societal and environmental challenges, simulation models should be used very carefully and consciously. Simulation models are based on assumptions made by individuals, just like stakeholder scenarios, and these assumptions are typically based on past data. This means that simulation models may not be good at providing meaningful information about futures where the interactions of human and natural systems are qualitatively different. Models are also typically highly simplified representations of real world phenomena, with their own biases coming from limitations in research disciplines, data, and the interests and capacities of those involved in developing them. Simulation models should therefore be used carefully, in combination with stakeholder-driven scenario development, and particular care should be taken to help policy makers understand the limits of such models and the problems with attempts at using them for prediction.

Benefits

When scenarios are used for planning in relation to adaptation and mitigation around agriculture and food and nutrition security, they have a number of benefits, provided that they are truly integrated in policy and planning processes:

- Scenarios can help policy makers engage with climate uncertainty by creating diverse, but concrete narratives about possible futures. They also allow for the integration of climate change with other drivers of change (see case study 6.1).
- Scenarios can be used to develop and test climate adaptation and mitigation policies, exposing policy ideas to diverse challenges and opportunities beyond what was previously considered, and resulting in more robust plans and/or a broader portfolio of actions and options.
- Scenarios encourage more reflexive, systemic, context-aware, multi-dimensional planning.
- Scenario processes can be used as a tool to make policy processes more inclusive, by involving vulnerable and usually under-represented groups in the development of scenarios and the review of policies under different scenario conditions. They provide an avenue for recognizing the need for diverse sources of knowledge, for instance from indigenous/existing knowledge systems.

- Scenarios can be used to enhance planning processes at all levels – with local communities, national governments, organizations operating in global regions, etc. – and they offer a way to integrate knowledge and decision-making across levels – for instance by downscaling or upscaling scenarios, or by focusing on policy gaps across jurisdictional levels (see case study 6.2).

When these benefits are combined, scenario-guided policy development can help create better policy contexts for successful climate adaptation and mitigation, while offering opportunities for those most likely to be affected by climate change to interact with those most likely to take significant action. Keys to success are strong collaboration with those involved in policy processes to ensure direct guidance of policies and plans; an inclusive approach to stakeholder processes that ensures involvement by vulnerable groups; and a careful and reflexive use of simulation models to complement and inform, not dominate, stakeholder processes.

Outlook

The following challenges are key to some of the obstacles to scaling the use of foresight methods:

- Foresight approaches such as scenario development and use require a broad range of skills and a specific approach to uncertainty around climate change and other driving factors which are not common among actors in governments and other sectors in vulnerable nations where such skills are needed. Those who are engaging with understanding future change are often focused on narrowly defined issues, and oriented toward prediction. Therefore, policy environments are not well suited to a scaling of foresight approaches.
- In climate-vulnerable country contexts, the link between policy development and implementation, and between national and sub-national policy levels, is often weak. There is also a danger of scenario processes only involving elites.
- Few simulation models exist that handle questions around food and agriculture related to climate adaptation and mitigation sub-national levels.

The following opportunities for scaling foresight methods can be identified:

There is great interest among governments, civil society organizations, academia and the private sector in the most climate-vulnerable countries to become better versed in foresight methods. Training and capacity development in such methods is a key opportunity for upscaling.

This should be combined with strong efforts in high-profile policy development processes, to provide powerful examples of how foresight can make policy and planning more climate resilient as well as inclusive.

Efforts should be made to design processes that link across jurisdictional and geographic levels – connecting local foresight processes to those happening at national levels, and linking national and regional processes to global foresight processes like those of the IPCC community.

The development of simulation models should be attuned to these opportunities – developing models that are accessible, able to deal with climate change questions at multiple levels, and more flexible, allowing for a better exploration of qualitatively different futures. This last point will require a rethinking of how models are developed.

Case Studies

Case study 6.1: Exploring future changes in smallholder farming systems through multi-scale scenario modelling in Kenya

This collaboration between the International Livestock Research Institute and the Kenyan Agricultural Research Institute ran from 2007-2010, with inputs from the AgriFood Research and Technology Centre of Aragon, Spain, the Oxford University's Environmental Change Institute, and Wageningen University. The work was an exploration of how smallholder agricultural systems in the Kenyan highlands might intensify and/or diversify in the future (Herrero et al. 2014b). Plausible socio-economic scenarios of how Kenya might evolve were developed with a range of stakeholders, based on the Kenyan Government's (2003) Economic Recovery Strategy for Wealth and Employment Creation and two less optimistic scenarios (lower growth and more inequitable growth). Evaluations were undertaken on how different farming systems might increase or diminish in importance under the various scenarios using a land-use model sensitive to climate change, prices, and the opportunity cost of land and labour. Household models, based on data collected from 3000 households, were then run to determine the different enterprises in which smallholders might engage and their impacts on a range of household indicators such as incomes and food security under different socio-economic conditions. Analyses carried out with this multi-level, stakeholder-informed, iterative framework showed that different farming systems in this region of Kenya may need different trajectories into the future, if incomes, food security and resilience are to be increased over the next 20 years. For example, diversification with cash crops is a key intensification strategy as farm sizes decrease and labour costs increase. Dairy expansion is particularly important in situations in which land availability is not a constraint, because of the need to planting fodder at the expense of crops.

Case study 6.2: Using scenarios to guide the Cambodian Climate Change Priorities Action Plan.

In 2013, the Cambodian Ministry of Agriculture, Forestry and Fisheries (MAFF) participated in the participatory future scenarios development process for Southeast Asia. Subsequently, MAFF expressed interest in using these scenarios for priority setting in its 2014-2018 Climate Change Priorities Action Plan (CCPAP). Over the next nine months, the CCAFS Scenarios team worked closely with the MAFF, building internal capacity for using scenarios for priority setting. By using climate/socio-economic scenarios to test and develop national and regional policies and investments, MAFF can create enabling policy environments for building resilience to climate change and sustainably improving agricultural productivity and incomes. Because of a focus on national policy, this type of process has the potential to benefit the entire population in the countries where it is used – over 15 million people in Cambodia, of which over 12 million live in rural areas (World Bank 2015).

7. Strengthening gender equality and social inclusion outcomes in adaptation measures in agriculture

Women farmers in developing countries are very vulnerable to climate change impacts as a result of their high dependence on natural resources for livelihoods and traditional roles at household level, coupled with the gender norms and discriminations they face to access capital, legal rights, land ownership, decision-making processes and political participation. As underscored in the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), climate change hazards contribute to greater climate change vulnerability of women whilst also increasing gender inequalities. Furthermore, UNFCCC Agreements from Cancun and Doha have emphasized the need to seek a gender-sensitive approach and effective participation of women in all aspects of climate change, specifically in adaptation and climate finance, including the promotion of gender balance "in order to inform gender-responsive climate policy" (UNFCCC 2013 p. 31). The preamble in the Paris Agreement states that countries should respect, promote and consider their respective obligations on a range of issues including gender equality, empowerment of women and intergenerational equity, when taking action to address climate change.

In Least Developed Countries, 79% of economically active women report agriculture as their primary economic activity, and rural women are playing an increasing role in smallholder agriculture as a result of out-migration of men (FAO 2011; Carvajal-Escobar et al. 2008). As a result, policies and programmes on climate change adaptation will need to include gender and social inclusion concerns if they are to achieve their objectives. CCAFS research has found that women and men farmers in developing countries have different vulnerabilities and capacities to adapt to climate change. For example, women experience greater financial and resource constraints as well as less access to information and extension services in agriculture (Twyman and Ashby 2015; Jost et al. 2015; Twyman et al. 2014; Tall et al. 2014; Huyer et al. 2015).

Rural women in particular are at high risk of negative impacts from climate change, due to household responsibilities including childcare, collection of fuel and water. Climate variability affects women's and men's assets in different ways. Women and men are changing cropping practices, with different impacts on control of the income from crops and on workloads, while environmental stress in farming systems can increase women's workloads and decrease assets of poor households (Jost et al. 2015; Nelson and Stathers 2009; Agwu and Okhimamwe 2009; Goh 2012). Cultural norms also affect control and ownership of assets during drought. In one case women gained increased control of household livestock because men were required to sell their livestock first as part of their responsibility to household food security (Kristjanson et al. 2010).

But women are also important agents of change in response to climate-induced stresses. Engaging women in technology design and management decisions improves outcomes and is central to gender justice: in Honduras, for example, women redesigned eco-stoves to meet local needs and developed agroforestry systems where trees would fruit at the same time as the coffee crop. This allowed families with distant farms to relocate together to harvest all tree crops at the same time (Wettasinha et al. 2014; Edmunds et al. 2013).

Benefits

The importance of integrating gender and social inclusion concerns into development has been recognized as a "foundational" issue for over 40 years and as critical for achieving international development goals (Asfaw et al. 2015). Differences in access and control of resources exist between women and men within households in all regions, including in agricultural production (Meinzen-Dick et al. 2010). Addressing this imbalance is critical for improving adaptation outcomes: increasing control of women over resources has been shown to lead to higher nutrition levels, increased food security, improved health, and education for children (FAO 2011).

Adaptation measures in agricultural systems have the potential to provide benefits for women: when they have access to information on these practices, they are just as likely as men, if not more so, to adopt them. In Kenya the most rapid adoption of climate-resilient farming was among women whose husbands were away and not making the day-to-day decisions (Goering 2015). The positive results of adaptation in agriculture – increased crop resilience, agricultural production, improved water management and decreased vulnerability – lead to benefits which include increased incomes and savings, diversification and increased availability of household food, increased nutrition, and often, increased status of women farmers (Gilbert 2015; Recha and Muchaba 2014). However, the possibility of increased labour loads for women and youth is a significant barrier (Jost et al. 2015).

Because of the knowledge and skills required to put in place these adaptation measures, specialized training can be provided on climate services and agro-advisories; appropriate on-farm tools and technologies; and access to microfinance and micro-insurance. This training produces a range of benefits for women (Recha and Muchaba 2014). In some cases, bringing women and men together to test agricultural options has helped change relationships within the household. Women in Vietnam, Honduras and Cambodia described increased confidence in their own technical capacities as well as increased control over decision-making and the benefits on agricultural production (CLRRI 2015).

Outlook

Challenges for achieving adaptation and gender equality goals include lack of land ownership or long-term user rights by women which reduce their opportunity to implement adaptation measures, as well as lack of access to inputs, credit, extension and information (Meinzen-Dick et al. 2010; FAO 2011). The general lack of consideration of gender issues in emerging national policies on climate adaptation may also be a barrier to ensuring equitable outcomes for men and women under climate change (Vermeulen 2015).

Scaling up of gender and social inclusion approaches can be achieved through different channels, in collaboration with a range of partners. More research is needed on scaling up strategies that are socially inclusive, but the following opportunities have been identified:

- **Training and capacity development** – Training women in agricultural adaptation measures produces positive results (see case study 7.2). In addition to increasing production and reducing water and fertilizer use, this kind of training often encourages women to develop collaborative income-generating projects or cooperatives, access credit through additional income, and additional investments in agricultural production or other income-generating activities (see Mutoko et al. 2015; CLRRI 2015)

- **Value chains and business development** – Agri-business approaches based on value chains may not be appropriate for informal sector or household agricultural production, so that there is a need to identify and address equity and gender concerns in value chain strategies (Haggblade et al. 2012).

- **Climate information services** – Gender-appropriate communication channels and services can be an effective tool for scaling up climate information services (see case study 7.1). Climate service needs are highly location-specific, so that local participation is needed to identify different local needs and ensure appropriate tailoring of climate information. Partnerships between government ministries and with civil society, universities and community-based organizations will expand the reach and accessibility of information (Tall et al. 2014; Huyer et al. 2015).
- **Participatory approaches** – Tension exists between scaling out and the participatory action-research (PAR) necessary to address the needs of different groups within a community, while giving farmers a voice in developing solutions. A positive way forward is training youth and women as experts in and teachers of adaptation knowledge.
- **Financial instruments** to support women's CSA-based livelihoods pose great potential to scale up successful climate-smart enterprises. For example, the W+ standard provides metrics to measure, quantify and verify gender equality outcomes from contributions and investments (WOCAN, 2014).

Case Studies

Case study 7.1: Women champion knowledge and technology based approaches to Climate-Smart Agriculture in Africa

CCAFS has been promoting climate information services and new adaptation technologies in the Nyando area of Kenya's Lake Victoria Basin. Here, late onset of seasonal rainfall leads to occasional flooding of agricultural fields, destroying crops and eroding productive topsoil. Early rainfall can substantially increase the chance of longer dry spells, often leading to pre-season pest outbreaks. Farmers must often replant to ensure a harvest. The Obinju Women's Group (21 members) uses an SMS message service to help them plan their planting season and adapt to climate variability. Rather than relying entirely on rainfed crops, they also use a mix of closed polythene tube greenhouses and open spaces fitted with water harvesting structures and drip supply lines. This offers protection for crops from drought, flooding, and insect and pest attacks. Four pilot units are now operational in seven villages. They showcase highly diversified and innovative vegetable and bean seed production under drip irrigation. The Obinju group, along with other women leaders, entrepreneurs and farmers, received special training on climate services and agro-advisories. The latest data show that these interventions have helped reduced by 60 percentage points the number of households that experience at least two months per year with one or no meals per day.

Source: Recha and Muchaba 2014

Case study 7.2: Enhancing the roles of women in rice farming as an adaptation strategy to climate change risks: a case study in submergence villages in Hau Giang province, South Vietnam

Women play crucial roles in rice farming in Vietnam, from production to postharvest operations. Due to floods, they lose their rice crop and livestock thus affecting their livelihoods. However, women have less access to information on crop production and management, pest and disease outbreaks and management through agricultural training and extension programmes, obtaining their information from informal sources. Increasing women's access to formal sources of information such as training on climate-smart technologies can help women make informed decisions on crop management, thus increasing rice productivity, especially when the men are away for non-farm work.

Seeds were distributed to 100 women farmers (farming a total of 13 hectares) in villages in Hau Giang province. The farmers were also trained on better crop management and production of healthy seeds, as well as improved rice technologies and practices. Results show that the women farmers involved in this training increased their knowledge in almost all aspects of rice production. After applying what they learned from the training, they obtained better yields from the seeds they planted and used lower rates of inputs such as seeds, fertilizer, and pesticides – decreasing production costs. Integrating training courses for women farmers in agricultural extension and research shows great potential for improving agricultural adaptation practices as well as increasing the production, income and participation in decision making of women in the household and community – serving both gender equality and agricultural adaptation objectives.

Source: CLRII 2015

8. Co-benefits to mitigation

When does adaptation lead to mitigation co-benefits?

Adaptation to climate change can lead to significant mitigation co-benefits under many conditions. Where mitigation is feasible, managing for multiple outcomes makes sense, as the agricultural greenhouse gases (GHGs) methane (CH_4) and nitrous oxide (N_2O) are significant components of emissions globally (10-12% of global anthropogenic emissions) and at country level (average of 12% in Annex I countries and 35% in non-Annex I countries). Many mitigation measures in agriculture are already promoted as best management practices.

Scope for mitigation

As agricultural production will need to increase globally, the emissions from CH_4 and N_2O overall and particularly from underproducing agricultural regions will have to increase relative to the present or a past base year. Given the need for increased production, the opportunities for mitigation in agriculture arise therefore mostly from (1) sequestering carbon through increased agroforestry or soil carbon, and (2) avoided emissions, including avoided deforestation. Avoided emissions can be relative to a future expected trend in emissions or yield (emissions intensity or GHG emissions per unit product). The scope for mitigation therefore depends on choice of reference point, whether a (1) past or present base year, (2) projected baseline in a future year, or (3) level of emissions per unit yield; and whether measures that reduce both CO_2 and non CO_2 gases are included.

In planning adaptation, mitigation in agriculture is thus best framed as a co-benefit of adaptation interventions and measured relative to the emissions that would have happened otherwise. This approach can be captured using low emissions development strategies as compared to single-purpose mitigation initiatives. Adaptation measures that help reduce future emissions do so by optimizing productivity, increasing efficiency, reducing waste and making use of the environmental services of trees and forests (Table 2). For many production systems, it is possible to decrease the emissions intensity by increasing production and decreasing emissions. Closing the emissions intensity gap would support sustainable development while achieving significant mitigation.

Table 2. Mitigation co-benefits associated with adaptation interventions

Climate risk	Adaptation measure	Potential mitigation co-benefit
Seasonal and short-term temperature and precipitation variability	Improve management practices to optimize productivity	Efficient nitrogen fertilizer use reduces nitrous oxide and use of nutrient amendments may help increase soil organic carbon
		Improved ruminant health and feed reduces methane per unit yield
		Improved grassland and pasture management increases carbon sequestration
		Increased soil organic matter increases carbon sequestration
		Alternate wetting and drying in paddy rice can save water and reduce methane
		Improved plant and animal productivity increases residues and manure that contribute to soil organic matter (or in the case of residues, feed for ruminant productivity)
		Restoration of degraded soils increases soil organic matter
	Irrigation	Improved plant productivity increases residues that contribute to soil organic matter or feed for ruminant productivity
		Irrigation allows for alternate wetting and drying in paddy rice to reduce methane
	Longer or shorter crop/livestock growing and harvesting periods	Shorter cropping cycles lead to reduced methane in irrigated rice
	Diversification of crops and livestock	Increased use of trees increases carbon sequestration
	Improved soil water holding capacity	Increased soil organic matter (where organic matter is cause of increased water holding capacity)
	New breeds	Breeding for multiple traits may enable reduced methane production in ruminants and rice
	Maintaining gene pools for future needs	Avoided deforestation supports increased biodiversity
Extreme events and crop failure or loss of yields	Food storage	Reduce food loss, thereby reducing emissions per unit product
	Relief services, trade	No clear implication for mitigation
	Improved drought and flood tolerance/control	Alternate wetting and drying in paddy rice can save water and reduce methane
		Improved productivity leading to residues that increase soil organic matter or improve ruminant productivity
		Avoided deforestation can protect "safety" foods that local populations collect in forests.
	Windbreaks	Increased use of trees increases carbon sequestration
	Crop or livestock insurance	INDIRECT: Reduces risk, enabling access to credit or willingness to use resources for other best management practices (see above) that can support mitigation
	High value trees provide buffer against losses	Increased use of trees increases carbon sequestration
Temperature increase	Management of microclimate (e.g. shade trees)	Increased use of trees increases carbon sequestration
	Move to higher elevation, or other location with more suitable climate	Relocating food production away from high carbon landscapes. May also increase emissions if high carbon landscapes are converted to lower carbon.
	New breeds	Breeding for multiple traits may enable breeding for reduced methane production in ruminants and rice
Rising sea levels and salt water intrusion	Water management	Increase freshwater irrigation, which allows alternate wetting and drying in paddy rice to make more efficient use of water and reduce methane
Indirect effects on availability of inputs	Efficient use of inputs, relocation	Efficient energy, land, water and nitrogen fertilizer use can reduce related emissions; substitution of fossil fuels with renewable energy (e.g. solar, biogas)

Major opportunities

Scalable interventions that support adaptation with mitigation co-benefits are summarized in Harvey et al. 2014 (see Table 2). Generally, activities that strongly support both adaptation and mitigation are those that enhance soil carbon. Increasing or maintaining carbon in the aboveground biomass can support both outcomes as well, although trade-offs can occur with food production through competition for nutrients, water and space. Setting aside cropland for biodiversity conservation for example reduces the land available for production. Sometimes other economic or social values are enhanced, however, that compensate for these losses (see case study 8.1).

Activities that support adaptation with some mitigation co-benefits are generally those related to crop or livestock breeding, maintenance of agrobiodiversity, timing of cultivation or water management.

Activities that primarily support mitigation include increasing efficiency of input use, substitution of fossil fuels and reduction in burning.

Deforestation and agroforestry – The highest impact on mitigation per hectare and globally is achieved with avoided deforestation, planting of forests or agroforestry. As Figure 1 shows, the large quantities of carbon in forests per hectare far surpass the carbon stocks that can be sequestered in croplands and are two to three times that of agroforestry systems, hence from the standpoint of quantity of carbon saved, avoided deforestation achieves the maximum mitigation per hectare and globally relative to any other single intervention. This is especially true in areas with high biomass forests such as in the tropics. Globally, forestry mitigation options could sequester 1.3–4.2 $GtCO_2e$ per year in 2030 at carbon prices up to USD 100 per tonne of carbon dioxide (CO_2) equivalent, or about half this quantity at less than USD 20 (Nabuurs et al. 2007; Candell and Raupach 2008). Depending on the composition and age of the trees, agroforestry can sequester 184-367 Mg CO_2e/ha (Verchot et al. 2007) (see Figure 1). Globally, converting 3.2 million km^2 of low carbon landscapes to agroforestry compatible with agricultural production is estimated to provide 3.67 $GtCO_2e$/yr or 1GtC/yr, assuming a 50% adoption rate (IPCC 2000; Zomer et al. 2014).

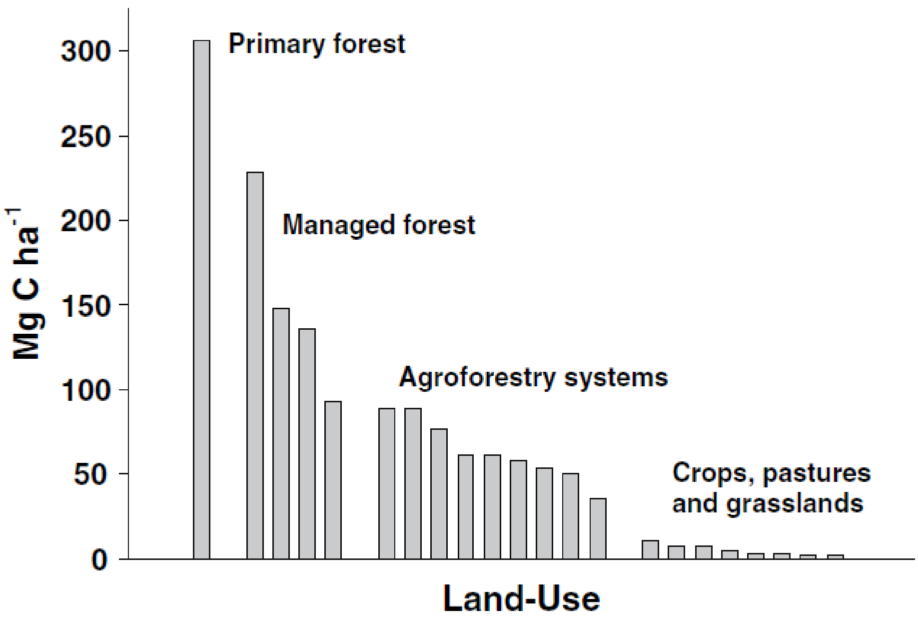

Figure 1. Summary of C stocks at maturity in different ecosystems of the humid tropics. Data are from benchmark sites of CGIAR's Alternatives to Slash and Burn Programme (Verchot et al. 2007).

Soil carbon – Improving the addition of organic matter to the soil through adapted crops, improved crop productivity, grassland management, or the use of compost or manure as inputs to the soil has a relatively small impact per hectare, but because of the large extent of cropland and grassland, could have massive impacts globally. The average annual carbon sequestration rates of arable land and pastures have been estimated to range from an average over a 50-year period of 0.125 Mg C/ha for low rates of sequestration (pasture and grazing lands) to 0.515 Mg C/ha where high rates are likely (e.g. arable crops, highly degraded soils) (Sommer and Bossio 2014). Sequestration builds over time and reaches an equilibrium point, so the average does not necessarily reflect the distribution of accumulated carbon over the 50-year period. At the global scale, by 2030, the global mean annual technical sequestration potential in cropland and grasslands soils is estimated at 5.1 GtCO_2e or 1.4 GtC/yr or (Smith et al. 2008). Managing increases in soil carbon, however, faces constraints to the availability of crop residues, the potential for reversibility and difficulties in monitoring small incremental changes.

Livestock intensification – Livestock contribute the highest GHG emissions in the agriculture sector, with beef (2.9 GtCO_2e/yr), and cattle milk (1.4 GtCO_2e/yr) being the largest contributors. With efforts to increase livestock production in the future, there is also an opportunity to introduce improved methods to shift the emissions intensity of production. Current average emission intensities are 2.8 kg CO_2e per kg of fat and protein (corrected for milk) and 46.2 kg CO_2e per kg of carcass weight for beef. (Figure 2). However, emissions intensities of livestock production systems range widely among producers (Gerber et al. 2013).

Gerber et al. 2013 provide a comprehensive review of the opportunities for mitigation in the livestock sector. They estimate that the sector's emissions could be reduced by 1.8 $GtCO_2$e/yr or about 30% if all producers shifted their practices to those used by the 10% of producers with the lowest emission intensity (Gerber et al. 2013). The global potential for mitigation in livestock and manure at USD 20/tCO_2e in 2030 is estimated to be 0.1 $GtCO_2$e/yr (Smith et al. 2008).

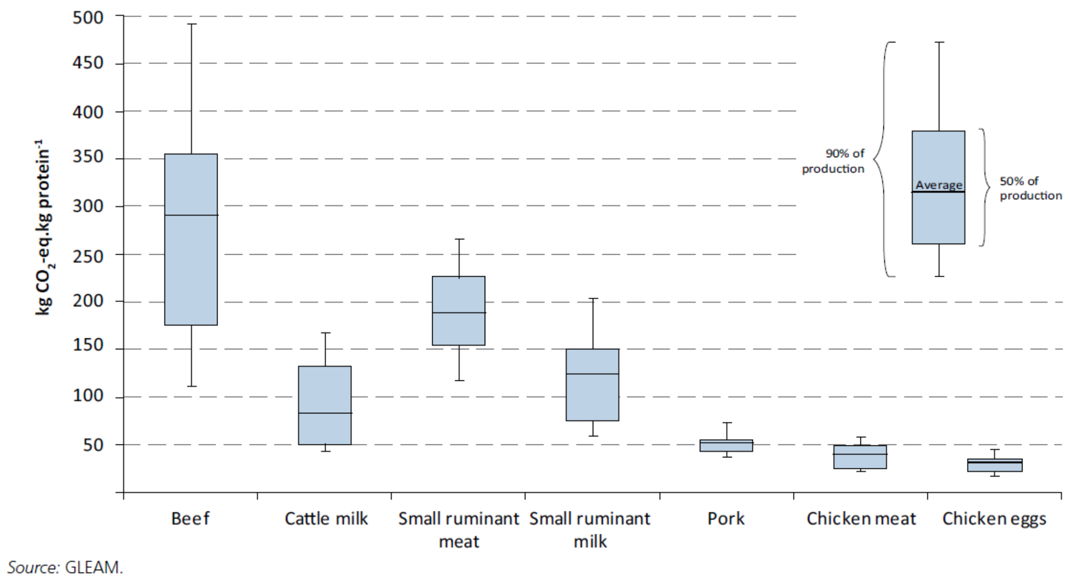

Figure 2. Global emissions intensity by commodity (Gerber et al. 2013).

Major opportunities for adaptation and mitigation exist in the shift from extensive low-return grazing systems susceptible to climate variability and extreme events to more stable, higher-profit intensive systems. The higher returns also enable farmers to be more resilient. Current emissions intensity gaps are mostly caused by poor digestibility of feed, poor animal husbandry, and lower slaughter weights and higher age at slaughter (longer life leading to more emissions) (Gerber et al. 2013).

Because livestock emissions tend to be the largest source of agricultural emissions in most countries, they are often a priority for national policy. For example, in Mongolia and Kenya, national climate frameworks exist or are being developed to support further intensification of livestock to improve livelihoods, increase climate resilience and reduce emissions (see case study 8.2).

Water management in paddy rice – Paddy rice emissions of methane contribute about 10% of agricultural emissions and hence present another major opportunity for mitigation. Use of alternate wetting and drying (AWD) in paddy rice can reduce water use by up to 30% and methane emissions by 48% without affecting yields (Richards and Sander 2014). With efficient nitrogen use and application of organic inputs to dry soil, the practice can reduce emissions even further, enhance nutrient efficiency, and deter insect infestation. AWD has been field tested and validated by rice farmers in Bangladesh, Indonesia, Lao PDR, Philippines, Myanmar, and Vietnam. An estimated 1.68 $GtCO_2e$/yr of methane can be reduced in paddy rice globally (Smith et al. 2008).

Other opportunities – Nitrous oxide from nitrogen fertilizer accounts for the majority of GHG emissions in croplands other than rice. Improving fertilizer-use efficiency in systems where these fertilizers are overused can reduce emissions and even increase yields. Reductions are highly specific to the local environmental conditions, nutrient management and fertilizer type. Many developed countries provide incentives, support planning processes, or regulate air and water quality to reduce leakage of nitrogen from agriculture. Under the EU Nitrates Directive (European Council 1991) more than 300 action plans have been created prospectively covering about 40% of the area of the 27 EU member states (Bustamante et al. 2014).

Energy use in agriculture is increasing globally. An estimated 0.77 Gt CO_2e/yr could be reduced by 2030 with energy efficiency in agriculture (Smith et al. 2008).

Two-thirds of the world's 600 million poor livestock keepers are rural women (Thornton et al. 2003), making the adoption of livestock mitigation practices that are gender-responsive and inclusive an important opportunity.

Where development and mitigation intersect

Agricultural development will be needed to address growing demand for food. The regions and production systems with current yield gaps offer an opportunity to introduce low emissions agriculture. Examining the productivity gap and importance of production to national economies based on areal extent of major staple food crops/animal products and high income crops/animal products, a review of 21 United States Agency for International Development (USAID) agricultural investments in three countries (Nash et al. 2015) showed major mitigation opportunities among staple crops for maize and rice; for livestock in dairy and beef, including meat exports for cash; and for coffee, cocoa and beans for cash crops.

Using future scenarios, Valin et al. (2013) showed that reducing the yield gap in agriculture by 50% for crops and 25% for livestock by 2050 would decrease agriculture and land-use change emissions by 8% overall. But the outcomes depend on the approach used (see e.g. case study 8.3 on using silvo-pastoralism for mitigation and food security). For example, emphasizing crop yield increases would achieve a larger increase in food production, while livestock productivity gains would achieve the most mitigation of GHG emissions. Valin et al. (2013) conclude that productivity should be increased in both sectors to best achieve both food security and mitigation co-benefits.

When are adaptation and mitigation not compatible?

Farmers subject to high vulnerability and risk associated with climate change should not be expected to bear the burden of mitigating climate change. They will need to put adaptation and food security first. It would be socially unjust to expect vulnerable smallholders to protect carbon at the expense of their livelihoods. Adaptation priorities that may have limited benefits for mitigation include increasing application of inorganic nitrogen fertilizers, expanding herds of livestock, or converting forests, peatlands and wetlands to croplands or pastures. Where possible, governments may seek to help farmers improve their livelihoods and adaptation capacity through greater productivity, rather than expansion of low-yielding agricultural lands.

Case Studies

Case study 8.1: Agroforestry as a buffer against climate variability

In the traditional farmed parklands of West Africa, dense shading by shea butter trees (*Vitellaria paradoxa*) and ne re (*Parkia biglobosa*) often reduces millet yield by 50–80% (Kater et al. 1992). Nevertheless, the trees are highly valued by farmers because economic yields from marketable tree products compensate for the loss of crop yield. In semiarid Kenya, farmers have recently developed an intensive parkland system using the fast-growing indigenous species *Melia volkensii* (Meliaceae), which is reputed to be highly compatible with crops and can provide high value timber in 5–10 years (Stewart and Blomley 1994).

Case study 8.2: A Dairy NAMA in Kenya

In Kenya, Unique Forestry and Land Use is supporting the development of a NAMA for sustainable development of the dairy sector that will contribute to climate change mitigation and adaptation. Farmers presently have problems with low productivity of dairy cattle, the dip in milk production during the dry season, and low resilience to climate change. Their production systems also yield high GHG emissions per kilogram milk. The NAMA will seek to improve dairy management practices, farmer organisation in dairy groups and involvement of formal processors The NAMA will enable zero-grazing management, fodder production, improved feeding practices, manure management, water harvesting and dairy hubs enabling cooperatives to procure inputs efficiently and pool resources for transport and processing.

The investment will trigger a number of mitigation benefits:

- efficiency gains from reduced emissions per product unit;
- enhanced soil and above ground carbon stocks through agroforestry;
- reduced emissions by the adoption of waste management (biogas technology);
- depending on the site conditions, reduced emissions from deforestation and forest degradation (REDD+).

Total emission reductions are estimated to be approximately 2.0 Million tonnes CO_2e/yr in 2025, representing 3.3% of Kenya's 2010 GHG emissions.

Case study 8.3: Colombian government prioritizes NAMA for reconverting pastures into fruit crops

The Colombian MADR and the Ministry of Environment and Sustainable Development (MADS) produced a national mitigation action (or NAMA) to reconvert pastures to fruit crops. The NAMA was developed based on the engagement by the Colombian Government agencies with CIAT and CCAFS. In particular, CIAT and CCAFS provided evidence base for the Colombian Low Emission Development Strategy. As part of this effort, scientists considered the mitigation potential of several measures, and identified improving pastures, developing silvo-pastoral systems and establishing fruit plantations on land previously dedicated to livestock would be the most effective strategies for reducing emissions without harming food security.

Source: CCAFS 2015a

Conclusions

A wide range of adaptation measures have been identified and piloted in diverse agricultural systems. These include measures related to governance, policy frameworks and readiness; national planning; local planning; finance, economic incentives and value chains; research, extension, capacity building and knowledge systems. These adaptation measures provide a range of entry points to initiate adaptation action in the agricultural sector. However, context-specific needs will determine the choice and configurations of adaptation measures.

Adaptation measures in agricultural systems will need to scale up rapidly to reach the millions of smallholder farmers facing the adverse impacts of climate change. This calls for urgent actions to create a conducive and enabling environment including appropriate governance arrangements, policy frameworks, provision of climate finance, creation of economic incentives, development of inclusive knowledge systems, and capacity building and technology transfer at multiple levels. National and local planning approaches coupled with foresight tools will help implementers plan for uncertainty and prioritize actions within specific contexts.

Adaptation measures in agricultural systems offer considerable opportunities to achieve co-benefits for gender and the environment. Greater engagement with women in technology design and management decisions can help maximize women's potential as agents of change and address their vulnerabilities. Co-benefits related to the environment include higher biodiversity, reduced soil erosion and higher water use efficiency. Significant mitigation co-benefits can also be achieved. These include mitigation co-benefits through carbon sequestration in soils and agroforestry systems, as well as from reduced emissions through avoided deforestation. Designing adaptation measures for multiple outcomes makes sense in situations where these additional outcomes can be achieved with little or no additional cost.

Considering the diversity within agricultural systems, there is no silver bullet which can be applied in all contexts. Adaptation measures need to be context-specific. A range of planning tools and foresight approaches are available to support planning and implementation. These tools and approaches should be applied in conjunction with stakeholder engagement efforts, and efforts to link with indigenous knowledge.

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