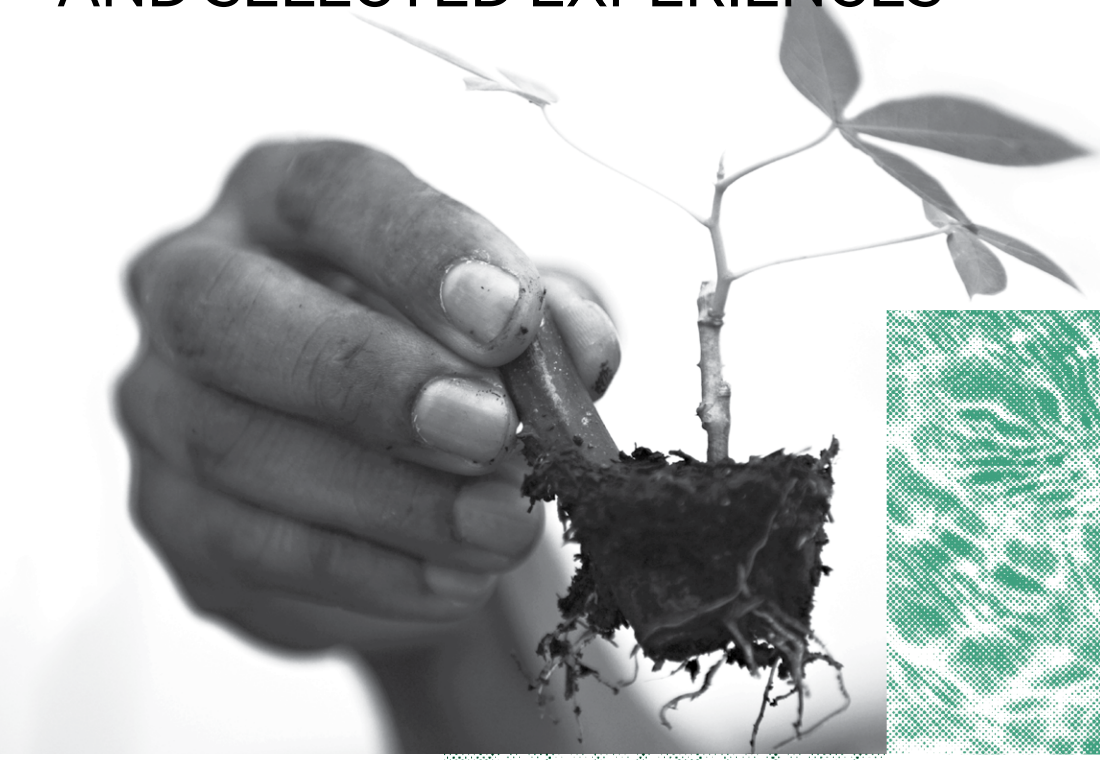
Food and Agriculture
Organization of the
United Nations

MAKING CLIMATE-SENSITIVE INVESTMENTS IN AGRICULTURE
APPROACHES, TOOLS AND SELECTED EXPERIENCES



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Abbreviations and acronyms

ADD	Agricultural Development Division
AE	Accredited Entities
AEZ	Agro-Ecological Zone
AF	UN Adaptation Fund
AFOLU	Agriculture, Forestry and Other Land Use
AR5	IPCC Fifth Assessment Report
ASAP	Adaptation for Smallholder Agriculture Programme
AWM	agricultural water management
BAU	business-as-usual
CA	conservation agriculture
CAFI	Central African Forest Initiative
CARD	Climate Adaptation in Rural Development Assessment Tool (Module 3)
CARD	Center for Agriculture and Rural Development (Module 4)
CAT-AR	Carbon Assessment Tool for Afforestation and Reforestation
CBA	cost–benefit analysis
CBD	Convention on Biological Diversity
CBIT	Capacity-building Initiative for Transparency
CBP	Carbon Benefits Project
CC	climate change
CCM	climate change mitigation
CMA	Conference of the Parties serving as the meeting of the Parties to the Paris Agreement
COP	Conference of the Parties
CPI	Climate Policy Initiative
CPMI	CARD Pioneer Microinsurance Inc.
CSA	climate-smart agriculture
CSAIP	Climate-Smart Agriculture Investment Plan
CS-FOR	Carbon Sequestration through Climate Investment in Forests and Rangelands
CWP	crop water productivity
DFI	Development Finance Institutions
EEZ	Exclusive Economic Zone
EFA	Economic and Financial Analysis
EIRR	economic internal rate of return
ER	emission reductions
ESMs	Earth system models
EX-ACT	EX-Ante Carbon-balance Tool
FAD	fish aggregating devices
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FFS	farmer field schools

FIAES	Initiative for the Americas Fund El Salvador
FOLUR	Food systems, Land Use and Restoration
FREL	Forest Reference Emissions Level
GCF	Green Climate Fund
GCM	global climate model
GDP	gross domestic product
GEE	Google Earth Engine
GEF	Global Environment Facility
GHG	greenhouse gas
GIS	Geographic Information System
GoZ	Government of the Republic of Zambia
HABs	harmful algae blooms
IA	Implementing Agency
IAE	International Energy Agency
ICZM	integrated coastal zone management
IDB	Inter-American Development Bank
IFAD	International Fund for Agricultural Development
IFI	International Financial Institutions
INDC	intended nationally determined contributions
IP	Impact Program
IPCC	International Panel on Climate Change
IRM	iterative risk management
IRR	internal rate of return
LDC	Least Developed Countries
LDCF	Least Developed Countries Fund
M&E	monitoring and evaluation
MDBs	multilateral development banks
MIE	Multilateral Implementing Entities
MOSAICC	Modelling System for Agricultural Impacts of Climate Change
MRV	monitoring, reporting and verification
MTS	medium-term strategy
NAMA	nationally appropriate mitigation action
NAP	National Adaptation Plan
NAP-Ag	Integrating Agriculture in National Adaptation Plans
NAPAs	National Adaptation Programmes of Action
NC	National Communication
NDA	National Designated Authority
NDCs	nationally determined contributions
NFMS	national forest monitoring system
NGO	non-governmental organization
NIE	National Implementing Entity
NIP-REDD+	National REDD+ Investment Plan
NPV	net present value
NYDF	New York Declaration on Forests

PA	Portfolio Analysis
PMD	Pakistan Meteorological Department
PPP	public-private partnerships
ProDAF	Family Farming Development Programme
RCM	regional climate model
RCP	Representative Concentration Pathways
REDD+	Reducing Emissions from Deforestation and Forest Degradation in developing countries
REO	real option analysis
RIE	Regional Implementing Entities
ROOTS	Resilience of Organizations for Transformative Smallholder Agriculture Project
SAP	Simplified Approval Process
SCCF	Special Climate Change Fund
SDG	Sustainable Development Goals
SECAP	Social, Environmental and Climate Assessment Procedures
SEPAL	System for Earth Observation Data Access, Processing and Analysis for Land Monitoring
SFM	Sustainable Forest Management
SGP	Small Grants Programme
SHARP	Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists
SIDS	Small Island Developing States
SLM	sustainable land management
SME	Small and Medium Enterprises
SPI	Standardized Precipitation Index
SRI	System of Rice Intensification
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation
VC	value chain
VDS	Vessel Day Scheme
WB	World Bank
WOP	without project
WP	with project

Foreword

Climate change is increasingly threatening agriculture – a vital source of food, nutritional health, income and employment for most of the world's poor. It is contributing to changes in crop yields and the loss of ecosystems and biodiversity on which agricultural livelihoods and global food security depend. At the same time, agriculture – including crops, livestock, forestry and fisheries – is a major contributor to global greenhouse gas emissions.

The challenge ahead is to make sure the world's growing population has sustainable access to safe, affordable and nutritious food while also reducing agriculture's emissions and making it more productive and resilient.

Agricultural investments that are climate-sensitive are key to realizing these goals. Climate science is evolving rapidly, further accelerated by digital technologies, providing more nuanced insights into the future of agricultural production and food security risks associated with climate impacts. Harnessing this knowledge as it becomes available, and sharing best practices and experiences, are essential for making informed investment.

This new knowledge product was produced by a multidisciplinary team from across FAO, coordinated by the FAO Investment Centre. It provides investment practitioners with practical reference material on integrating climate risk considerations at all stages of the investment project cycle, from design to implementation, monitoring and evaluation. It draws on the most recent information and data sources, including the latest Intergovernmental Panel on Climate Change reports. And it showcases a wealth of FAO-developed tools, tested approaches and selected experiences that will help investment practitioners design and implement more and better climate sensitive investments in agriculture.

We are grateful to all those who contributed to this investment toolkit, providing their valuable technical expertise, insights and advice.

We, at FAO, will continue supporting public and private investments in climate sensitive agriculture for better production, better nutrition and better lives, leaving no one behind.

Mohamed Manssouri
Director, FAO Investment Centre

Eduardo Mansur
Director, Office of Climate Change Biodiversity and Environment

Introduction

The first edition of this guidance document entitled 'Incorporating climate change considerations into agricultural investment programmes: a guidance document' was published in 2012. Since then, considerable progress has been made towards strengthening global commitments to tackle climate change. The United Nations Sustainable Development Goals (SDGs) have been adopted by world leaders, and 179 countries have put forward Nationally Determined Contributions (NDCs) – part of the global process coordinated by the United Nations Framework Convention on Climate Change (UNFCCC). Many countries are now integrating climate change adaptation into national development planning, such as National Adaptation Plans (NAPs) and National Adaptation Programmes of Action (NAPAs). There has also been a shift in both the levels and scope of global climate finance. For example, the Green Climate Fund (GCF) has become the world's largest dedicated climate fund, helping developing countries to reduce their greenhouse gas (GHG) emissions and to enhance their ability to respond to climate change. Multilateral development banks (MDBs) and bilateral donors have been scaling up global climate finance for climate change actions, and climate finance instruments are starting to appear within national budgets.

The last decade has also witnessed climate science moving forward rapidly and providing more nuanced insights into the future of agricultural production, and societal and environmental risks associated with climate impacts on agriculture and food security. While there is still great uncertainty about many aspects of the Earth's carbon cycle, particularly when it comes to natural sinks like forests or the ocean, advances in climate science now provide greater certainty of changes we are already seeing, and greater confidence in the projections derived from climate models, such as those presented in reports by the Intergovernmental Panel on Climate Change (IPCC, 2018), including the Climate Change 2014 Synthesis Report (AR5) and the Special Report on Climate Change and Land, 2019.

The IPCC (2018) Special Report reiterates that communities dependent on agricultural production are amongst the most vulnerable to climate change. In addition, recent findings illustrate how rapidly we are now seeing changes in weather patterns. Taken together, these findings reinforce the urgent need to take action so that agricultural systems not only adapt to these changes, but also mitigate the effects of climate change, reducing GHG emissions while at the same time ensuring local, national and global food security. Scientific knowledge is a cornerstone of climate change adaptation and mitigation strategies, providing the basis for designing sound approaches and investment options to respond to this challenge.

This knowledge product updates and builds upon the best practices presented in the aforementioned FAO guidance document (FAO, 2012a). It also complements and links to relevant FAO resources, such as the updated Climate-Smart Agriculture (CSA) Sourcebook (FAO, 2017c), The State of Food and Agriculture (SOFA, 2016a), as well as FAO sub-sector experiences and publications.

This knowledge product provides international and national practitioners with practical reference material on the integration of climate change risks throughout all stages of an investment project cycle. It draws on the most recent information and data sources, including the latest IPCC reports, and provides significant updates and new content on approaches and tools developed by FAO, with a particular focus on the following: climate risks and vulnerability assessments; the incorporation of climate risk and uncertainty in project design; project appraisals; and monitoring and evaluation of climate-related project results. It also illustrates selected approaches and tools with practical examples and case studies, and discusses climate financing opportunities. References are made to recent FAO publications on the integration of climate change into policies and national development planning – though these publications are not discussed in great detail.

The expectation is that this knowledge product will strengthen the capacity of FAO member countries, FAO professionals and development partners to support, design and implement agricultural projects with climate considerations. It showcases FAO-developed tools, tested approaches and experiences that could be used in designing climate-smart agricultural investments.

This reference material can be used to support a variety of projects and funding arrangements, and to complement different project development methodologies. All agricultural investments have to become "climate smart" to ensure the robustness of the sector to the impacts of climate change, reduce GHG emissions, and increase carbon sequestration where possible. This is the case for more generic agricultural investments focusing on development outcomes, as well as more adaptation and mitigation focused projects, or where there is a combination, through specific project components dedicated to climate change. This knowledge product will bring to light the many approaches and tools that technical experts can explore and adopt in project development, and in appraising and validating adaptation and mitigation options as part of the formulation of agricultural investments.

Organized as a compendium of modules and thematic sections, this knowledge product is a concise and technically sound guide to integrating climate change considerations into agricultural investment projects. Module 1 provides an overview of the linkages of climate, agriculture and food security and the role that climate-smart investments play in addressing climate-related challenges in the sector. Module 2 describes a framework for – and an overview of – tools and approaches for integrating climate risk considerations into project design, appraisal and implementation, including climate considerations in strategic investment planning. Module 3 provides a set of technical and sector-specific notes illustrating relevant practical applications and good practices. Module 4 provides an overview of the main climate financing options as well as opportunities and experiences with the Green Climate Fund (GCF) and the Global Environment Facility (GEF).

While the private sector is an emerging and potentially important source of financing for climate change adaptation and mitigation in agriculture, the scope of this knowledge product is limited to a discussion of the range of public financing options. A separate publication on private sector climate financing options may be developed in the near future.

This knowledge product will be published online as reference material, allowing for a continuous learning process in the context of evolving experiences in the design and implementation of climate-smart investments; it is expected to be updated regularly.

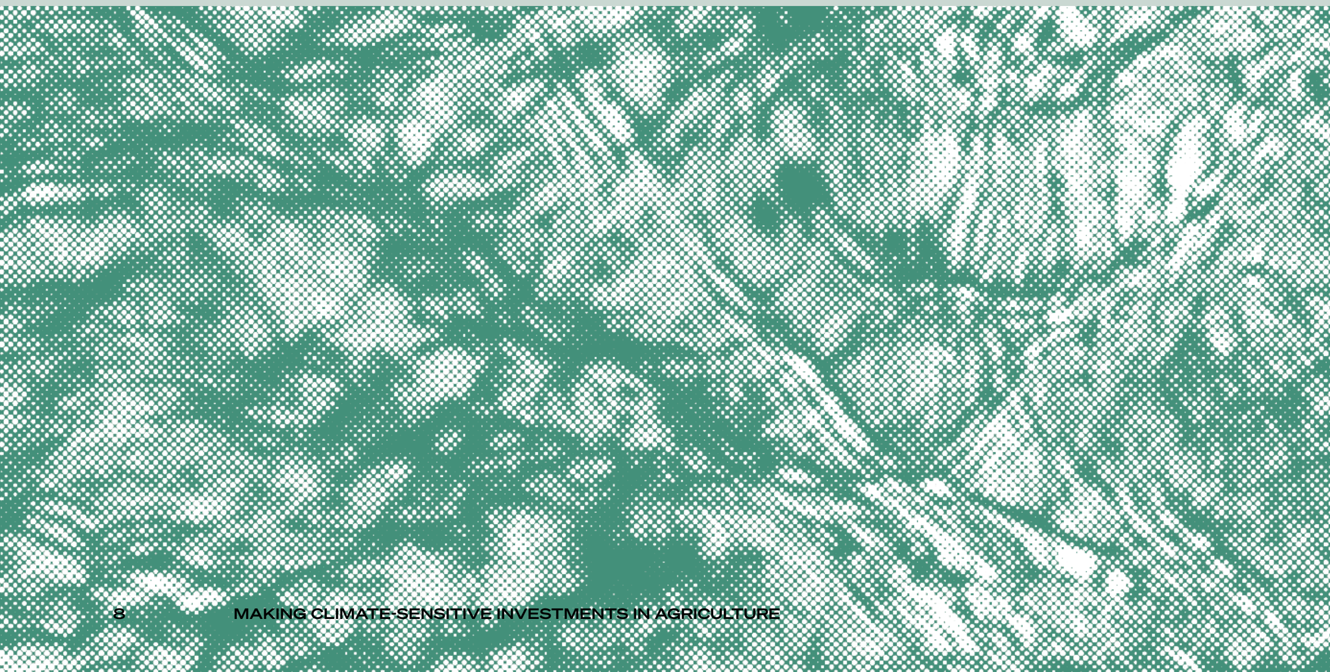
Module 1
Climate change and the agriculture sector

Most of the world's poor live in rural areas and are dependent on agriculture for their livelihoods (including income and employment) and food and nutrition.[1]

Agricultural production is directly threatened by negative climactic changes and, if no action is taken, will continue to increasingly be so. These climatic changes will also negatively affect food and nutrition security and livelihoods.

All agricultural investments have to be progressively more "climate smart", ensuring the robustness of their outcomes to the impacts of climate change, and applying a long-term perspective in designing transformational adaptation and mitigation investment projects.

1 Module 1 by R. Dankova and N. Azzu (FAO)



1.1 CLIMATE, AGRICULTURE AND FOOD SECURITY

Climate change, natural disasters and human-induced disasters pose a serious threat to the future of agriculture and global food security. The impacts of climate change are expected to be long term and far-reaching: damage and losses to production; degradation of land, forests, water, fish stocks and other natural resources; declining rates in productivity growth; and added pressures on agricultural livelihoods and ecosystems (FAO, 2017a).

Despite a decades-long decline in the prevalence of undernourishment in the world, FAO (2018a, 2019a) finds that hunger is slowly on the rise; currently, over 820 million people, or about one in every nine people in the world, suffer from hunger. Food systems are under pressure from both non-climate stressors (e.g. population growth, increased demand for animal-based products) and climate stressors, both of which impact food security (FAO, IFAD, UNICEF, WFP and WHO, 2018). According to the World Bank (2016a), climate change is expected to have the greatest impact on the world's over two billion poor or near-poor people, a large portion[2] of whom work in the agriculture sector and live in rural areas. Indeed, by 2030, climate change could push over 100 million people back into extreme poverty, while over 200 million people could be displaced due to more frequent and severe climatic disasters (World Bank, 2016b).

From a biophysical perspective, climate change affects the conditions under which agricultural activities take place. Agricultural productivity is impacted both directly and indirectly, including through changing precipitation patterns, the geographical redistribution of pests and diseases, and greater frequency of extreme events, such as drought and flooding. Increased temperatures at higher latitudes, for example, are linked to increasing crop yields for maize, cotton, sugar beet and wheat; at lower latitudes, by contrast, wheat and barley yields are declining. These physical, biological and biophysical impacts affect ecosystems and agroecosystems as well as agricultural production – including the quantity, quality and price of agricultural products – with impacts on the income of farm households and on the purchasing power of non-farm households.

All four dimensions of food security and nutrition are affected by climate change. The risks of climate change on agricultural production trickle down to additional risks to the food security and nutrition of people who are directly dependent on agriculture for their food and livelihoods. Climate change risks cascade from agroecosystems to agricultural production, to economic and social consequences and finally to food security and nutrition (FAO, 2016b).

Agriculture-based livelihood systems that are already vulnerable to food insecurity face additional risks, such as increased crop failure, new patterns of pests and diseases, lack of appropriate seeds and planting material, and loss of livestock. This may lead to major shifts in the way in which food is produced, distributed and consumed worldwide – and to new food security, nutrition and health challenges (FAO, 2008). Vulnerable communities and people living in fragile environments – including drylands, mountainous areas, coastal zones and in Small Island Developing States (SIDS) – are already particularly affected by climate change and extreme climactic events. Low-income producers and consumers are the most likely to be affected due to their lack of resources for investing in adaptation and diversification measures.

2 A 2016 World Bank analysis found that 65 percent of poor working adults made a living from agriculture. The same analysis found that agriculture is also crucial to economic growth: in 2014, it accounted for one-third of global Gross Domestic Product (GDP).

According to the 2019 International Panel on Climate Change (IPCC) Report on Climate Change and Land (IPCC, 2019a), food security will be increasingly affected by projected future climate change. Although effects will vary regionally, global crop and economic models projected a 1–29 percent cereal price increase in 2050, impacting consumers globally through higher food prices. And while increased carbon dioxide (CO_2) is projected to be beneficial for crop productivity at lower temperature increases, it is projected to lower nutritional quality. Cumulatively, climate variability and extremes directly and indirectly affect all four dimensions of food security and nutrition – the availability of food supplies; access to food; the stability of food supplies; and the way food is utilized (Box 1.1).

1.2 CLIMATE CHANGE ADAPTATION AND MITIGATION IN AGRICULTURE

As discussed in Section 1.1, agriculture and climate change are indivisibly linked. The agriculture sector is a major contributor to climate change, but it is also vulnerable to the impacts of climate change. Climate impacts relevant to food production and availability can be categorised as:

- modal climate changes (e.g. shifts in climate envelopes causing shifts in cropping varieties planted);
- seasonal changes (e.g. warming trends leading to extended growing seasons);
- extreme events (e.g. high temperatures affecting critical growth periods, and frequency and severity of flooding/droughts); and
- changes in atmospheric conditions (e.g. CO_2 concentrations, short-lived climate pollutants [SLCPs], and dust) (Mbow *et al.*, 2019).

The most recent IPCC report (2019) on land degradation concludes, with high confidence, that climate change – including increases in the frequency and intensity of climate extremes – has adversely impacted food security and terrestrial ecosystems, and has contributed to desertification and land degradation in many regions. Ongoing coastal erosion is also intensifying and impinging on more regions with sea level rise, thus adding to land use pressure in some regions. Examples of climate extremes include temperatures (e.g. heat waves), droughts, precipitation, dust storms, and permafrost thaw.

Disruptions in agricultural production because of climate change are being felt by farming communities, and, consequently, downstream by consumers because of increases in production costs, fluctuations in food supply and price variations. Examples of the effects of climate change across agricultural sub-sectors – crops, livestock, fisheries and forestry – are presented in Annex A: Selected potential impacts of climate change on agriculture, forestry and other land use (AFOLU) sectors, by region.

Agricultural sectors, such as crop and livestock production, face the paradox of being both major contributors to climate change and greenhouse gas (GHG) emissions at the global level, and at the same time, highly vulnerable to the impacts of climate change. FAO (2019b) finds that agriculture – including forestry and land-use change – is responsible for approximately 24 percent of global anthropogenic GHG emissions, including some 56 percent of total non-carbon dioxide (CO_2) emissions. Despite being a major contributor to global GHG emissions, the agricultural sector is also part of the climate solution; it has the potential to contribute to stabilizing the world's climate through better management of crops, land and livestock in a way that reduces emissions and increases carbon sequestration in plant biomass and soils. Investing in agriculture and food and nutrition security that is "climate smart"

Box 1.1.
Climate change impacts on food security

- A drop in food production resulting from climate change impacts will reduce the **availability** of food. Examples of such impacts include extreme climactic events (e.g. floods, droughts, storms); changes in the suitability or availability of arable land and water; and the unavailability or lack of access to crops, crop varieties, and animal breeds that can be productive in changing conditions. Agriculture also absorbs about 20 percent of total damage and loss in developing countries.

- **Access** to food may be worsened by climate change-intensified events that lead to damaged infrastructure and losses of livelihood assets as well as loss of income and employment opportunities. Price rises and spikes have effects on low-income consumers, in particular women and children, due to lack of resources to purchase food.

- Changes in seasonality, increased variance of ecosystem productivity, greater supply risks and reduced supply predictability can affect the **stability** of food supply. This in turn could lead to food price fluctuations and a higher dependency on imports and food aid, as well as to the loss of assets and income of small-scale food producers. Household purchasing power will be reduced, meaning that people may either reduce the amount of food consumed, or consume foods of lower nutritional value.

- The **utilization** of food can be indirectly affected by food safety hazards associated with pests and animal diseases. A decline in nutritional quality can result from increasing atmospheric CO_2.

SOURCES: Asian Development Bank (ADB). 2012. *Guidelines for climate proofing investment in agriculture, rural development and food security.* Mandaluyong City, Philippines, ADB; FAO. 2015. *The impact of natural hazards and disasters on agriculture and food security and nutrition: A call for action to build resilient livelihoods*; FAO. 2017b. *Addressing agriculture forestry and fisheries in national adaptation plans (supplementary guidelines)*. Rome; IPCC. 2019a. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.* P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, *et al.* eds. In press; Mbow, C., Rosenzweig, C., Barioni, L.G., Benton T.G., Herrero, M., Krishnapillai, M., Liwenga, E. *et al.* 2019: Food Security. In P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, *et al.*, eds. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*, 437–550. In press.

is one of the most effective ways to stimulate economic growth, improve livelihoods and reduce poverty, especially in rural areas where the majority of the world's poor live.

There are two main interlinked "pathways" for responding to the impacts of climate change in agriculture – adaptation and mitigation, which should be pursued simultaneously. *Adaptation to climate change* is the process of adjustment to actual or expected climate and its effects (IPCC, 2014a). It aims to reduce *vulnerability* to the impacts and risks of climate change, and to make sure that development initiatives do not inadvertently increase vulnerability.

Climate mitigation refers to human interventions to reduce the sources or enhance the sinks of GHGs (IPCC, 2014a). Climate change mitigation in the agriculture sector can be realized by: (i) reducing emissions through efficient management of carbon and nitrogen flows; (ii) avoiding or displacing emissions by improving energy use efficiency or replacing fossil fuel energy with clean energy; and (iii) removing GHG emissions from the atmosphere by enhancing soil carbon sequestration above and below ground and reducing forest degradation and deforestation (FAO, 2012b).

There is an array of adaptation practices to increase resilience to negative climate impacts as well as a wide range of mitigation measures to address GHG emissions from agriculture. Mitigation can often be a significant co-benefit of actions to strengthen adaptation and enhance food security. Many countries have included climate adaptation and mitigation measures in their Nationally Determined Contributions (NDCs). Measures are related to the following:

- data and knowledge for impact and vulnerability assessment and adaptation;
- institutions, policies and financing to strengthen capacities for adaptation;
- sustainable and climate-smart management of land, water and biodiversity; and
- adoption of technologies, practices and processes for climate adaptation and disaster risk management (see Annex C. Selected examples of adaptation measures to climate change, in NDCs, by sector).

Climate-Smart Agriculture

The dual challenges of climate change adaptation and mitigation, together with the need for agricultural production to increase by 60 percent by 2050 to meet food needs, drives the requirement for a comprehensive approach (FAO, 2017c). The challenge is to increase agricultural production in ways that are more sustainable (for example, through enabling sustainable healthy diets), more climate-resilient, and at the same time reduce GHG emissions. Climate-smart investments in agriculture can significantly contribute towards this triple win objective.

Climate-smart agriculture (CSA) is often defined as *"agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces or removes greenhouse gases where possible and enhances achievement of national food security and development goals"* (FAO, 2013). Its overall objective is to simultaneously address climate-related challenges while capturing synergies and managing trade-offs with the priorities of the agricultural sectors, i.e. food security, rural livelihoods and sustainable development.

The CSA concept provides a consistent framework for the design and prioritization of climate-related interventions in agriculture as part of a country's integrated efforts to achieve the Sustainable Development Goals (SDGs) and its NDC objectives.

Adaptation and mitigation through agricultural investment projects

Over the past decades, a range of technically feasible interventions have been identified to adapt agriculture to climate change, and to mitigate GHG emissions from agriculture. Options for climate change adaptation include *altering exposure, reducing sensitivity and increasing adaptive capacity* (Box 1.2). The range of adaptation options includes tested practices in sustainable agriculture as well as climate-sensitive approaches which have been extended for incorporation throughout entire value chains, including the minimization of food waste and losses. At farm level, successful adaptation methods include crop diversification, integrated farming systems, and soil and water management interventions. Together with better access to and use of climate

Box 1.2.
Vulnerability, exposure, sensitivity and adaptive capacity

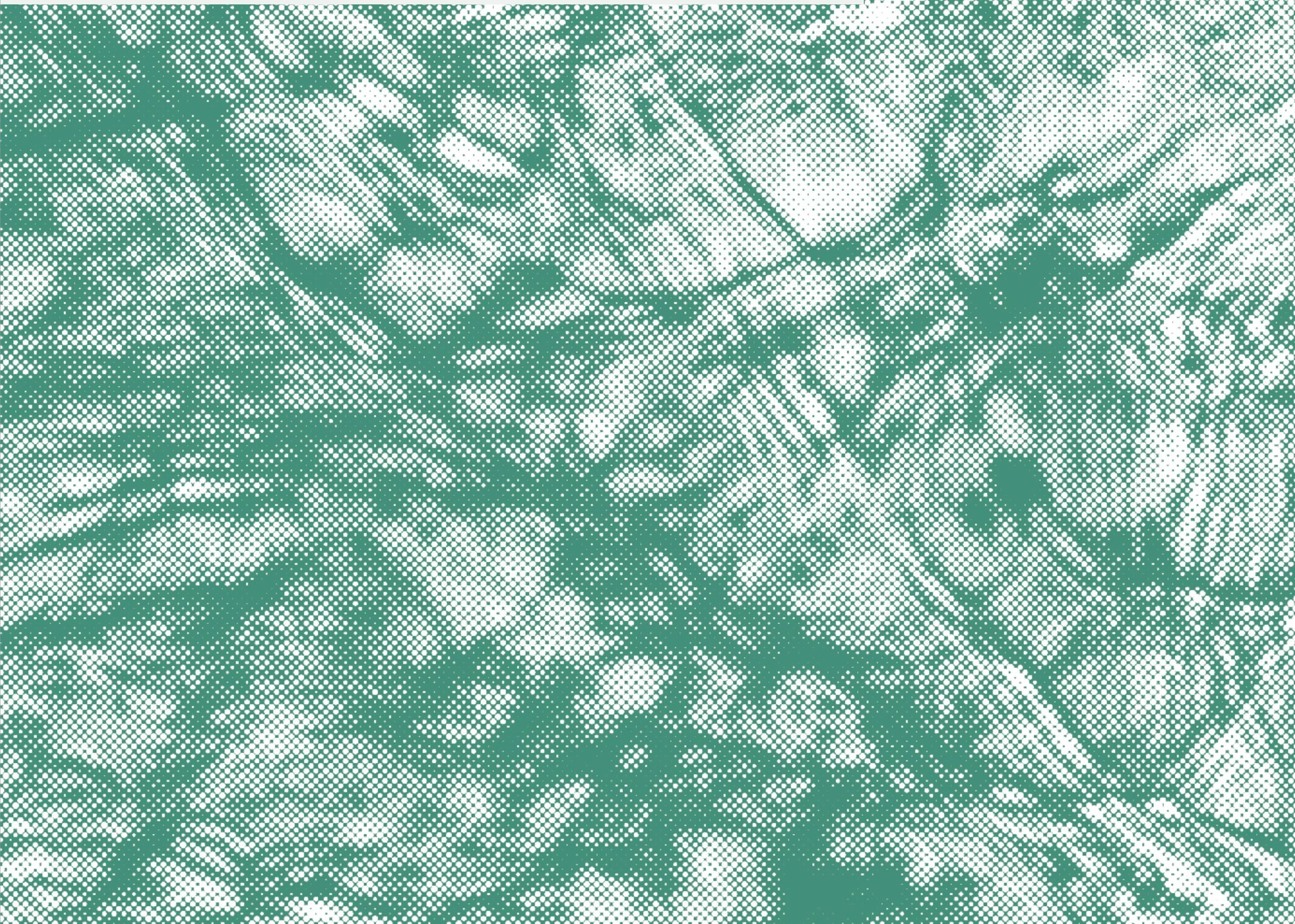
Vulnerability is defined as the degree to which a system is susceptible to and unable to cope with the adverse effects of climate change, including climate variability and extremes. It is a function of exposure, sensitivity and adaptive capacity.

Exposure refers to people, property, systems or other elements present in hazard zones that are subject to suffering potential losses.

Sensitivity is the degree to which a system can be affected by climate variability or change.

Adaptive capacity is the ability of a human or nature system to adjust to climate change to moderate potential damages, to take advantage of opportunities or to cope with the consequences. Climate change adaptation can be enhanced by altering exposure, reducing sensitivity and increasing adaptive capacity.

SEE: Glossary of terms.



Box 1.3.
Returns on climate adaptation investments in agriculture

Ex-ante economic analysis shows that, over a 20-year time frame, the 32 country-level Adaptation for Smallholder Agriculture Programme (ASAP) investments approved since 2010 will generate and redistribute a net worth of USD 0.44 to 1.63 per dollar invested to smallholder farmers and other project beneficiaries, and generate a mean net present value of USD 6.8 million.

SOURCE: Ferrarese, C., Mazzoli, E. & Rinaldi, R. 2016. *Review of economic and livelihood benefits for ASAP-supported investments.* Rome, IFAD.

data and access to financing mechanisms, this provides a basis to manage climate risks through climate adaptation actions.

Numerous technically feasible options have also been found to mitigate agriculture-related GHG emissions, including sustainable livestock intensification, agroforestry, carbon sequestration, and changes in rice production. In particular, changes in land use related to cropland, grazing land, and soil restoration have great mitigation potential in agriculture. Reducing agriculture-driven deforestation is another important mitigation option from agriculture. According to available estimates, because of the projected decline in net annual baseline emissions from agriculture, forestry, and other land use together, the AFOLU sectors could become a net CO_2 sink before the end of the century (IPCC, 2014c).

In addition to their established technical feasibility, many adaptation and mitigation options have been found to be economically viable. According to a recent OECD review (MacLeod *et al.* 2015), a set of highly cost-effective mitigation measures and enabling policies in agriculture are emerging globally. The IPCC (2014b) AR5 report identifies cropland management, grazing land management, and the restoration of organic soils as the most cost-effective mitigation options. Agricultural adaptation interventions have also been found to be economically feasible. Despite differences in estimates of the costs and benefits of adaptation – due to variations in methods, measures and sectors – results from various global studies suggest that the costs of inaction far outweigh the costs of adaptation to climate change (OECD, 2012; Stern 2014; OECD, 2015). For example, the International Fund for Agricultural Development's (IFAD) Adaptation for Smallholder Agriculture Programme (ASAP) – the world's largest programme for building the resilience of smallholder agricultural producers to climate change – will deliver positive returns to investment across a range of climatic scenarios if adoption rates are high (Box 1.3). Some adaptation options also offer "no-regret" solutions that contribute to food security and resilience without requiring trade-offs for mitigation. Importantly, due to synergies between food security, adaptation and mitigation, agricultural adaptation interventions often have mitigation co-benefits. Integrated crop-livestock systems are an example of adaptation practices that have mitigation benefits (FAO, 2013). In turn, many cost-effective mitigation options also provide significant adaptation and resilience benefits. An adaptation practice (or approach) for one sub-sector – for example, crop production – often has beneficial impacts on other sectors, such as improving ecosystem services, increasing the resilience of livelihoods, and mitigating the impacts of climate change.

Climate-smart agricultural practices have been shown to be technically and economically feasible, delivering multiple benefits in terms of increased production and enhanced climate change adaptation and mitigation, thus making a strong case for increased climate-smart investments in agriculture. Agricultural investments need to be increasingly "climate smart", not only to ensure the robustness of the sector to the ongoing and future impacts of climate change, but also to reduce the sector's contributions to GHG emissions, and to increase carbon sequestration where possible. This is the case for more generic agriculture investments focusing on development outcomes, as well as more adaptation- and mitigation-focused projects, or where there is a combination, through specific project components dedicated to climate change.

Over the last decade, many governments, International Financial Institutions (IFIs), United Nations (UN) agencies, and bilateral development agencies have made important climate change commitments and have established targets to integrate climate change into their operations and strategies. For example, in its Climate Change Action Plan (CCAP), the World Bank (2016c) committed to screening all of its agricultural projects for climate risks, and to accounting for GHG emissions in all of its investment operations by 2019. IFAD's Social, Environmental and Climate Assessment Procedures (SECAP) now explicitly include climate considerations in its safeguards policies (IFAD, 2017). Major climate finance mechanisms, such as GCF, reinforce this commitment, promoting innovations that catalyse transformational change and drive a "paradigm shift" towards slow-emission and climate-resilient development pathways. Designing transformational adaptation and mitigation investment projects requires a long-term perspective, grounded in a strong climate rationale, based on verified information about climate impacts and risks, vulnerabilities, and climate evidence; these aspects are discussed in this knowledge product.

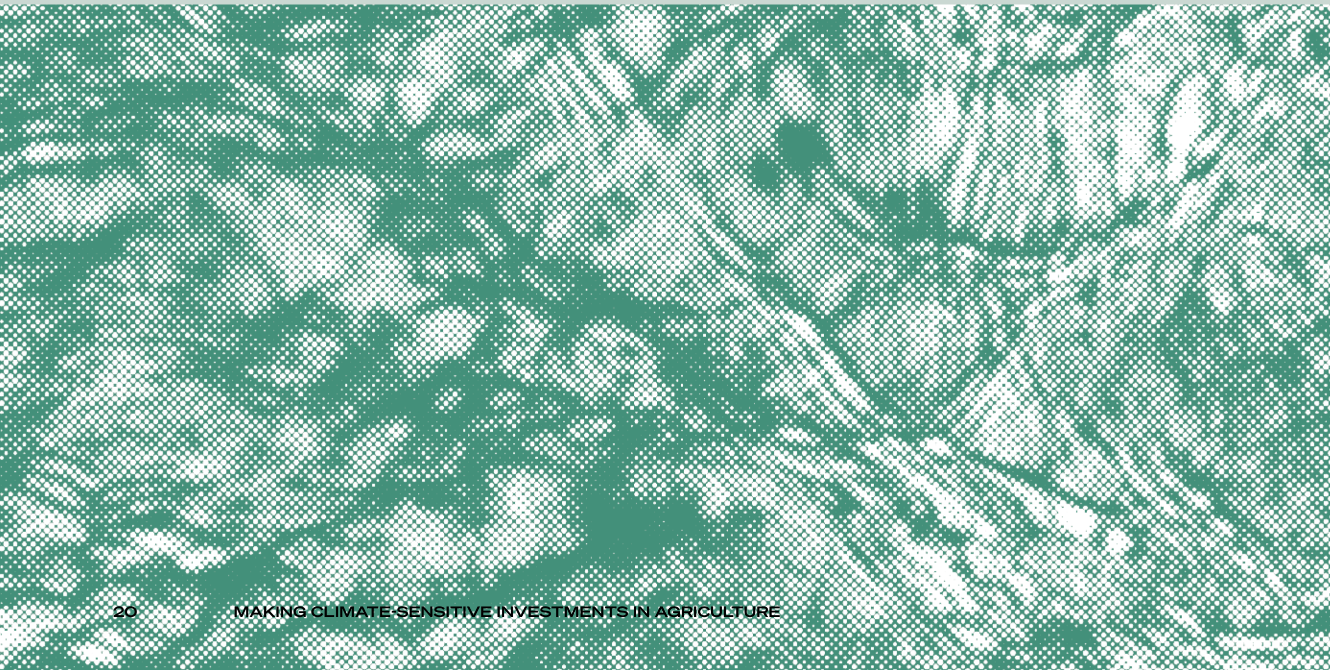
Module 2
Integrating climate change considerations into agricultural investment projects

Understanding climate change and its potential impacts can inform and shape the design and implementation of agricultural investments. This module[3] outlines a framework for the integration of climate considerations throughout phases of the agricultural investment project cycle, focusing on climate risks and vulnerability assessments, and appraisal of the response measures.

Screening and assessment of climate risks at the earliest stages of project design allows for a more climate-resilient outcome of the investment by informing fundamental decisions around the climate risks associated with the project location, targeted communities, and investment options.

The module presents an overview of concepts, approaches, and tools for the assessment of climate risk and vulnerability, and appraisal of investment options, taking into consideration the uncertainties and complexities.

3 By A. Heureux, J. Monzini, H. Kanamaru, R. Dankova, and J. Hancock (FAO).



2.1 CLIMATE CONSIDERATIONS IN AN INVESTMENT PROJECT CYCLE

Integration of climate change considerations should be initiated at an early stage of project development (preferably starting from strategic investment planning at sector level), so that appropriate climate-proofing, adaptation and mitigation measures can be built into project conceptualization, design, appraisal and implementation in order to promote climate resilience. Successful integration of climate change considerations requires specific actions at each stage of the project cycle (Figure 2.1).

Climate considerations in strategic investment planning

As indicated in Figure 2.1, the agricultural investment cycle includes a strategic investment planning stage that aims to set priorities for investment in the sector in the medium term. To be successful, any agricultural investment needs to align with a country's overarching strategies and policies, taking account of their interpretation and implementation at subnational levels. This not only ensures national level buy-in to the investment, but also allows for close coordination with the local government, NGOs and the private sector that can help to drive the investment project. The integration of climate considerations into investment decisions directly concerns the mainstreaming of climate change into a range of policies and action areas that are highly relevant to agriculture and food security. The development of climate-smart policies and plans should also be relevant to a country's integrated efforts to achieve the SDGs and its NDC objectives and priorities (FAO, 2019b). A series

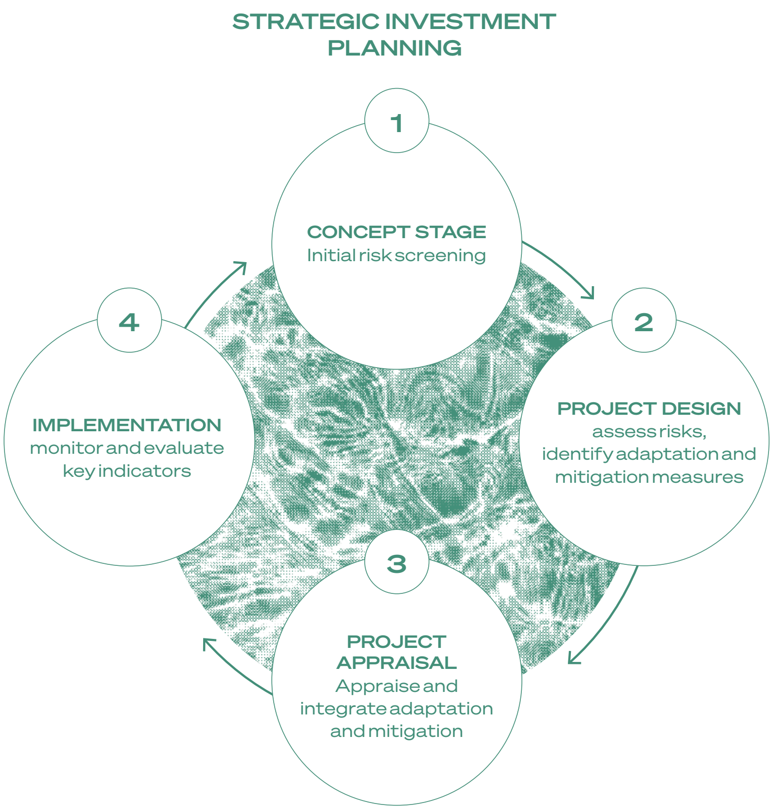


Figure 2.1.
Integrating climate considerations into the project investment cycle

of instruments designed under the UNFCCC for linking international climate change commitments to concrete action for mitigation and adaptation at the country level could be used for the mainstreaming of climate considerations in national planning and programming. This includes:

- *National Adaptation Programmes of Action (NAPAs)* as a dedicated, harmonized, country-led instrument for least developed countries. The programmes identify priority activities responding to "urgent and immediate needs" – for which further delay could increase vulnerability or lead to increased costs at a later stage – for climate change adaptation. To date, over 50 countries have prepared NAPAs (Meybeck *et al.,* 2012);
- *National Adaptation Plans (NAPs)* with a focus on addressing medium- and long-term adaptation needs. NAPs provide a significant opportunity to integrate the concerns and needs of the agriculture sectors and actors in broad national strategies and policies (FAO, 2017b);
- *Nationally Appropriate Mitigation Actions (NAMAs),* as defined by the UNFCCC, are prepared by national governments in the context of sustainable development and provide for nationally appropriate actions that reduce emissions in developing countries (UNFCCC, 2016a). They typically include more detailed actions than NDCs and can be project-based, programmatic, sector-wide, or focused at the policy level.

The recently introduced Climate-Smart Agriculture Investment Plan (CSAIP) Development Guide provides an instrument for developing prioritized investment strategies in agricultural development in the face of climate change (World Bank *et al.*, 2019). The CSAIP development process includes an extensive analysis of the context and entry points for climate-smart investments in agriculture, based on the priority goals set up by national stakeholders. The result of the CSAIP is a suite of country-supported and scientifically justified investments that are most likely to achieve national food security and climate targets (Box 2.1). Another example of strategic investment planning is the National Agriculture and Food Security Investment Plans (NAFSIPs), developed by a number of countries under the Comprehensive Africa Agriculture Development Programme (CAADP) (FAO, 2012b). The NAFSIPs provide the opportunity to integrate the scaling up of climate-smart practices that benefit countries' development, food security and climate change adaptation and mitigation actions. A methodological framework has been developed for examining the potential of the NAFSIPs to generate climate change benefits and is discussed in the FAO (2012b) document, *Identifying opportunities for climate-smart agriculture investments in Africa*.

Climate considerations in a project cycle

Sector investment plans and strategies set up priorities for project level investments. Incorporating issues related to climate-smart agriculture into agricultural investment projects requires a number of steps to be taken throughout the investment project cycle (Figure 2.1). These steps include:

Box 2.1.
A Climate-Smart Agriculture Investment Plan in Zambia

As climate change and uncertainty increasingly threaten Zambia's agricultural productivity, the country's climate-smart agriculture investment plan (CSAIP) promotes the rollout of technologies with the greatest potential for sustainability, enhanced resilience and reduced GHG emissions. The Zambia CSAIP was designed to inform the government, development partners and the private sector about promising climate-smart agriculture technologies and funding requirements to scale up climate-smart investments.

The Zambia CSAIP finds that the four most promising agriculture practices to achieve the "triple win" of productivity increases, climate resilience and mitigation of GHG emissions are crop diversification, commercial horticulture, agroforestry and reducing post-harvest losses.

Findings from the report indicate that most climate-smart agriculture (CSA) technologies are expected to have positive welfare effects on households in the long term. The practices are intended to support agriculture sector goals – e.g. increase production, net trade in key food crops, and food availability – and can lead to substantial climate change mitigation co-benefits.

The CSAIP ranks promising climate-smart interventions that can be prioritized for scale-up, and the type and cost of investments needed for such interventions in Zambia.

SOURCE: World Bank. 2019. *Zambia Climate-Smart Agriculture Investment Plan: Analyses to Support the Climate-Smart Development of Zambia's Agriculture Sector.* Washington, DC.

1. Project conceptualization stage:
    - conduct preliminary screening of climate risks and vulnerabilities of agriculture at the sector and project target area levels.
2. Project design:
    - assess the identified climate risks and associated climate impacts in the project area; assess vulnerabilities of the project's targeted communities; and
    - identify climate adaptation and mitigation activities or options for refining project activities to better address identified risks.
3. Project appraisal:
    - appraise and prioritize the climate-smart responses identified during project design; and
    - integrate the prioritized activities in the project design.
4. Project implementation:
    - build institutional capacities to implement climate-smart activities in agriculture; and
    - monitor and evaluate the project climate-resilience results along key selected indicators, and build institutional capacities in the implementation of climate-smart investments in agriculture.

The sections below discuss and outline climate risk assessment steps, approaches, information requirements, and tools that could be used for integrating climate considerations in relevant stages of an investment project cycle.

2.2 CLIMATE IMPACTS AND RISKS

In the context of climate change, the term "risk" refers to the potential for adverse consequences of a climate-related hazard on the identified system or area. Risk results from the interaction of vulnerability and adaptive capacity (of the affected population or system), exposure to a hazard over time, as well as the climate-related hazard and the likelihood of its occurrence (see Figure 2.2).

In order to appraise climate risk in the context of a particular project, an assessment should address the three major components contributing to risk as outlined in Figure 2.2: *hazards, exposure and vulnerability*. The main concepts used in climate risk assessment are defined in the Glossary of terms. The updated IPCC framework for risks and risk assessment accounts for the interrelated nature of the three major components. For example, in an area with high exposure and likelihood of climate-related hazards, the risk is much higher for those communities that have less means and capacity to cope and adapt, and are thus are more vulnerable. Risk is highest when all three of the components in Figure 2.2 – hazard, exposure and vulnerability – are categorized as high.

The incorporation of climate considerations into agricultural investment decision-making processes requires applying a climate lens at every stage of the project cycle. Climate considerations require project teams to think about historical climate trends as well as future projections of climate change and potential impacts in both the short and long term. Identification of appropriate adaptation and mitigation actions as part of project conceptualization

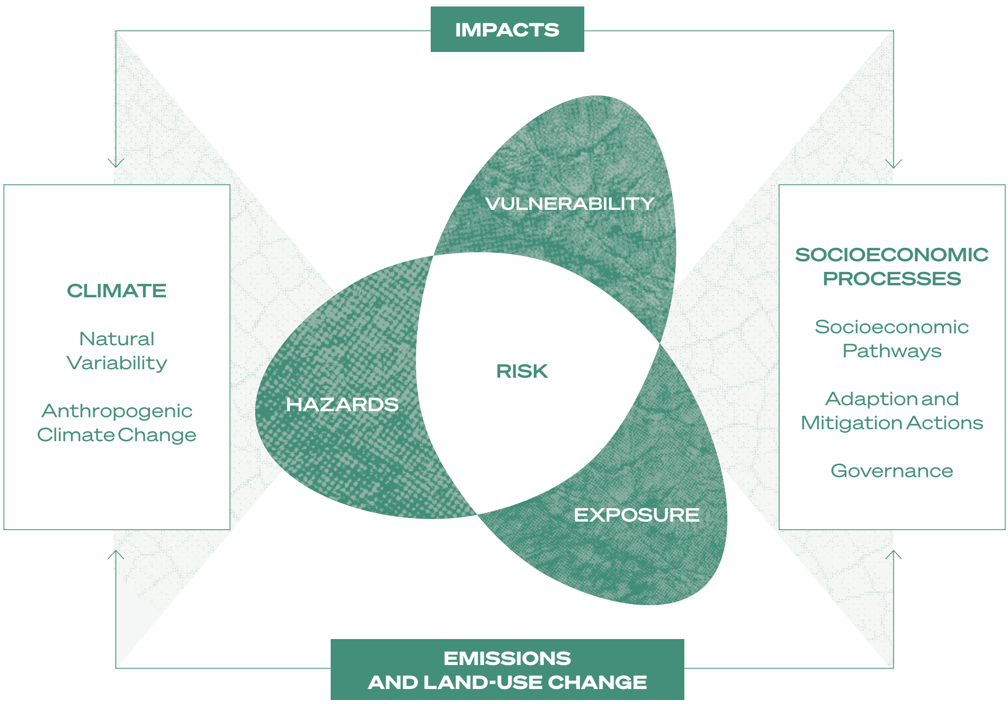


Figure 2.2.
IPCC AR5 conceptual framework of risk

Risk in this new framework is considered as the interaction between the 3 parameters: hazards, exposure and vulnerability. Impacts are considered as a function of a given risk on socioeconomic processes.

SOURCE: IPCC, 2014b.

and design should be based on evidence and understanding of how climate will affect the country, target areas and project activities. To build this understanding, climate risk assessments (i.e. climate hazards, exposure and vulnerability assessments) should be an integral part of the preparation of an investment operation in agriculture.

2.3 CLIMATE RISK SCREENING

The potential risks associated with climate change and natural disasters need to be considered at the early stages of project development. Screening is an initial and essential step to ensure that climate and disaster risks are assessed and that further steps are identified for the subsequent stages of project development. Climate risk screening takes place at the concept stage, while a more in-depth assessment of climate risk should be considered at the formulation and appraisal stages of the project cycle (Figure 2.1).

Climate risk screening is often undertaken by reviewing existing information and is carried out by relevant national experts or by the project design team. Stakeholder engagement and data collection should inform the process and be integrated into project design. Before initiating the screening process, a thorough understanding of the geographical, agricultural, political and socioeconomic context and climate is required. The initial simplified risk screening should act as the first step in assessing the likelihood of the project interventions addressing or increasing the vulnerability of the expected target populations to climate hazards. The initial screening process will rate climate-related risk on the scale below:

High/Substantial	A detailed climate impact/risk assessment is highly recommended in order to adequately identify measures to reduce risks
Moderate	Further screening or detailed assessment is recommended
Low	No action is required, but monitoring risk throughout the project development is recommended

Based on the risk rating, climate risks should be incorporated into project formulation. If the project is identified as a high or substantial climate risk, it is recommended that a detailed climate risk assessment be carried out.

The requirement for climate risk screening by international donors, including the GEF and GCF, has led agencies, institutions, and investment funds to move forward with the establishment of standards for the screening process and risk categorization. Risk assessment and screening tools are currently available from a number of development institutions, such as the Asian Development Bank (ADB), Department for International Development (DFID), German Technical Cooperation Agency (GTZ), International Institute for Sustainable Development (IISD), International Union for Conservation of Nature (IUCN), Stockholm Environment Institute (SEI), Swiss Agency for Development and Cooperation (SDC), United States Agency for International Development (USAID), World Bank, and World Meteorological Organization (WMO). Table 2.1 provides some examples of tools available for climate risk screening in development institutions.

Table 2.1
Climate risk screening tools relevant to the agricultural sectors

Organization	Sector	Scale	Open access	Name of tool	Link
World Bank	Agriculture, water, energy, health, transportation, policy	Global	Yes	World Bank Climate and Disaster Risk Screening Tools	https://climate-screeningtools.worldbank.org/
International Union for Conservation of Nature (IUCN), Stockholm Environment Institute (SEI), International Institute for Sustainable Development (IISD), and Swiss Agency for Development and Cooperation (SDC)	Food security and resource efficiency	Africa, East Asia and Latin America	Yes	Community-based Risk Screening Tool – Adaptation and Livelihoods (CRiSTAL)	www.iisd.org/cristaltool/
World Resources Institute (WRI)	Water scarcity and land degradation	Global	Yes	Aqueduct Water Risk Atlas	www.wri.org/our-work/project/world-resources-report/information-needs-climate-risk-management
Asian Development Bank (ADB)	Agricultural, rural development, food security	Global	Yes	Climate change adaptation through integrated risk assessment (CCAIRR)	www.adb.org/sites/default/files/institutional-document/33720/files/guidelines-climate-proofing-investment.pdf
Japan International Cooperation Agency (JICA)	Water, irrigation, farmland, forest, disaster prevention	Global	Yes	Climate Finance Impact Tool	www.jica.go.jp/english/our_work/climate_change/adaptation.html
International Fund for Agricultural Development (IFAD)	Food security and rural development	Africa	Yes	Social, Environmental and Climate Assessment Procedures (SECAP)	www.ifad.org/en/secap

SOURCE: Authors.

2.4 CLIMATE RISK ASSESSMENT

In case of high, substantial or moderate climate and disaster risk screening results, a more in-depth assessment of climate risk and impacts on the project areas is recommended at the formulation and appraisal stages of the project cycle.

Climate risk assessment is the process of identifying and evaluating, in physical or economic terms, the effects of climate change on natural and human systems. A more in-depth assessment of climate risk should be considered at the formulation and appraisal stages of the project cycle (Figure 2.1). Such assessments will aid in understanding the impacts that climate has or will have on the proposed project activities and the identification of appropriate and effective climate change adaptation actions to address risks. In parallel, the assessment process can also investigate the project mitigation potential to guide mitigation activities and seek co-benefits between adaptation and mitigation. The information required and assessment carried out will differ depending on the project area, data availability, target sector(s) and time constraints. Questions to be answered during the assessment are summarized in Box 2.2.

Carrying out a climate risk assessment for agricultural projects that are identified as high climate risk involves the following general steps:

1. identify the objectives and scope;
2. collect data and identify stakeholders;
3. assess climate change trends, hazards, and impacts;
4. identify exposure; and
5. assess climate vulnerability in the project area.

Step 1: Setting objectives and scope of assessment

The scope and context of the project or study area determines the approach for the risk assessment, including the appropriate methodologies and feasible scope of the assessment. The assessment objectives should be defined specifically for the sector and thematic areas relevant to the project. The spatial scope of the assessment is defined based on the local climatic characteristics and the potential areas of high climatic risks and related vulnerabilities. This may be regional, national, district or basin level. Once identified, the baseline situation of the project site must be outlined, including climatology, agro-climatic context and agricultural baseline.

In order to understand the average climate or "normal" climate in a region, it is important to start by outlining the climate baseline. Developing an overview of the climate baseline can be done by defining the study area by climatic zones (polar, temperate, arid, tropical, Mediterranean or mountainous), or by agroecological regions, which include information about the topography and land cover, climate, soil and irrigation. With this information, the average climatology, or climate averaged over the last 30-year period, can be assessed within the identified area.

The specific objectives and scope of the assessment will also define a selection of appropriate approaches and tools. Table 2.2 organizes FAO climate-related tools according to the main objective and application requirements. The tool descriptions can be found in Annex E: FAO tools for assessment of climate hazards, impacts and vulnerability.

Step 2: Data collection

The data collection and stakeholder engagement step will require the review of existing datasets and studies, stakeholder consultations, workshops and additional analysis where data gaps are identified. A number of available tools may be used to facilitate the process (Table 2.2). The minimum data requirements for the climate risk assessment include climate data, agricultural data and socioeconomic data; they are summarized in Box 2.3.

There are numerous organizations and institutions involved in the monitoring, interpretation and application of climate change data. During the data collection stage of the assessment, it is advisable to consult the national meteorological service about the availability of national climate data or studies. A large amount of academic literature on climate change and its impact on agriculture at global and regional scales is available and open source. Information at national and subnational scales are more limited, but useful information can be found from the list of information sources outlined in Box 2.4.

Box 2.2.
Guiding questions for the climate risk assessment – characterising the climate context of the project

Setting the baseline: defining study area
- How is the study area defined? By administrative boundaries? By river basins?
- What are different agroecological zones within the area?
- What is the baseline/average climate in the project site?
- What is the seasonal cycle of the local climate?
- What kind of extreme events are common in the project site?
- What is the vulnerability/exposure of the target population?

Historical climate trends
- Do you find a trend in the climate records (temperature and precipitation) for the project site?
- Do you find a trend in the frequency, intensity or duration of climate extremes (discussion of extreme climate indicators to follow)?
- Do you see a shift in the timing or seasonality of these events relevant to agriculture?

Historical climate impacts on local agriculture
- How has the productivity of local agriculture changed in the past and for what reasons? Do you find a trend in the state of local agriculture?
- Is there a relationship between climate trends and agriculture in the local area?
  How has climate been affecting agriculture in the local area?
- What climatic factors affect agriculture more: temperature, rainfall or extreme events?
  During what time of the year is agriculture more sensitive to climatic factors?

Projected future climate trends
- What is the projected change in the local climate in the future?
- What are possible ranges of change?
- Are the (extreme) values of climatic variables increasing or decreasing?

Projected future impacts
- What is the projected climate impact on local agriculture or ecosystems in the future?
- What can be done to cope with projected future impacts?

Vulnerability and exposure
- What are non-climate factors that contribute to the vulnerability of agriculture?
- How might the expected changes in climate increase or decrease the vulnerability or exposure of target populations?
- What is the adaptive capacity of the local communities or ecosystems?

Table 2.2.
Examples of FAO tools for climate risk assessment organized by thematic areas, assessment objectives and requirements

		Earth map	AEZ	MOSAICC	ASIS	WaPOR	GLEAM	SHARP	RIMA
Thematic areas	Crops		■	■					
	Water	■	■	■	■	■			
	Livestock						■		
	Fisheries								
	Forest	■	■	■					
	Socioeconomic	■						■	■
	Economy			■					
Data collection required	None	■			■	■			
	Climate data		■	■					
	Local data		■	■			■		
	Survey data							■	■
Spatial scale	Global	■	■		■				
	Regional	■	■		■	■			
	National	■	■	■	■	■	■		
	Subnational	■		■			■	■	■
Temporal scale	Historical	■	■	■	■	■	■	■	■
	Short-term future				■				
	Long-term future		■	■					
Specific expertise required	None	■							
	Basic knowledge		■		■	■		■	■
	Expert			■			■		
Output	Hazard information	■	■	■	■	■	■		
	Impacts		■	■	■				
	Exposure	■	■	■					
	Vulnerability							■	■

Step 3. Assessing climate change trends and hazards

Historical mean climate trend

Data availability and quality varies significantly by location, country, climatic variables and temporal frequencies. Using the data sources outlined in Step 2, analysis of the trend in historical climate data can be performed, as demonstrated in the Pakistan case study (Module 3, Technical note 1). In this case example, trends are calculated by applying linear regression analysis, complemented with the test on the significance of the resulting trends[4] (see, e.g. Zhang *et al*., 2001; Manzanas *et al*. 2015).

The trend analysis should identify the spatial distribution of changes in climate variables, such as where temperature is increasing and decreasing in the country. Trend analysis of climate data by month or by agricultural grow-

4 The non-parametric Mann-Kendall (MK) statistical test has frequently been used to quantify the significance of trends in hydro-meteorological time series. The main reason for using non-parametric statistical tests is that, unlike parametric tests, the non-parametric tests are considered to be more suitable for non-normally distributed and censored data, which are frequently encountered in hydro-meteorological time series.

Box 2.3.
Minimum data requirements for climate risk assessment

Climate data

- Meteorological data (30+ years recommended) for mean temperature, maximum temperature, minimum temperature and precipitation. In some regions, obtaining long-term data may be difficult, therefore less data or global datasets can be justified.
- Daily climate data is recommended for analysis of extremes including frequency, intensity and duration of extreme climate events.
- Future modelled/projected climate variables for the mid- to long-term future. Climate projections, at minimum global products, but if available, downscaled climate data (either statistically or dynamically) is preferred for local level assessment (see Box 2.6 on climate downscaling).

Agricultural data

- Agroecological or climate zones in project area
- Land cover and land-use data
- Major agricultural products/livelihoods, agricultural data (i.e. crop calendars), statistics (crop yields, livestock statistics, etc.) for study area
- Remote sensing data (land cover)
- Hydrological data, river flow data, sea level, irrigation.

Socioeconomic data

- Information on population and major livelihoods in study area
- Poverty, nutrition and hunger statistics
- Gender and age disaggregated data
- Housing statistics, heath conditions, economic conditions (possibly including migration statistics)
- Political situation and institutional support.

ing season will provide additional details about changes in seasonality. For example, temperature is increasing more in the summer or winter season, and therefore the analysis can specify which crops will be impacted depending on this temperature increase pattern. This analysis will aid in the identification of where and when the country or study area experiences climatic changes (see Box 2.5).

Historical trend of climate extremes and extreme events

Trends in historical extreme weather events for the study area can be analysed from daily meteorological data using temperature or precipitation-based extreme indicators. The Expert Team for Climate Change Detection and Indices (ETCCDI) has developed a set of 27 core indicators that can be applied in this context, as outlined in the link and for temperature-based indicators in Table 2.3 (http://etccdi.pacificclimate.org/; http://etccdi.pacificclimate.org/list_27_indices.shtml).

Other sources of extreme event and disaster information include the EM-DAT[5] database of historical disasters at the country level, and the UNEP PREVIEW,[6] which provides an overview of natural disaster risks in a given country.

When analysing extreme events, pay particular attention to intensity and frequency – both of which are expected to change in the future. Heavy preci-

5 The WHO Collaborating Centre for Research on the Epidemiology of Disasters (CRED) maintains an Emergency Events Database EM-DAT.

6 PREVIEW stands for Project for Risk Evaluation, Information and Early Warning. It is supported by UNEP, UNDP/Bureau for Crisis Prevention and Recovery's (BCPR) Global Risk Identification Program (GRIP), UNISDR and World Bank.

Box 2.4.
Sources of initial information for climate risk assessment

UNFCCC **National Adaptation Programmes of Action** (NAPAs) and **National Adaptation Plans** (NAPs) are nationally formulated plans aimed at identifying appropriate medium- to long-term adaptation needs and developing strategies and programmes to meet those needs. (See: https://unfccc.int/topics/resilience/workstreams/national-adaptation-programmes-of-action/introduction; https://unfccc.int/topics/adaptation-and-resilience/workstreams/national-adaptation-plans).

Nationally Appropriate Mitigation Actions (NAMAs) are actions identified at national or individual level to reduce GHG emissions in developing countries. National level submissions are formal submissions declaring intent to mitigate GHG emissions, while individual submissions may detail actions designed to help a country meet their objectives. (See: https://unfccc.int/topics/mitigation/workstreams/nationally-appropriate-mitigation-actions).

Database on GHG emissions from agriculture, forestry and other land-use sectors (FAOSTAT)
The emissions database provides a coherent and internationally neutral data platform, and it is a useful resource for member countries. (See: www.fao.org/faostat/en/#data).

Academic papers
Institutions like FAO have subscriptions to literature databases, such as Scopus (www.scopus.com) and Web of Science (www.isiknowledge.com), and to major academic journals. Peer-reviewed journal articles can be located by searching on these databases with relevant keywords.

Grey literature (non peer-reviewed reports and other documents)
A large amount of information produced for developing countries tends to be published in non peer-reviewed reports. The academic databases mentioned above cover grey literature to some extent. Google Scholar (http://scholar.google.com) can also point you to both peer-reviewed and grey literature.

National ministries, climate change bodies, research institutions and universities
It is highly recommended to inquire with relevant ministries, institutions and universities in the country for other useful information that is not published. Data and publications may be available on the websites of the national institutions.

Open source databases
The data portal for the Coupled Model Intercomparison Project 5 (CMIP5) was completed for the IPCC fifth assessment report and is available at https://cds.climate.copernicus.eu/cdsapp#!/home.

pitation events can be found in monthly rainfall data (compared with climate normals) or daily rainfall data (i.e. a sum of daily values for a series of consecutive rainy days). Heat waves can be recognized in monthly temperature averages (i.e. either daily maximums, daily minimums or daily means, compared with the normal climate for the same month), or the number of consecutive hot days (above a certain threshold which can be defined for a given location) in daily temperature data. Droughts can be characterized by total monthly precipitation (compared with a normal climate), or by the number of consecutive no-rain days. Frequency can be expressed, for example, in the number of extreme events per year or per growing season. For examples of this analysis, refer to the case study in Module 3, Technical note 1.

Box 2.5.
A note about climate data

Basic climatic variables of interest to the agricultural sector include precipitation (i.e. rainfall), temperature (i.e. daily maximum, daily minimum, daily mean), wind speed and direction, solar radiation, humidity, evaporation and runoff. The data are measured at tens of thousands of land-based weather stations across the world at least once a day and often more frequently. They are complemented by observation by ships, radiosondes, aircraft and satellites. Station data are archived by national weather services; some are with the international community through the World Meteorological Organization (WMO), while others are held by the national institutions. Therefore, it is advisable to contact the national weather service to inquire about data availability at the earliest stages of project design. Whenever possible, choose quality-controlled data.

Meteorological data are usually available at points (e.g. weather stations) or on grids (spatial resolution may vary). If you are dealing with a large area and want to visualize climate and impacts on a map, gridded data may be easier to use than station data. In the example presented in Technical note 1 we focus on climate information at a particular location, mainly from land-based weather station data, because they are the primary data source for any local area. Although Technical note 1 gives general pointers on useful online resources, proper processing and interpretation of climate data often require expert knowledge.

It is strongly recommended to read the background document that accompanies data sets to understand the nature of the data before using them for your work. In case you cannot find data at your project location, use data from neighbouring locations or at different scales (e.g. national or regional datasets), but interpret the data carefully considering spatial heterogeneity in climate, agricultural practices and ecosystems. It is advisable to obtain the longest-possible datasets in order to establish observed trends, but be aware of changes in observation locations and measurement methods which may cause discontinuity in time series.

Future climate trends

Future projections of climate are outputs from general circulation models (GCMs) or Earth System Models (ESMs) and typically have a low resolution of 150–300 km by 150–300 km. GCM and ESM outputs are available from the IPCC Data Distribution Centre. Coupled Model Inter comparison Project Phase 3 and 5 (CMIP3 and CMIP5) archives provide global climate model outputs, but expert knowledge is usually needed to analyse the data. Data on such a coarse resolution should ideally be downscaled (either statistically or dynamically) for local applications at subnational level (Hanssen-Bauer *et al.*, 2005; See Box 2.6). Downscaling is a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution GCMs. Many impact models require future climate information at scales of 50 km or less, so some method is needed to estimate the smaller-scale information (Giorgi *et al.*, 2001).

Climate impacts on agriculture

Building upon the assessments of historic and future climate trends, climate impact analysis on agriculture in the project area should be conducted. An analysis of how climate variability and change are impacting the agriculture sector needs to take into account agricultural input markets, food demands, transportation, distribution channels and agricultural production. Impact assessment models can be physical models (e.g. crops, hydrology, fisheries

Table 2.3.
Temperature and precipitation-based extreme indicators (ETCCDI)

Precipitation-based		
Indicator	**Description**	**Units**
CDD	Largest number of Consecutive Dry Days (PRECIP<1mm)	days
RR	Annual precipitation sum	mm
RR1	Number of wet days (PRECIP>= 1mm)	days
SDII	Simple Daily Intensity Index	mm/day
CWD	Largest number of Consecutive Wet Days (PRECIP>=1mm)	days
R20	Number of very heavy precipitation days (PRECIP>=20mm)	days
RX1DAY	Maximum 1-day precipitation	mm
R95PTOT	Precipitation fraction due to very wet days (PRECIP>=p95)	%
Temperature-based		
Indicator	**Description**	**Units**
TXX	Maximum value of daily maximum temperature	ºC
TNN	Minimum value of daily minimum temperature	ºC
SU	Summer days: Number of days with TASMAX>25C	days
TR	Tropical nights (days): Number of days with TASMIN>20C	days
HW	Heat waves (days) – Number of days with TASMAX > certain threshold (crop dependent) 35ºC.	days
CW	Cold waves (days) – Number of days with TASMIN < certain threshold (crop-dependent)	days
DTR	Mean diurnal temperature range	ºC
ETR	Extreme diurnal temperature range	ºC
VDTR	Mean absolute day-to-day difference in DTR	ºC
DTR	Mean diurnal temperature range	ºC
ETR	Extreme diurnal temperature range	ºC
VDTR	Mean absolute day-to-day difference in DTR	ºC

SOURCE: Authors.

and forestry), or economic models that are highly specialized, thus experts in the field should be consulted.

A common climate impact assessment of agricultural productivity (e.g. crop yield) follows a top-down approach, as applied in FAO's MOSAICC approach (Table 2.2), and Section 3.1., Technical note 6. This approach requires a good understanding of current and past impacts of climate change on agriculture sectors and local perceptions of climate change as well as the collection of long-term historical data of weather and agriculture. For details on how to analyse the impacts of climate change on each sector, such as fisheries and livestock, refer to Section 3.2.

All assessments should begin with data collection and an investigation into the annual variability of national or subnational agricultural production of the most important agricultural commodities in the country or area of interest. National or subnational statistics of field crops, livestock, fisheries (freshwater and saltwater species) and forest products can be obtained from the relevant ministry. For example, the Ministry of Agriculture should have statistics related to the agricultural commodities that are most important to a country. While it is preferable to use national crop statistics, FAOSTAT can be used to supplement available data if national data is insufficient or

Box 2.6.
Climate change is global but impacts are local: downscaling of climate projection

Global averages of climate change are useful in certain contexts; however, for the purpose of project development within a study area, global averages may mask a high degree of heterogeneity both spatially (i.e. between regions) and temporally (i.e. seasonality). The use of local-level information is necessary in order to formulate a project to address the specific climate-related hazards and impacts experienced by that region. Climate downscaling reinterprets coarser outputs from GCMs or ESMs to a scale more suitable for the assessment of local impacts. Two methods for downscaling of climate projections include:

- Dynamical downscaling, which uses a limited-area, high-resolution model (a regional climate model, or RCM) driven by boundary conditions from a GCM to derive smaller-scale information. RCMs generally have a resolution of 20 to 100 km.
- Statistical downscaling, which uses statistical relationships to predict local climate variables from large-scale variables (the predictors).

Uncertainty
Future changes in climate and the resulting impacts cannot be predicted with precision. Climate scientists talk of climate change scenarios or projections instead of predictions. Uncertainty arises due to the following:

- The magnitude of climate change depends on future GHG emissions, which are unknown. Climate models are usually driven by more than one GHG emission scenario, resulting in various climate scenarios.
- Different climate models produce different results. Depending on the parameterization of the climate model, slight differences in the values, range and extremes of climate variables are shown in climate model outputs.
- Models used for impact assessments, such as changes in crop yields, also have uncertainties.

Uncertainties in climate change projections do not mean that the results aren’t useful; instead, uncertainty should be appropriately addressed and documented. There is high confidence from all models that climate will change severely if GHG emissions continue at the present level or even rise.

SOURCES: Rockel, B. 2015. The regional downscaling approach: A brief history and recent advances. Current Climate Change Reports, 1: 22–29; Benestad, R. E., Hanssen-Bauer, I. & Chen, D. 2008. *Empirical-statistical downscaling.* World Scientic.

incomplete. With this data, agricultural statistics can be compared with climatic information to assess the potential impacts of climate events on agricultural production, loss or damage.

Step 4: Exposure to hazards

As outlined above, exposure describes the presence of people, livelihoods, species or ecosystems, environmental functions, services, resources and infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected by the identified hazards. While some frameworks consider exposure to be a component of vulnerability, the IPCC AR5 framework differentiates the two as individual factors contributing to risk. As vulnerability and exposure are not fixed, understanding the trends in vulnerability and exposure is therefore an important aspect of the discussion.

The assessment of exposure is achieved by identifying areas where the occurrence of hazards overlaps with the presence of people, ecosystems, resources, infrastructure, etc. At this stage, the assessment of socioeconomic information is required together with the assessment of hazards and impacts. For example, population data overlain with previous assessment of climate trends and impacts can identify the number of people exposed to a given impact. Similarly, the land-use maps of a region or area overlain with hazard maps can identify which livelihoods are exposed to each hazard. This stage will require socioeconomic data, and ideally, the use of geographic information systems (GIS) expertise to produce relevant maps.

Step 5: Assessing vulnerability

The IPCC (2007) defines vulnerability as "the degree to which a system or society is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes." In addition to biophysical impacts of climate change, an analysis of vulnerability would require an evaluation of local adaptive capacities of exposed communities to cope with the expected impacts. There is a significant difference in exposure and vulnerability between developing and developed countries. For example, while a similar (average) number of people in low and high human development countries may be exposed to hazards each year (11 and 15 percent respectively), the average number of people killed is very different (53 and 1 percent respectively) (Peduzzi, 2006).

Impacts on agricultural productivity and other aspects of the sector can lead to different repercussions in household income and food security. Vulnerability of livelihoods depends on the capacity of local communities to substitute a negatively affected production system with an alternative that could prevent losses in agricultural income, provide subsistence production, or supply food to urban markets. Vulnerability assessments characterize and identify areas, households or subpopulations that have particularly low livelihood resilience. This helps planners prioritize their actions and target vulnerable communities (e.g. youth, the elderly, landless people, and women). Vulnerability assessments also provide the basis for the development of strategies to increase the resilience of livelihoods to climate change; they can take a top-down or a bottom-up approach.

The bottom-up approach focuses on collecting different indicators that would characterize the vulnerability and associated sectors by various risks, including climate change (for example using the SHARP or RIMA tools outlined in Table 2.2). There are a wide variety of possible indicators: socioeconomic resources, technology, infrastructure, information and skills, institutions, biophysical conditions and equity (Dessai and Hulme, 2004). Climate change and variability are considered a major threat to society and the environment, and contextual conditions (socioeconomic, political, institutional, etc.) determine the adaptive capacity and vulnerability to potential threats.

Within each category, a variety of existing tools might facilitate the assessment. For example, desktop reviews might be used to do the following: systematically design impact-response tables or vulnerability matrices; identify and list relevant climate hazards for a specific area based on available disaster databases; and highlight key impacts by sector for a specific time period (USAID, 2019). Stakeholder consultations might involve a workshop with plenary and small group discussions among government stakeholders, or use participatory rural appraisal techniques. Assessments of vulnerability often involve more than one method and multiple sources of information.

In order to assess different aspects of climate risk for investment projects, FAO offers a range of climate-related tools that provide information and analysis for different climate risk assessment objectives which are shared throughout the document and summarized in Annex E.

2.5 IDENTIFYING RESPONSE OPTIONS

Results of the climate risk assessment inform project planning and design. They facilitate the identification and appraisal of a range of adaptation options for tangible improvements in the climate resilience of agricultural systems and rural livelihoods, while also considering productivity and priority types of interventions towards achieving the SDGs (FAO, 2018a).

Both "soft" and "hard" adaptation measures should be considered in response to the project-specific climate risks identified. These measures can include a range of actions, from establishing the favourable enabling environment, including policies and institutional capacity for addressing climate change impacts in agriculture (soft measures), to adopting alternative or improved technologies and agricultural practices, and investments in physical infrastructure designed to reduce the impact of current and future climate risks (hard measures). An illustrative framework of resilience-enhancing actions along an agriculture value chain is summarised in Annex D. Established "best practice" standards or guidance on adaptation should be used wherever possible and appropriate. Selected examples of adaptation measures to climate change, in NDCs, by AFOLU sector, are summarized in Annex C. Some sector-specific approaches to, and experiences with, the integration of climate considerations in agricultural projects are discussed in Section 3.2.

Designing climate-smart investments also requires consideration of the level of uncertainty with which future climate impacts will occur. A useful classification of adaptation measures is based on the framework of "no-regret", "low-regret", and "high regret" investments, and examples of such investments are widely discussed in the literature (World Bank, 2014). Both no-regret and low-regret options can be "win-win" options, enhancing adaptive capacity and also contributing to the achievement of other social, environmental and economic outcomes. They create synergies between mitigation and adaptation through adaptation measures that not only increase carbon sequestration, but also lead to increased climate resilience and higher yields.

Climate change adaptation options can be incremental and transformational. Incremental adaptation maintains the essence and integrity of a system or process at a given scale, while transformational adaptation changes the fundamental attributes of a system in anticipation of climate change and its impacts (IPCC, 2014b). In the agriculture sector, improvements to crops (e.g. drought- or flood-tolerant varieties), or to on-farm management practices can be considered incremental adaptation. It is recognized that incremental adaptation will not be enough, and that transformational adaptation will be required to ensure resilience in certain agroecosystems. Transformational adaptation takes a variety of forms – switching crop types, shifting locations for producing certain crops and livestock, shifting farming systems to a new area, exploring alternative livelihood strategies, etc. (Rippke *et al.* 2016). Major climate finance mechanisms, such as the Green Climate Fund, support a paradigm shift to low-emission and climate-resilient development pathways by promoting innovations that are catalytic to transformational change (Section 4.2). Designing transformational adaptation requires a robust climate rationale, including information on climate risks and vulnerabilities of

Box 2.7.
Bicol region study in the Philippines

The project objective was to identify, validate, field test and evaluate good practice options for adaptation based on the current and future vulnerabilities of farming communities in the Bicol region in the Philippines. The project focused on the areas that were experiencing the adverse impacts of climate change on food production systems. This included saline intrusion, drought and flooding, and their adverse impacts in the project area were expected to become more severe and frequent in the future.

The starting point of the project implementation was a climate vulnerability assessment, carried out in the selected districts of the Bicol region. The assessment found that, contrary to the traditional beliefs of local communities, flooding (resulting from frequent typhoons in the area) had a larger impact on rice production than drought. A number of options have been identified in the project to improve drainage systems and to introduce water-tolerant varieties to reduce rice yield losses due to excessive water reaching the fields. It was also found that corn was more sensitive to droughts than rice in the studied areas, and therefore better irrigation practices were suggested as climate adaptation measures for corn fields.

SOURCE: FAO Analysis and Mapping of Impacts under Climate Change for Adaptation and Food Security (AMICAF) project in the Philippines. FAO, 2014.

the agroecosystem, in order to select appropriate evidence-based actions to address the specific and locally identified climate risks (Box 2.7).

2.6 CLIMATE RISK AND UNCERTAINTY IN INVESTMENT APPRAISAL

Cost–Benefit Analysis (CBA) is listed among the main methodologies to be used to rank and prioritize investment options in light of their costs and benefits to society (UNFCCC, 2012, section B.3). The goal of CBA is to inform decision-makers and sector stakeholders on the economic efficiency of alternative investment options.

Building on a CBA methodology, economic and financial analysis (EFA) is a requirement of most governments and IFIs at appraisal, during implementation and at completion of investment projects. At appraisal, an EFA plays an important role, providing an economic and financial justification of proposed interventions and guiding investment decisions.

In the context of climate-smart investment projects in agriculture, EFA is used as a tool for assessing investment options, accounting not only for the benefits of sustainable increases in agricultural productivity, but also for climate co-benefits, such as the improved climate resilience of farm systems and livelihoods, and reduced GHG emissions. These climate-related benefits need to be considered in the technical and economic appraisal of agriculture investment options. This in turn requires the EFAs of such projects to account for climate uncertainty and risks, making these appraisals an increasingly difficult exercise. A number of approaches and tools are emerging in order to tackle these challenges, including the IFAD-developed CARD model, Monte Carlo probabilistic risk modelling, and carbon calculation tools (i.e. EX-ACT) that also allow for the incorporation of climate mitigation benefits in project EFA. Examples of practical applications of these tools are presented in Section 3.1, Technical notes 2 and 3.

2.7 MONITORING AND EVALUATION OF CLIMATE-SMART INVESTMENTS

The main building blocks of a monitoring and evaluation (M&E) system for climate-sensitive investment projects include:

1. *a framework of indicators* suitable to identify risks, objectives, context and proposed climate-smart investments;
2. *baseline surveys* designed to be able to compare the incremental changes and eventual impacts attributable to project activities as compared with control areas;
3. *georeferenced management information systems* (MIS) should be established to collect, store, track and help analyse the range of data and indicators relevant to the project;
4. *monitoring* of all aspects of project implementation progress and performance review for projects and programmes, in a participatory manner, to become flexible and responsive to changing climatic and developmental contexts; and
5. *evaluation* of results, outcomes, and impacts of a project. Estimation of project efficiency is based on ex-ante (at design) and ex-post (at project end) EFA.[7]

Developing indicators for measuring climate-related results

Indicators are very project specific; many agencies have their own policies and frameworks around M&E for agriculture and CSA.[8] Depending on the design of the investment project and its objectives, a combination of indicators relevant to a project should be selected, maintaining the logic between inputs, outputs, outcomes and impacts (Table 2.4). Selected indicators should be closely aligned to national level outcome and impact indicators (e.g. adaptation in NAPs and mitigation NDCs, and SDGs), or show how they contribute to them.[9] Where possible, programmes and projects should draw on the nationally consistent data sources.

As illustrated in Table 2.4, indicators should be able to measure deliverables through the following:

- tracking activities and immediate results (outputs);
- households and farm behavioural changes and adoption of new or modified practices;
- land-use change;
- increased production and incomes;
- functioning of institutional systems (outcomes);
- changes in household resilience and vulnerability; and
- carbon sequestration (impacts).

M&E indicators need to adequately capture expected changes, but at the same time also be SMART.[10] Approaches such as the CCAFS CSA Programming and Indicator Tool[11] can help generate suitable indicators. FAO (2017d) provides a comprehensive approach to identifying and setting up a framework of indicators for tracking adaptation. Similarly, the USAID (2019) ATLAS

7 More information on EFA/FEA can be found on the FAO Investment Learning Platform http://www.fao.org/investment-learning-platform/themes-and-tasks/financial-economic-analysis/en/

8 See: FAO (2019b) for a more in-depth analysis.

9 For more details on NAP Agriculture processes for developing indicators, see FAO and UNDP. 2019. ***Strengthening monitoring and evaluation for adaptation planning in the agriculture sectors***. Rome. http://www.fao.org/in-action/naps/resources/learning/monitoring-and-evaluation-guide/en/

10 Specific, and Measurable, Achievable, Relevant, and Time-bound

11 See: https://ccafs.cgiar.org/csa-programming-and-indicator-tool#.XZsGbUYzZbU

Table 2.4.
Generic simplified logical framework structure with examples of indicator areas relevant to agricultural projects with adaptation and mitigation expected outcomes

	Inclusive Sustainable Agriculture	Adaptation	Mitigation
Inputs and actions	· Capacity building events · Information delivery and exchange systems on agriculture and climate · Inputs and credit · Infrastructure – soil and water conservation	· Capacity building events · Information delivery and exchange systems on agriculture and climate · Inputs and credit · Cash transfers · Climate proofing of infrastructure	· Capacity building events · Information delivery and exchange systems on agriculture and climate · Inputs and credit · Cash transfers · Infrastructure finance
Outputs	· Livelihood support systems in place: rural credit, insurance, market support · Institutional mechanisms – extension, community groups strengthened · Digital agriculture tools in place and delivering information to farmers · Nutritional support for women and children and through agriculture	· Extension systems delivering appropriate CSA advisory · Weather and climate advisory in place, delivering information, including early warnings · Critical inputs for CSA being delivered to farmers · Social protection including weather insurance mechanism established	· Inputs and incentives in place for adoption for emissions reduction · Technologies disseminated through extension · Local institutional mechanisms to manage natural resource management in place (e.g. forest user groups)

Outcomes	· Adoption of sustainable agriculture practices (water saving, soil conservation, supporting biodiversity, reducing chemical inputs, etc.)
	· Relevant land-use change
	· Increased production
	· Livelihood strategy changes
	· Improved diets
		· Adoption of locally appropriate climate-resilient practices (drought, flood, saline tolerance practices and crop and livestock varieties)
		· Diversification of cropping
		· Relevant land-use change
		· Uptake of climate insurance and other social protection
			· Relevant land-use change
			  · Reforestation
			  · Reduced deforestation
			· Adoption of emission reducing livestock practices
			· Adoption of emission reducing rice practices (e.g. AWD)

Impacts	· Increased agriculture productivity · Reduced negative environ-mental impacts and improved environmental services · Increased food security · Increased incomes and reduced poverty	· Reduced loss and damage to households and agriculture sector · Farming and livelihood strategies operating viably under new climate conditions	· Reduced GHG emissions · Increased carbon sequestration

SOURCE: Authors.

Box 2.8.

Indicators of household agriculture production benefits and land-use changes

- Number of households or area (ha) of farmland benefited from climate-proofed, improved infrastructure systems, e.g. for irrigation, or farm to market roads.
- Number of farmers participating in functional associations as a result of the project (disaggregated by sex and by type of association (e.g. cooperatives, producer associations).
- * Land-use changes.
- Number of farmers who have applied at least 3 out of 6 core elements of new, climate-resilient practices for crop Z, in at least 0.5 ha of their land.
- * Crop diversification in X ha (%) of total project target area.
- Average number of intercropping species increases from 3 to 6 (to be confirmed in baseline survey).
- Increased application of flood-resistant rice varieties (YY kg/ha) in defined flood risk areas.
- Reduced soil siltation/decreased variability in stream flow.
- Percentage change in crop yield per hectare and year as a result of the climate-smart agriculture intervention (disaggregated by male- or female-headed households and household members).
- * Crop productivity percent change (measured by remote sensing NDVI, and farm sample survey).
- * Permanent productive crop cover increased by Z% by end of project.
- Number of farmers who consider themselves better-off (e.g. in terms of livelihood, income, nutrition, well-being, social status or empowerment) as compared to before the CSA intervention (disaggregated by sex), assessed through satisfaction surveys.

* Can be also captured by remote sensing.

Box 2.9.
Examples of institutional and service-oriented indicators

- Tools for assessing water balance being applied in XX number of provinces and districts.
- Number of farmers accessing climate advisory and farm-related weather warning services (sex disaggregated).
- Number of community level disaster risk preparedness groups established and trained, and getting regular weather information updates.

Box 2.10.
Example of mitigation-related outcome indicators

- * Change in area, and % of target area covered by forest land.
- * Species composition and structure of forest cover.
- * Changes in forest productivity based on the Normalized Difference Vegetation Index (NDVI).
- Estimates of soil and biomass carbon based on the above parameters (ground-truthed based on sample survey).
- Area of grazing land (ha), or number of herder households, and/or livestock units, that have adopted mitigation-related livestock technologies – with estimate of methane reduction, carbon sequestration.
- Area (ha) under changed rice growing methods, such as alternate wetting and drying – with estimated methane reduction.

* Can be also captured by remote sensing.

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project has developed a toolkit for Evaluating Climate Change Adaptation Program Interventions with a step-by-step process, from identifying climate risks and adaptation activities to templates for indicators.

Common tools for tracking indicators of outputs, outcomes and impacts

Tracking changes in agricultural practices and land use is at the core of all three CSA pillars. Often measuring changes involves relying on standard farm and household survey methods (to assess changes at farm level), but these methods are increasingly being combined with more remote sensing assessments (Box 2.8). Wherever possible, remote sensing data together with appropriate tools should be used (e.g. Collect Earth[12] and SEPAL[13]), provided that project areas have been carefully geo-referenced (see also Technical note 7).

Household surveys play a key role in measuring socioeconomic changes (outcomes) at the household level, assessing livelihood benefits as well as increases in resilience to climate variability and shocks. These capture a range of household parameters, from assets to coping behaviours, diversification in sources of income, management of productive activities, social interactions, and the resulting impacts in terms of food security, employment and overall incomes and their stability. Examples of tools that can be used for the M&E of climate-related project indicators include RIMA,[14] SHARP,[15] and methodologies developed under the BRACED projects.[16]

When **measuring changes in institutions**, support services and broader adaptation, it is very important to consider the institutional dimensions of resilience, particularly for adaptation. Examples of indicators to measure institutional changes (at least, semi-quantitatively) are outlined in Box 2.9.

It is also often necessary to plan for and measure project results at the landscape/ecosystem and system levels. To capture overall changes and provide a comparison of measures across complex sets of indicators, from ecological to socioeconomic and institutional, indices have been proposed which combine a number of the abovementioned parameters, from household level agriculture production and land use, to institutional changes. For example, the World Bank Climate-Smart Agriculture Indices (Braimoh *et al.,* 2016) capture the broad range of relevant technologies and results.

Unlike sustainable agriculture and adaptation, **measuring mitigation results** involves a narrower set of parameters, as the ultimate measures are the contributions to a reduction of GHG emissions, and carbon sequestration. This means more specific measurements for all changes in soil carbon, carbon stocks in trees and crops, and calculated emissions from livestock and soil (Box 2.10). Measured adoption rates of relevance to forestry and agricultural practices and related land-use changes are important intermediate outcomes, and also offer proxy measures for assessing mitigation. For example, FAO's Ex-ACT tool incorporates standard parameters for carbon

12 FAO Collect Earth – Open foris www.openforis.org/tools/collect-earth.html

13 FAO System for Earth observations, data access, processing & analysis for land monitoring: https://sepal.io/

14 Resilience Index Measurement and Analysis (RIMA): www.fao.org/resilience/background/tools/rima/en/; For example, the pillars of resilience in RIMA II are: Access to Basic Services, Assets, Social Safety Nets, Sensitivity and Adaptive Capacity.

15 Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists (SHARP): www.fao.org/in-action/sharp/en/

16 Building Resilience and Adaptation to Climate Extremes and Disasters: www.braced.org/

sequestration and emissions based on land-use changes and livestock husbandry practices. While carbon emissions can be monetized, precision in measuring changes in carbon stocks is crucial. For forest related REDD[17] projects, a rigorous measurement, reporting and verification (MRV) system is applied, which has to follow careful protocols to be able to generate carbon related results-based payments.[18] Methane emissions are rarely directly measured; rather, they are estimated based on established parameters.

New mobile applications, technologies and remote sensing offer significant opportunities for developing data gathering and analytical tools for climate-smart assessments. These tools can provide up-to-date information at desirable scales, covering a range of parameters related to adoption of climate-smart practices and land use change. It is important to build common standards, share knowledge, and build capacity in the use of these advanced tools in order to develop modern M&E systems.

Finally, **mainstreaming M&E systems** requires that they be perceived as a tool for national and local stakeholders to track their own performance and success with regard to agricultural investments. There is often the perception at national levels that M&E requirements are donor driven, and therefore seen as an externally brought, additional responsibility for the governments and project implementation units. Hence, the task of the M&E project team must be to internalize, and wherever possible, mainstream M&E systems in agriculture ministries, or with local institutions responsible for climate-smart agricultural development. It is important to generate ownership, by project managers and stakeholders, of project objectives and expected changes.

17 Reducing Emissions from Deforestation and Forest Degradation.

18 To note, however, payments require national monitoring and other frameworks and policies in place: https://redd.unfccc.int/fact-sheets/redd-mrv-and-results-based-payments.html

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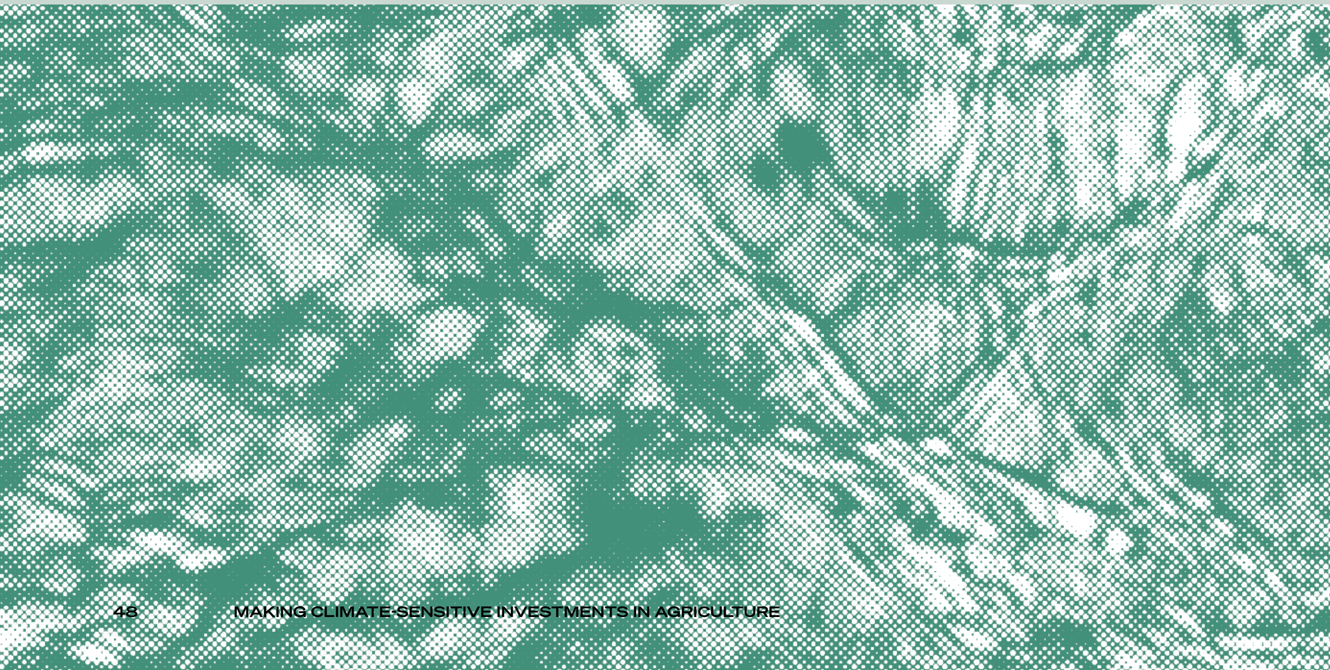
Module 3
Good practices, approaches, and tools for integrating climate change considerations into agricultural projects

Agricultural investments need to be “climate sensitive” to ensure the robustness of the sector to the impacts of climate change, reduce GHG emissions, and increase carbon sequestration where possible. This applies to more generic agricultural investments focusing on development outcomes as well as more adaptation and mitigation focused projects.

This module provides a set of technical and sector-specific notes illustrating practical applications and good practices of integrating climate change considerations into agricultural investment projects. Investment practitioners can explore and adopt these approaches and tools in the formulation of agricultural investment projects, and in appraising and validating adaptation and mitigation options.



Technical note 1 Developing a climate evidence base at local scale: Pakistan case study[19]

In the context of preparing a Green Climate Fund (GCF) proposal in Pakistan, a strong evidence base was required to identify the risks of climate in the study area.

The case study presents the assessment of climate and climate impacts at a local scale in the project area. This study explores in detail the spatial and temporal distribution of historical and future trends in climatic change as well as the implications for agricultural production and extreme events in the Indus River Basin.

Climate projections in the Sindh and Punjab provinces find an expected increase in: (i) heat stress and drought risks; (ii) heavy precipitation events and flood risks; and (iii) shifting rainy season timing and length. The observed variability highlights the need for more resilient agricultural systems and adaptation options.

Background

In the context of preparing a GCF proposal in Pakistan, an initial step was the development of a strong evidence base of climate risks in the study area. In addition to reviewing existing academic literature published on climate and climate impacts in the region and country, FAO – together with national institutions – prepared a climate impact assessment. This novel analysis utilized data from the Pakistan Meteorological Department (PMD) to assess historical trends as well as perform statistical downscaling of future projections to station level. The following case study outlines the process and the basic results.

This projected variability in the amount and timing of water availability within the Indus River Basin has great implications for water-dependent sectors, such as agriculture and energy. To investigate the trends and potential impacts of climate variability and change in Pakistan at a local scale, this study employs daily meteorological station records across the country to assess the frequency, amplitude and persistence of climate extremes. Additionally, this study uses statistical downscaling to assess future climate projections at a local level, relevant to the agriculture sector. The analysis of historical and future climate trends and extreme climate indicators within the major agricultural growing seasons in Pakistan provides a more in-depth look at how climate change will impact the future of agricultural production in the region. By combining meteorological data with country-specific agricultural

19 By R. Manzanas (CSIC-University of Cantabria, Santander, Spain); A. M. C. Heureux, M. Ali, R. Wahaj, M. Dowlatchahi, and H. Kanamaru (FAO); M. Afzaal, D. H. Kazmi, and B. Ahmed (Pakistan Meteorology Department, Islamabad, Pakistan).

information, this study highlights some of the key trends and potential impacts on the agriculture sector.

Defining a study area

The definition of a study area can be based on various criteria depending on national and project priorities. In the Pakistan example, the study areas were selected (Figure 3.1) in consultation with the Ministry of Climate Change (MoCC), Ministry of Food Security and Research (MoFSR), and the Provincial Governments of Punjab and Sindh. Districts were rated and ranked for inclusion according to selected criteria so as to prioritise the most vulnerable districts: those most exposed to climate change risks in terms of the extent of the physical area and number of households affected; those most sensitive or prone to climate change risk; and those where the capacity of rural people to adapt is most limited. The indicators used to discern these characteristics were as follows:

- cropping area;
- drought hazard;
- flood hazard;
- poverty;
- food consumption levels;
- number of agricultural households;
- percentage of farms that are small farms; and
- prevalence of undernourishment.

Among the indicators, a greater weight was given to the percentage of cropped area and drought hazard. These were assigned weights of 20 while all other parameters received an equal weight of 10 for a total of 100.

Data collection

In addition to a review of relevant national reporting and journal publications, this study used country level data to perform climate analysis and assess agricultural impacts. Daily observed precipitation as well as maximum and minimum temperature (the three meteorological target variables of this work) over 25 stations covering the entire country were available for the period 1997–2016. The Pakistan Meteorological Department provided the data; it is the prime custodian of the majority of weather and agrometeorological stations in the country with many different branches, including the National Agromet Centre (NAMC).

Setting a baseline in the project area

In order to develop an overview of the climate baseline, the study area can be defined by climatic zones (polar, temperate, arid, tropical, Mediterranean or mountainous), or by agroecological regions which include information about the topography and land cover, climate, soil, irrigation, etc. The Agro-Ecological Zones (AEZ) approach, developed by FAO in collaboration with the International Institute for Applied Systems Analysis (IIASA), enables land-use planning on the basis of an inventory of land resources and an evaluation of their biophysical limitations and potential for crop production. See the example of agroecological regions for Pakistan in Figure 3.2.

In order to understand the average or "normal" climate in a region, it is important to start by outlining the climate baseline from which the climate is changing. Climate normals are usually an average of a 30-year period (e.g. from 1961 to 1990). Mean climatology at station level was assessed in Paki-

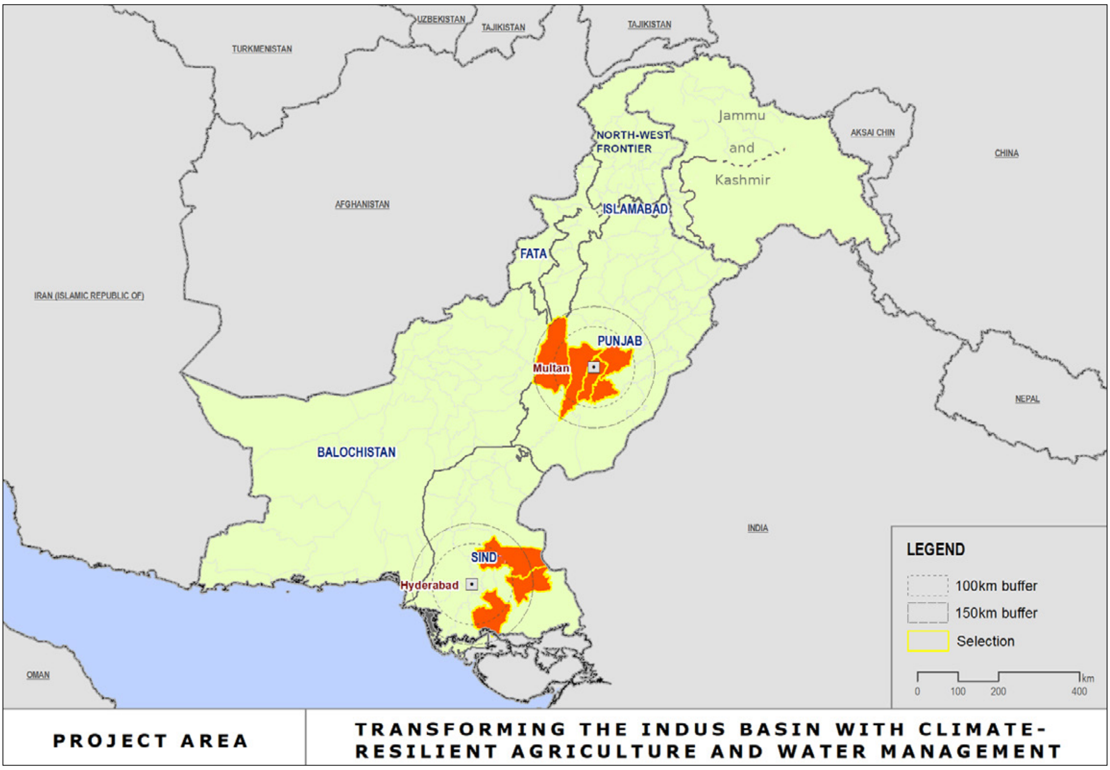


Figure 3.1.
The provinces and districts within the Indus River Basin that are included in the project

Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties

SOURCE: Derived from a map produced by Giulio Marchi, Geospatial Specialist, FAO. 2020.

stan over the period 1997–2016, as shown in Figure 3.3. Analysis of mean or average climatology was performed over the course of the year as well as during the two main seasons in Pakistan, Kharif (May–October) and Rabi (November–April), as shown in Figure 3.3.

Agricultural baseline

The agricultural baseline, considering the project focus on cropping systems, outlines the major cropping systems and crop calendars (Table 3.1) in the study area. Crops are affected by climate differently throughout their life cycle. Figure 3.4 illustrates the sensitivity of rice to different types of extreme climate events throughout its growth cycle, and the stages of crop growth that are most commonly affected by seasonal extreme climate events. FAO's crop calendar application offers a useful starting point (www.fao.org/agriculture/seed/cropcalendar/welcome.do), though this information should always be verified by national institutions or local officers.

Table 3.1 is an example of the crop calendar for the major crops in the Indus Basin in Pakistan. The Kharif season, characterized by the summer monsoon, starts in February for sugarcane, March–May for cotton, June–July for rice, and July–August for maize. Harvesting for the Kharif season starts in September and continues until December. Harvesting of sugarcane can last

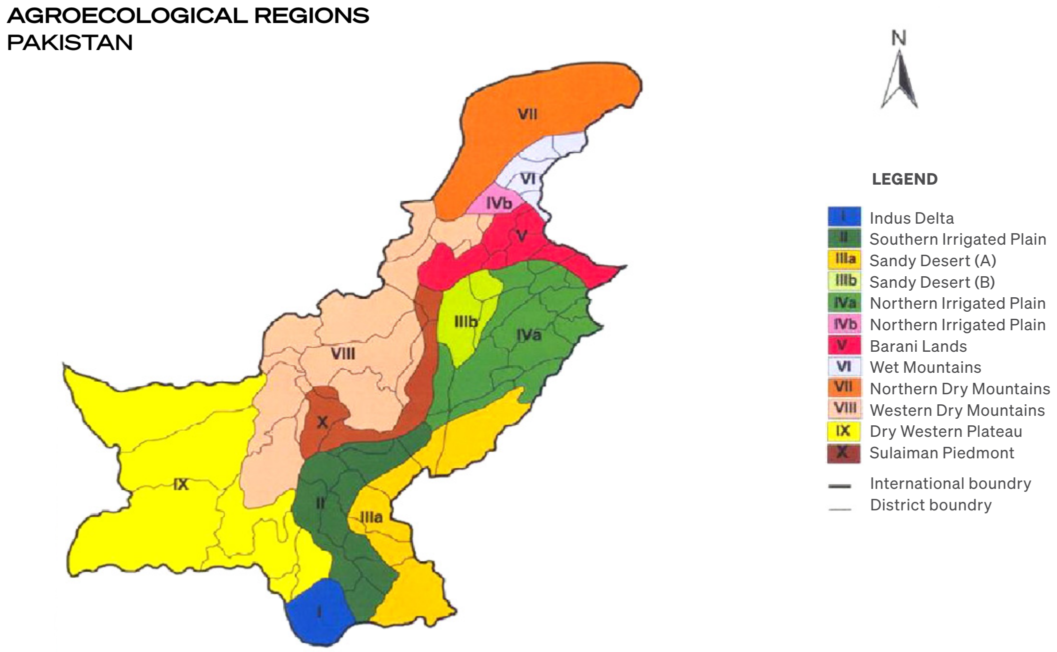


Figure 3.2.
Agroecological regions in Pakistan

SOURCE: University of Punjab, Lahore, 2020.

up until March or beyond (see crop calendar in Table 3.1). The Rabi season crops are sown between October and December, and harvested between March and April. The following examples will show how climate can be analysed specifically within each cropping season – both the Kharif and the Rabi seasons – and project teams can use the crop calendar to identify which crops will be impacted by each climate extreme during the life cycle, as illustrated in Figure 3.4.

Analysis of historical climate data

To further elucidate trends and extremes in the climate data, the study applies precipitation- and temperature-based extreme indicators (described in Module 2, Table 2.4), most of which are defined by the Expert Team for Climate Change Detection and Indices (ETCCDI).[20] Some have been modified (e.g. by changing the involved thresholds) in order to better adapt to the agricultural sector in Pakistan.

The analysis of temperature trends in this study over the period 1997–2016 illustrates some of the temporal and spatial variability across the country. Trends are calculated by applying linear regression analysis, and the "non-parametric two-sided Mann-Kendall test" to test the significance of the resulting trends (see, e.g. Zhang *et al*., 2001; Burn and Hag Elnur, 2002; Manzanas *et al*. 2015). Trends over the observed period are analysed over the entire year as well as specifically within the two main growing seasons, Kharif and Rabi.

20 See: http://etccdi.pacificclimate.org; http://etccdi.pacificclimate.org/list_27_indices.shtml

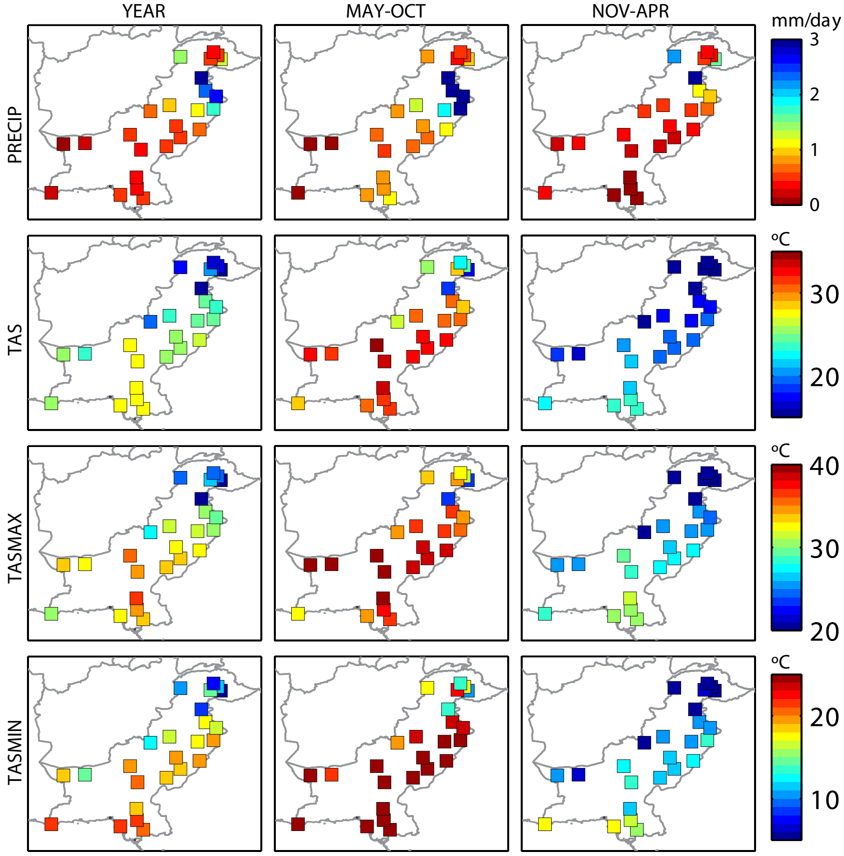


Figure 3.3.
Mean climatology at station level

Observed mean climatology for precipitation (precip), average temperature (tas), maximum temperature (tasmax) and minimum temperature (tasmin) (in rows) over the 25 stations considered, for the entire year and the Kharif (May-Oct) and Rabi (Nov-Apr) seasons (in columns). The mean climatology or climate normal were calculated as the average of each variable over the period measured. The scale is shown to the right of each row.

SOURCE: Manzanasa, R., *et al.* Observed and projected climate change in Pakistan from an agricultural perspective. University of Lahore, Pakistan. Unpublished.

Analysis of the trends in the Kharif (May–Oct) and Rabi (Nov–April) seasons highlight significant increases of tropical nights (TR) in both seasons; however, in the Kharif the most significant increases are in the upper Indus Basin, while in the Rabi these increases are in the south-east. This finding highlights that different regions observe increased night-time temperatures during different cropping seasons, and therefore the crops impacted by the increased heat stress will differ spatially. The increase in minimum temperature (tropical nights) in these agriculturally important regions has resulted in a decrease in the diurnal temperature range (or difference between day and night temperature) over the past two decades. This increase in night-time temperature and decrease in diurnal temperature range can have a detrimental impact on agricultural systems due to increased evapotranspiration and heat/water stress at the farm level.

The effects of heat stress on crops can be physiological, biochemical or impact crop yield production. Specifically, in relation to rises in minimum temperature, as is observed in this study, leaf temperature and respiration will

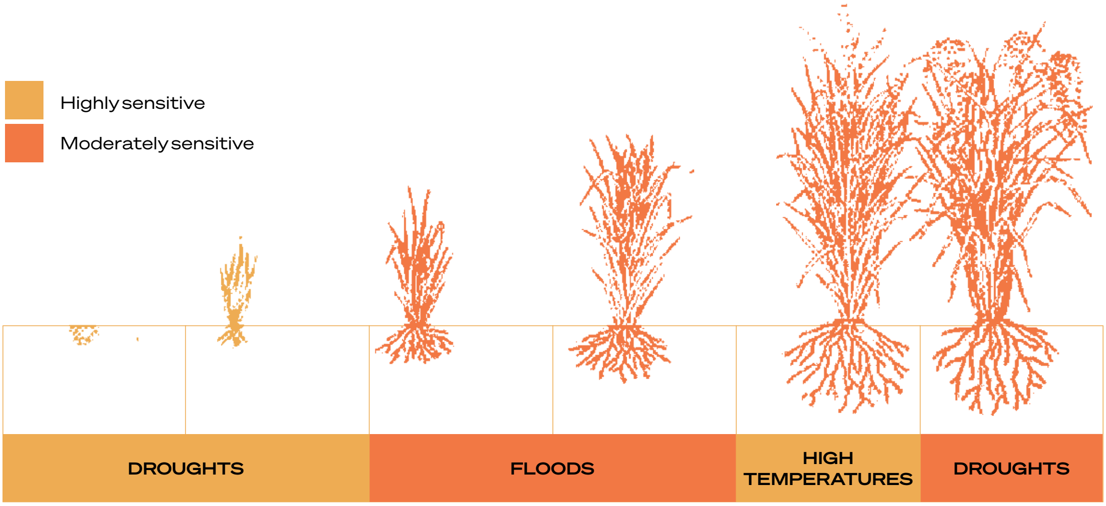


Figure 3.4.
Sensitivity of rice crop to climate-related extremes

SOURCE: FAO, 2010. Planning for Community Based Adaptation to Climate Change E-learning Tool FAO, Rome.

remain high also throughout the night, resulting in consumption of assimilates that would have been used for growth (CSIRO). For wheat crops, heat stress significantly reduces seed germination, seedling growth and plant water-use efficiency. With each degree rise in temperature, wheat production is expected to decrease by 6 percent, as regular crop function is inhibited (Akter and Islam, 2017).

Cotton, with an upper temperature threshold of 32 °C and lower threshold of 12 °C, is at risk of heat stress with increasing temperature in Pakistan. Under heat stress, cotton plants open their stomates and allow water to pass from the leaves in order to maintain optimal growing temperatures. This water loss increases the water requirements of the plant and can inhibit growth. The impacts of the observed heat stress in Pakistan, therefore, could have large implications for the growth and water-use efficiency of two major crops in the Indus Basin.

The analyses of trends in precipitation-based indicators over the observed period (as outlined above) show increases in both intensity and duration of rain events in the south-eastern regions of the country. Specifically in the agricultural areas of interest (Punjab and Sindh), the indicators show an overall decrease in the number of consecutive dry days (CDD), an increase in the number of consecutive wet days (CWD), and an increase in the number of very heavy precipitation days (PRECIP>=20mm or R20) over the period 1997–2016. The precipitation fraction due to very wet days (PRECIP <=p95) – an indicator of the percentage of precipitation that falls during rainy days classified as very wet (above the 95th percentile of precipitation on wet days over the period) – shows an increase between May and October, and a decrease or no change between November and April in the south-eastern regions. Results from a study carried out by Zahid and Rasul (2012) also show that the frequency of extreme precipitation events (daily precipitation ≥ 50 mm, ≥100 mm, and ≥150 mm) increased in all regions for the period 1965–2009.

Analysis of these indicators, specifically in the Kharif and Rabi seasons, highlights that the increase in consecutive dry days shows a stronger positive

Table 3.1
Crop calendar for the four main crops in Pakistan (wheat, cotton, rice and sugarcane), which occupy the majority of cropped land in the country

CROPPING CALENDAR

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wheat (Rabi/winter)	G	G	H	H						P	P	G
Rice (Kharif/summer)				P	P	P	G	G	G/H	H	H	
Cotton (Kharif/summer)			P	P	P	G	G	G	H	H	H	
Sugarcane (Kharif/summer)	G/H	P/H	P	P/G	G	G	G	G	G	G	G	G
Sugarcane (Rabi/winter)	G	G	G	G	G	G	G	G	P/H	P/H	P/H	G

The yellow boxes labelled "H" represent harvesting periods, and the green boxes labelled "G" represent growth periods; the blue boxes labelled "P" represent planting periods.

SOURCE: Data compiled by Pakistan Ministry of Agriculture, 2018.

shift in the Rabi season (November–April). This increase in dry days will impact Rabi crops – in particular wheat and sugarcane – which will be in critical growth phases during this period and may experience water stress. The season-specific analysis also highlights the increase in consecutive wet days and precipitation fraction, because the number of very wet days is increasing more significantly, especially in Punjab and Sindh, during the Kharif season. This increase in extreme precipitation events in the already wet monsoon season will increase the risk of flooding and potential crop damage for rice and cotton.

The overall increase in the frequency and intensity of heavy rainfall events in the study area suggests flooding events may be exacerbated in the already wet monsoon season. This increase may also result in a decrease in the amount of agriculturally available water retained in the soil due to rapid run-off. In particular, the contribution (or fraction) of heavy rainfall days to total precipitation has been increasing.

Projected future climate

In order to assess impacts of climate change at a local level, downscaling of Global Climate Models (GCMs) is required. Such downscaling can be done either statistically or dynamically. In the Pakistan example, statistical models were calibrated in order to obtain local-scale climate change projections (up to 2100) of precipitation, as well as minimum and maximum temperature from four GCMs at twenty-five weather stations.

In the fifth Assessment Report (AR5), the IPCC (2014b) adopted the Representative Concentration Pathways (RCPs) approach, identifying four climate futures depending on the concentration of GHGs in the years to come. RCP2.6, RCP4.5, RCP6, and RCP8.5 represent a possible range of radiative forcing values in the year 2100 relative to pre-industrial values, +2.6, +4.5, +6.0, and +8.5 W/m2, respectively.

RCP 4.5 shows 3 °C to 5 °C rise in mean average temperature, and RCP 8.5 shows a more rapid increase of 7 °C to 9 °C in temperature by the end of the century (Ikram *et al.*, 2016). These projections suggest a continuation of the observed national trend of warming. For precipitation, national level analysis of future climate projections and statistical downscaling analysis agree that rainfall projections are highly variable in both spatial and temporal domains (Figure 3.5). Area average rainfall projection over Pakistan shows a large inter-annual variability (ADB, 2017; Ikram *et al.*, 2016).

Figure 3.5 shows the projections obtained for the three target variables, averaged over the 25 stations. Each colour corresponds to a different GCM. As already indicated, the RCP8.5 scenario was considered for the period 2010–2100. Overall, the results show significantly increased temperatures are expected for the end of the century, whereas projections for precipitation show high variability, but no significant trend.

To further analyse these results, Figure 3.6 shows the *delta* changes for precipitation as well as maximum and minimum temperature. Deltas are computed as the mean difference between the climatology for a future period (under the RCP8.5 scenario), and the climatology for the control period 1971–2000 (historical scenario). Here we analyse two different future periods, 2041–2070 (top row) and 2071–2100 (bottom row). For precipitation and temperature, deltas are shown in percent with respect to the control period (ºC). The boxplots show the spread of the results along the 25 stations analysed. The red and black dots correspond to the 5 and 3 selected stations over Punjab and Sindh provinces, respectively. This figure shows that the spatial patterns of delta changes for temperature increase over all stations, while for precipitation, the result is mixed. This result supports the conclusions from Figure 3.5 below.

Additional analysis specifically in the Indus Basin (Punjab and Sindh districts), show increased daily maximum temperature under both RCP4.5 and RCP8.5, reaching higher values in the Sindh province than in Punjab under both scenarios. Analysis shows higher daily minimum temperature warming compared to daily maximum temperature warming, projecting further reduction in the diurnal temperature range following the historical trends within the regions discussed in previous section.

While Figure 3.5 shows large variability and no significant trend in future projected precipitation averaged over the country, the trends are clearer in our analysis in the Indus Basin. In Sindh specifically, total precipitation will increase by more than 20 percent in the latter part of the twenty-first century; however, the variability in both historical and projected future data is large. The results show that variability (range between minimum and maximum) is much larger over the Sindh province when compared to the Punjab region, and absolute values reach numbers up to 600 mm. The signal for precipitation in the Punjab region shows significantly lower values as well as no significant increasing or decreasing trend over the time period.

Conclusions

In order to identify appropriate climate adaptation actions, robust climate evidence should be the basis of all investments and interventions. Understanding how climate impacts agriculture in Pakistan is of particular importance due to the extent and relative vulnerability of the population that relies on agriculture within the country. This study explores in detail the spatial and temporal distribution of historical and future trends in climatic change as well as the implications for agricultural production and extreme events in the Indus River Basin. The results support previous findings that climate is expected to become more variable and unpredictable (Lutz *et al.*, 2016).

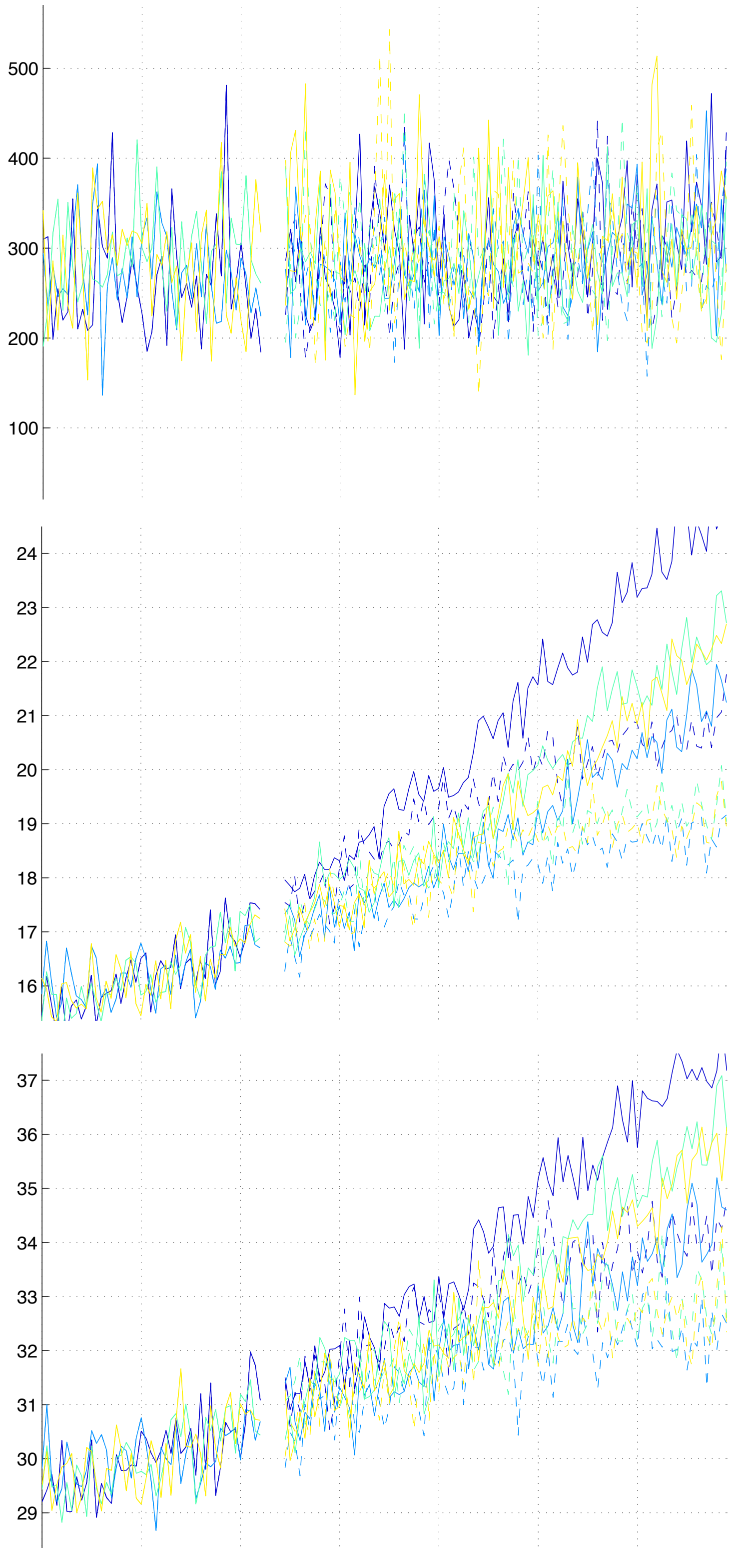


Figure 3.5.

Mean annual temperature and precipitation projections across four GCMs in Pakistan under RCP8.5.

SOURCE: Manzanasa, R., *et al*. Observed and projected climate change in Pakistan from an agricultural perspective. University of Lahore, Pakistan. Unpublished.

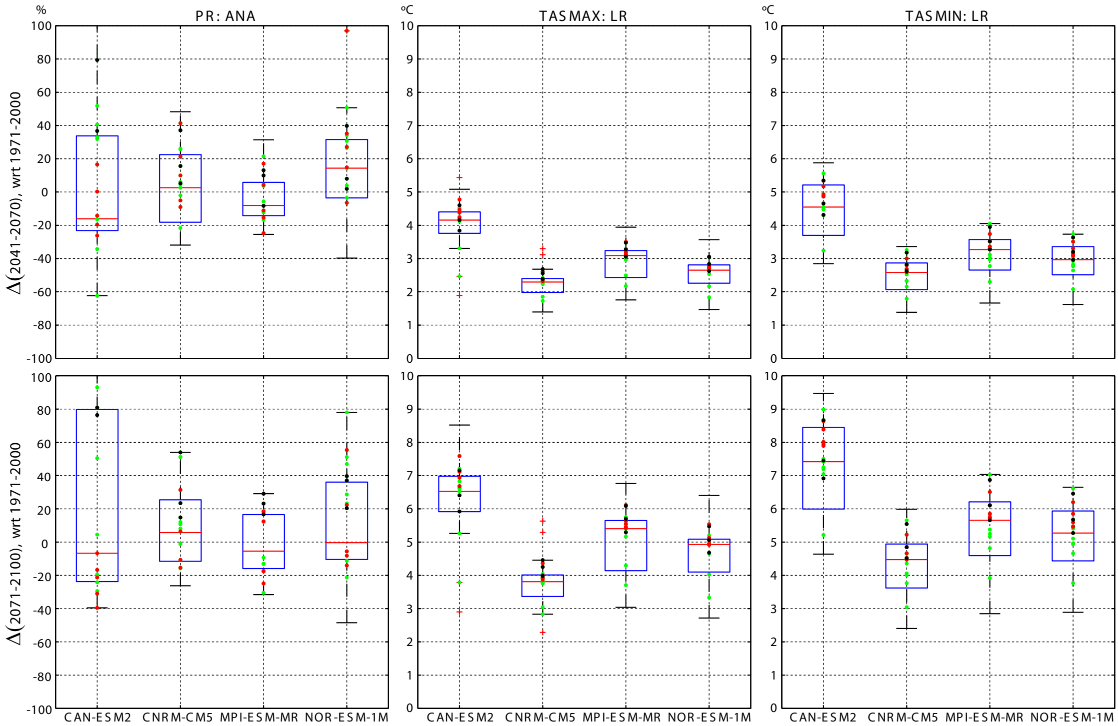


Figure 3.6.
Deltas (with respect to 1971–2000) for the periods 2041–2070 and 2071–2100 (top and bottom row, respectively), as projected by the four GCMs considered

Relative (absolute) changes are shown for precipitation (temperature).

SOURCE: Manzanasa, R., *et al*. Observed and projected climate change in Pakistan from an agricultural perspective. University of Lahore, Pakistan. Unpublished.

The findings show that the basin may also face water scarcity hand-in-hand with increasing water requirements from crops due to rising temperatures. Seasonally, the Indus Basin has experienced hotter summers (April–May) and cooler winters over the historical period analysed. Increased daily minimum temperature in the project target areas of Punjab and Sindh is increasing faster than daily maximum temperature, suggesting a decrease in the diurnal temperature range. Changes in temperature will result in increased evapotranspiration and water stress at the farm level. Rising temperatures in the north also suggest that snowpack will melt earlier in the season, and that the seasonal timing of river water flow will change.

In addition to climate change impacts on water availability in the Indus Basin, crop yields in the basin are projected to decrease due to the shortened growing period under a warmer climate (Zhu *et al*., 2013). Precipitation has increased in the rainy months of August and September, while October rainfall has decreased both in Punjab and Sindh in most recent years, suggesting that the onset of the rainy season is shifting to end earlier in the year. In addition, the number of very heavy rain days (precipitation >=20mm) has increased, with larger increases in the rainy season already vulnerable to flooding.

From a climatological perspective, increased flood risks are possible in the future, as studies suggest further glacier melting and increased heavy precipitation events in some parts of the country. It is also expected that future drought risks will increase as daily maximum and daily minimum temperature increase, accompanied by a decrease in the number of rainy days and consecutive dry days. Climate projections in the Sindh and Punjab provinces find an expected increase in (1) heat stress and drought risks, (2) heavy precipitation events and flood risks, and (3) shifting rainy season timing and length. The increase in extreme weather events highlights the need for more resilient agricultural systems. National and local level planning and policy-making should consider the climate change impacts and implications on the agriculture sector to formulate evidence-based actions to address the increasing risks in the Indus River Basin.

Technical note 2 Accounting for climate risks in appraisal of agricultural investment projects and strategies

Economic and Financial Analysis (EFA) is one of the main methodologies to rank and prioritize investment options. It is a requirement of most governments and IFIs to conduct an EFA at appraisal, during implementation, and at completion of investment projects.

The CARD tool and Monte Carlo simulations allow for the integration of climate risks in EFA when appraising climate-smart investment options in agriculture.

The application of these tools is demonstrated in the economic appraisal of an agricultural project in the Gambia, and in preparation of a climate-smart agricultural investment strategy in Zambia.[21]

Cost–Benefit Analysis (CBA) is listed among the main methodologies to be used to rank and prioritize investment options in light of their costs and benefits to society (see UNFCCC, 2012, section B.3). The goal of CBA is to inform policymakers and public sector stakeholders about the economic efficiency of alternative interventions and policy options.

Building on a CBA methodology, EFA is a requirement of most governments and IFIs at appraisal, during implementation, and at completion of investment projects. At appraisal, an EFA plays an important role: it provides an economic and financial justification for the proposed interventions, and it guides investment decisions. In the context of a climate-smart agriculture investment, EFA is used as a tool for assessing climate adaptation options. This, in turn, requires the EFAs of such projects to account for climate uncertainty and risks, making these appraisals an increasingly difficult exercise.

New tools are emerging to allow for a better integration of climate risks into EFA. As discussed below, these include the modelling of extreme weather events (fast onset) with tools, such as Monte Carlo simulations (if there is sufficient information to determine the risk distribution), and the Climate Adaptation in Rural Development – Assessment Tool (CARD) to explore the effects of climate change on the yield of major crops (slow onset events).

21 By G. Boc and N. Sitko (FAO).

The Climate Adaptation in Rural Development Assessment Tool

The Climate Adaptation in Rural Development (CARD) Assessment Tool[22] is a platform to explore the effects of climate change on the yield of major crops. It is intended to support the quantitative integration of climate-related risks in agricultural and rural development investments and strategies, including EFA. This tool provides data for 17 major crops in nearly all African countries. It is currently available for North Africa, West and Central Africa, and East and Southern Africa. CARD has been developed with funding from IFAD's Adaptation for Smallholder Agriculture Programme (ASAP2).

The CARD tool was developed to provide simplified estimates of climate change-induced yield variability. Temperature and precipitation are essential input factors to crop growth, and with climate change increasingly disturbing their patterns, agricultural production is projected to be more and more affected. Due to its reliance on temperature and precipitation, particularly in rainfed agricultural systems, agriculture is often presented as the sector that is most vulnerable to climate change. The tool is built on the IPCC Representative Concentration Pathway RCP8.5 scenario, projecting the highest concentration in GHGs. Adding to this scenario, the tool uses global gridded crop–climate models that simulate the biophysical processes related to crop growth in order to capture the long-term effects of climate change.

For the user, the CARD tool has been implemented through workbooks in Microsoft Excel software that allow rapid selection of parameters and generation of yield trends. The tool is currently available as separate editions for each of the three African regions mentioned above. The core of the tool is the *crop yield data* worksheet, where the analytical process starts with selecting the *country*, the *region* or *agroecological* zone (AEZ). In terms of region, a national or subnational/AEZ overview can be selected depending on the need. Subsequently, the *irrigation scenario* is selected: no irrigation means that crop production is rainfed only, while full irrigation means that crops are fully irrigated to the extent that water is available.

The tool allows the user to select the climate risk scenario, among three pre-determined options, which impacts the way the underlying crop–climate models are analysed:

- The **Median** setting reflects a "best guess" of the uncertainties reflected in the Models (the models are aggregated using the median).
- The **Pessimistic** setting reflects a pessimistic consideration of the uncertainties reflected in the models (the models are aggregated using the 10th percentile of all underlying crop yield projections – i.e. close to the model with the largest decline, or smallest increase, in crop yields).
- The **Optimistic** setting reflects an optimistic consideration of the uncertainties reflected in the models (the models are aggregated using the 90th percentile of all underlying crop yield predictions – i.e. close to the model with the least decline, or largest increase, in crop yields (IFAD, 2019).

A large spread between the projections under the Optimistic and Pessimistic risk settings signals significant uncertainty in future crop yield projections.

22 For full details, please refer to the IFAD CARD User Guide, from which this section is adapted: https://www.ifad.org/documents/38714170/41085512/Card_usermanual_W.pdf/e867a16c-e581-8038-aa6f-1767a10629a3

Depending on the user's approach to and parameters of the EFA, the CARD tool allows the selection of the period for analysis and impact calcultion. The user can define a first and last year and opt between using the first year as a base for calculations (option *relative to base year*), or use the default option (relative to 1995, the first year included in the tool). At the moment, based on the underlying models, the tool can project yields up to 2050.

With all these parameters selected, the CARD tool then provides the time series evolution of yields and an accompanying graph for the selected period and for all the crops applicable to the respective country, region/AEZ and irrigation scenarios. The results can be directly imported into the EFA analysis and applied to the yield assumptions for a with-project situation. Theoretically, the CARD projections could also be applied to the without project (WOP) scenarios, but in general, in African countries the available agricultural statistics are poor and do not allow the visualization of a clear trend. In addition, the full assumptions of WOP scenarios are difficult to model in the absence of data on future public investments in the sector.

Application of the CARD tool: The ROOTS project

The Resilience of Organizations for Transformative Smallholder Agriculture Project (ROOTS) is an upcoming IFAD-financed agriculture and rural development investment project in The Gambia. With a total budget of USD 80 million over six years (2020–2025), the project is designed to increase agricultural productivity and access to markets in order to improve food security, nutrition and smallholder farmers' resilience to climate change in The Gambia. The two key value chains included in the project are rice and horticulture, under different production systems. For rice, in particular, the focus of the project is on irrigated tidal systems, some of which will be rehabilitated, others developed from traditional schemes, or from zero.

The EFA used the IFAD CARD tool in order to include the estimate of climate-induced yield variability. Given the project's target value chains and the tool's current scope, only rice production has been considered, using the data for irrigated production, under the pessimistic scenario, for the analysis period 2020–2039. As shown in Figure 3.7 (all three scenarios included for reference), the climate-induced yield decrease for irrigated rice is expected to reach about 9 percent by the end of the analysis period, when compared with the base year.

The impact of this climate-induced yield variability on the project's interventions is not significant, but it does depress the expected yield gains. As mentioned, ROOTS' key activities (rehabilitation and development of schemes, coupled with extension and input provision) for the rice value chain have been targeted to irrigated tidal systems (under Sustainable Rice Intensification (SRI) and non-SRI practices). As such, the with-project (WP) yields are expected to more than double from about 1.5 to 1.6 tonnes per ha/season, to 3.2 to 3.6 tonnes per ha/season for non-SRI practices, and 6 tonnes per ha/season for SRI practices. Yet, for wet season tidal rice, the effects of climate change are visible, as shown in Figure 3.8. By the end of the project in 2025, the gap will be 77 kg per ha/season, and by the end of the analysis period in 2039, it will be 275 kg per ha/season.

In financial terms, the climate change effects highlighted above have a similar magnitude and do not affect the profitability of the investments. Additional benefits per year and per hectare as well as the net present value over 10 years (at 8 percent discount rate) are 3–5 percent lower, depending on the production system (Table 3.2 and Table 3.3).

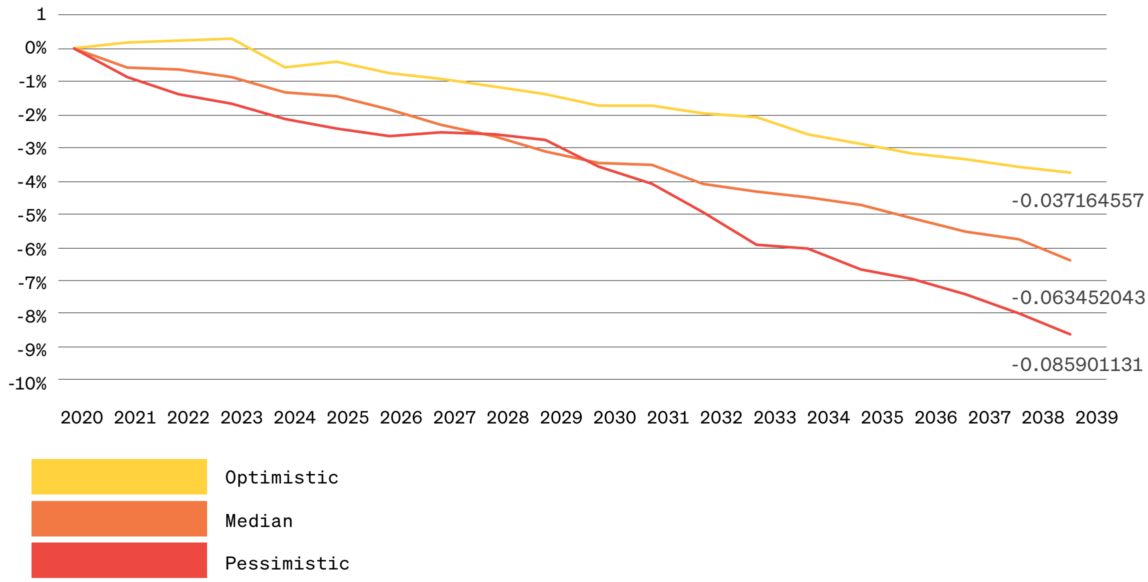


Figure 3.7.
Climate-induced yield variability for irrigated rice in The Gambia

Percentage change relative to base year 2020.

SOURCE: IFAD, 2019. Climate Adaptation for Rural Development (CARD) Tool.

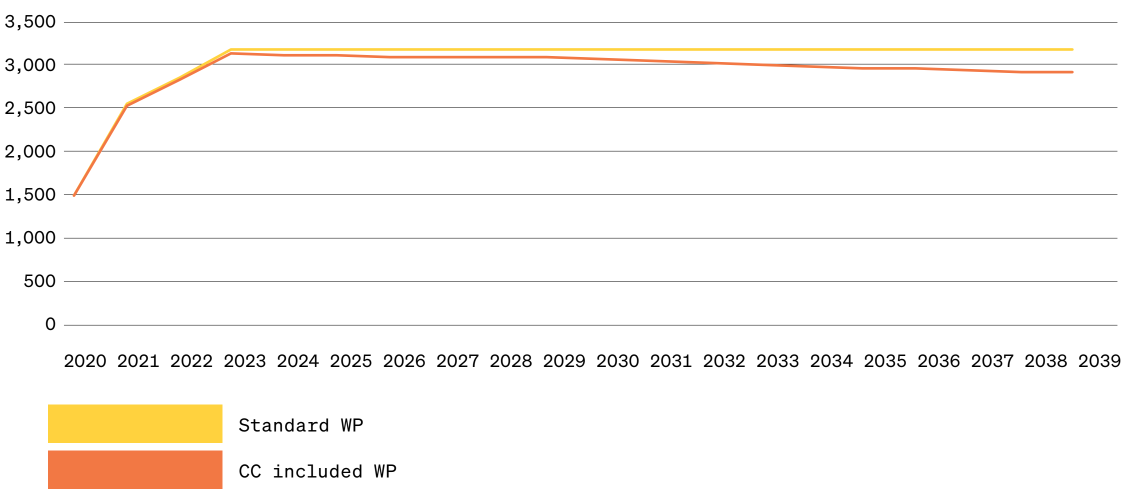


Figure 3.8.
Comparison between standard with-project and CC-included evolutions of yield for wet season tidal rice

Learning curve included for the first 3 years.

SOURCE: Author's calculations based on ROOTS EFA, 2019.

In terms of economic feasibility, the inclusion of climate change-induced yield variability reduces the project's economic return by USD 5.1 million in terms of net present value (NPV) over 20 years, and its economic internal rate of return (EIRR) by 0.8 percent. Overall, the project remains a justified investment, even when accounting for the climate change risks for rice production (see Table 3.4). Yet, it is worth stressing that the CARD's data limitations at the moment imply that the horticulture value chain is excluded from this analysis. While horticulture activities are expected to be done under full irrigation, the impact of increasing temperatures could still negatively affect yields (given the effects on plant growth and pest occurrence). As such, a full analysis would adjust the results of the EFA downwards.

Table 3.2.
Financial results for irrigated tidal rice – standard With-Project

Financial Analysis: Summary results			Additional benefits/years		FIRR	NPV @ 8% (10-year)	
		Unit	(GMD)	(USD)	(percentage)	(GMD)	(USD)
Irrigated tidal rice	Rehabilited perimeters	ha	44.37	887	N/A	269.769	5 395
Non-SRI (80%)	New perimeters	ha	49.912	998	N/A	306.956	6 139
Irrigated tidal rice	Rehabilited perimeters	ha	109.332	2 187	N/A	691.6	13 832
SRI (20%)	New perimeters	ha	115.042	2 301	N/A	729.914	14 598

SOURCE: Author's calculations based on ROOTS EFA, 2019.

Table 3.3.
Financial results for irrigated tidal rice – CC yield variability included

Financial Analysis: Summary results		Additional benefits/years			FIRR	NPV @ 8% (10-year)	
		Unit	(GMD)	(USD)	(percentage)	(GMD)	(USD)
Irrigated tidal rice	Rehabilited perimeters	ha	42.238	845	N/A	255.386	5 108
Non-SRI (80%)	New perimeters	ha	47.948	959	N/A	292.573	5 851
Irrigated tidal rice	Rehabilited perimeters	ha	105.345	2 107	N/A	656.12	13 122
SRI (20%)	New perimeters	ha	111.055	2 221	N/A	694.434	13 889

SOURCE: Author's calculations based on ROOTS EFA, 2019.

Table 3.4.
Summary of the overall economic results

Economic Results	Standard WP	CC included WP	Difference
NVP (USD MN, 20Y, @6%)	41.2	36.1	-5.1
EIRR (%)	17.1%	16.3%	-0.8%

SOURCE: Author's calculations based on ROOTS EFA, 2019.

Conclusion

Although it is an improvement over the standard EFAs, the CARD tool's inclusion in the analysis also presents some challenges. First, as previously mentioned, the tool currently includes the main staple crops, and even for those, data coverage is not yet complete. Further updates should include more crops and more countries, as well as more subnational granularity. Second, the correct integration of the CARD inputs into EFA requires more complicated calculations, in particular, in order to account for the phasing of project activities. Third, to gain the most from the tool's insights, EFAs should be conducted early in the project formulation process to allow for the fine-tuning or the development of alternative solutions, especially in cases where climate risks render the investments unprofitable. At the same time, this approach would help justify the inclusion of more climate-related activities (technologies for adaptation and mitigation) in agricultural and rural development projects.

The Monte Carlo simulation method

Ex-ante EFAs are fundamentally about estimating the future outcomes of an investment. By their very nature, EFAs are risky endeavours. In the context of agricultural sector investments, risks are magnified, due to the wide range of exogenous risk factors related to climate variability and market factors. Anticipating sources of risk and uncertainty, and quantifying the sensitivity of rates of return to different sources of risk, is essential for identifying and prioritizing appropriate agricultural sector interventions.

Rather than seeking to eliminate risk, investment planners must identify which variables in the NPV equation are particularly exposed to identifiable risks, and then assess the sensitivity of the NPV analysis to changes in these variables.

The Monte Carlo simulation method implemented with the @Risk tool[23] (or other software packages) is designed to better account for investment risks in EFA, including rapid onset climate events, which are likely to become more frequent and stronger as climate changes. This method is used to determine the probability distribution of NPV under different scenarios, such as yield scenarios caused by weather variations and probabilistic extreme weather events. Using historical productivity data under different weather conditions, a probability distribution of productivity levels is determined. With this information, a Monte Carlo simulation can be run, where random outcomes are drawn from the probability distribution. Typically, between 1 000 and 10 000 simulations are run to determine the probability distribution of the NPV of the investment based on scenarios with different probabilities of occurring. The Monte Carlo simulation determines the expected value or the average of the NPV, its variance and standard deviation. Moreover, using this approach it is possible to determine the probability that the NPV of a project intervention takes a negative value, and thus helps to prioritize interventions with higher likelihoods of success.

Of course, given the changing climate, basing future investment choices on historical weather patterns is, in itself, a risky undertaking. To address this, the sensitivity of investment plan interventions to different future climate scenarios can be considered. This is feasible for

23 The tool can be downloaded here: https://www.palisade.com/risk/default.asp

interventions that generate crop productivity benefits, but less feasible for other sectors, such as livestock or fisheries, for which information is limited. To incorporate future climate impacts into an EFA assessment, crop level yield outcomes under different Global Circulation Model (GCM) projections and different Representative Concertation Pathways (RCP) can be used to inform a Monte Carlo based sensitivity analysis. This can be done with various level of spatial precision depending on available data.

The Government of Zambia's climate-smart agriculture investment plan (CSAIP) applied the Monte Carlo approach to assess the risk sensitivity of interventions under probable future rainfall distributions. As shown in Figure 3.9, two average NPV estimates were generated for the CSAIP interventions. This example focuses on the adoption of Conservation Agriculture, based on Monte Carlo simulations with rainfall distributions under different climate scenarios. On the left, the figure shows an average NPV of USD 447 104 based on crop yield distributions under current climate conditions; on the right, it shows the average NPV of the interventions based on projected crop yield distributions from the GFDL-ESM2M global circulation model assuming RCP8.5, as shown. Based on 10 000 random draws, the average NPV of the investment increases to USD 2 568 759, suggesting a substantial increase in the returns on the investment under pessimistic climate conditions. These sorts of forward-looking economic analyses are critical for long-term investments in the agricultural sector.

Using econometric techniques to measure impacts of interventions under climate stress

Econometric techniques can be used to inform an investment plan by helping to assess (a) the impact of a proposed intervention on actual farm households, rather than experimental plots and pilots, and (b) how impacts vary under different climate conditions. However, there are several limitations associated with using econometric approaches in investment planning: The first is empirical, and is related to the challenges associated with identifying the causal relationship between an investment intervention and an outcome; the second is that to conduct an econometric analysis, there must be a sufficient number of households in the population practicing a proposed intervention or using a proposed technology.

Several methodological tools are available to address the first concern. The choice of methodological approach is a function of the available data and the skills of the analyst. Experimental and quasi-experimental approaches that measure the impact of an intervention by comparing control households with those adopting the intervention are particularly useful. The second limitation cannot be addressed without carrying out primary data collection that oversamples households exposed to an intervention. This, however, is costly and time consuming, and beyond the scope of most investment planning approaches.

The proliferation of georeferenced panel household survey data and spatially-explicit weather data create new opportunities to assess the impact of agricultural interventions under different weather conditions. With these data, it is possible to merge historical weather station and interpolated granular geospatial rainfall data to household spatial coordinates, and subsequently to identify households that were exposed to severe weather conditions during the survey years, as well as the frequency that a household has been exposed to severe weather over time.

In the rainfed production systems, deviations in rainfall are arguably the most pressing adverse weather risk. When developing an investment plan, it

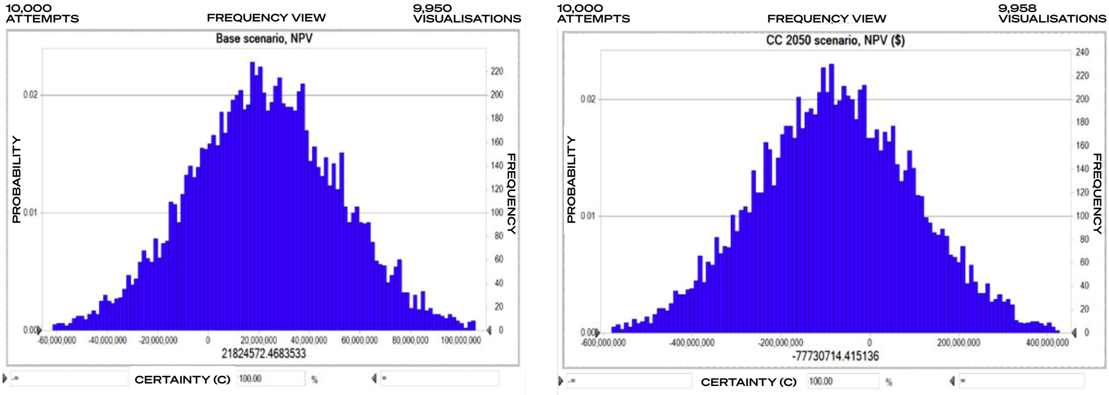


Figure 3.9.
Average net present value of Conservation Agriculture interventions under current and pessimistic climate scenarios

SOURCE: Elaborated by Giacomo Branca, FAO, 2018.

is useful to know which technologies or interventions perform well under adverse rainfall conditions, particularly adverse conditions that are becoming more frequent due to climate change. To identify severe rainfall events, calculating the Standardized Precipitation Index (SPI) for a particular spatial location is useful.

In Zambia, the SPI merged with household survey data was used to estimate the impact of seven different potential investment interventions under normal, high rainfall and low rainfall conditions (Table 3.5). The multidimensional assessment of impacts for these interventions – crop income, crop income variability, and food security – guided investment prioritization. As shown in Table 3.5, most of the proposed interventions showed little significant impact relative to conventional practices under normal rainfall conditions. However, positive impacts materialized for many proposed interventions under drought conditions.

Table 3.5.
Assessing the impacts of farm practices and technologies on famers' welfare under normal and drought conditions

	Crop income		Crop income variability		Food insecurity	
	Normal rainfall	Drought conditions	Normal rainfall	Drought conditions	Normal rainfall	Drought conditions
Minimum soil disturbance	-0.011	-0.000	0.012	-0.000	0.002	0.000
Residue retention	0.006	-0.160	0.041	-0.045	0.039	-0.236***
Legume rotation or intercropping	-0.011	-0.037	-0.020	-0.089	0.010	-0.104*
Commercial horticulture	0.096***	0.211**	-0.015	-0.246	0.011	-0.160**
Agroforestry	-0.048	0.000	0.017	-0.000	0.031	-0.000***
Crop/livestock integration	0.006	0.000***	0.008	-0.000	0.019	0.000
Improve timing of planting	-0.000	0.085**	-0.042	-7.826***	0.014	-0.020
Use of drought-tolerant maize seeds	0.030	0.365***	-0.021	-0.246*	-0.002	-0.138***
Use of heat-tolerant maize seeds	0.022	0.383***	0.007	-0.241*	-0.006	-0.174***
Crop diversification	0.003***	0.006***	-0.001	-0.005***	0.001	0.001

Grey cells indicate no statistical difference between the practice/technology and conventional practices. Green cells indicate that the direction of the impact is beneficial to farmers' welfare relative to conventional practices.

SOURCE: Based on Authors' calculations, 2018.

Concluding summary

The proliferation of geospatial climate data and detailed household survey information is opening up new opportunities to improve investment plans in ways that better incorporate climate change as a source of risk, and to better target intervention to reduce the risks it poses. However, when using the Monte Carlo simulation and the SPI–based tools, their limitations must be well understood and acknowledged.

First, while these tools help to measure potential risks and risk probability associated with climate change, they cannot predict systemic changes that may result from these risks. For example, the target populations for a project or investment may alter their farming systems in significant ways in response to climate risks. These sorts of widespread autonomous adaptation responses cannot be predicted using these tools and could lead to significant and unanticipated outcomes.

Second, projects are often implemented within small geographic areas with significant climatic variability. The sort of downscaled climatic and household level data required to anticipate sources of climatic risks within these small and diverse geographic areas is typically not available. This limits the effectiveness of econometric and Monte Carlo simulation approaches to identifying climate risks.

Finally, there remains considerable uncertainty over how global or regional climate patterns will change in the future, particularly with regard to precipitation and the impacts of GHGs on crop and pasture productivity. While climate models are getting better every year, this uncertainty remains an important constraint to effective long-term investment planning and risk management.

Box 3.1.
What is the Standardized Precipitation Index?

Mathematically, the SPI is based on the cumulative probability of a given rainfall event occurring. Historic rainfall data is smoothed using a moving width equal to the number of months desired (typically 1, 3, 6 or 12) and is fitted to a gamma distribution through a maximum likelihood estimator.

Representing the rainfall distribution with a cumulative probability function allows for the identification of weather shocks of varying severity within a given year by using different standard deviation thresholds from historical means, where positive deviations indicate higher than normal rainfall, and negative deviations lower.

Moreover, by summing the number of extreme weather events over the reference period, it is possible to use the SPI index to create a measure of risk exposure to climate shocks. Mathematically, the risk exposure index is the ratio between the number of extreme weather events during the reference period and the number of years considered.

Technical note 3 Assessing the mitigation potential of agricultural investments

FAO's EX-ACT is a tool that allows users to estimate the mitigation potential of agricultural investment development projects by assessing the net carbon balance from GHG emissions and carbon sequestration.

The carbon balance provided by EX-ACT can be integrated into economic and financial analyses to evaluate the mitigation benefits, using the "social cost of carbon".

This section[24] provides a summary of the EX-ACT methodology and examples of its practical application in agricultural projects.

As discussed in the previous modules, agriculture has a high climate change mitigation potential, both in the form of reducing emission intensity per unit produced, as well as carbon sequestration in the biomass and the soil, and many technical options are readily available for immediate deployment. Since most of the mitigation potential of agriculture is in developing countries, many agriculture, forestry and other land use (AFOLU) development projects can play an important role in climate change mitigation, either by reducing emissions and/or by sequestering carbon.

To support the international community's efforts with quantifying changes in GHG emissions, the Food and Agriculture Organization of the United Nations (FAO) developed the EX-Ante Carbon-balance Tool (EX-ACT) (Bernoux *et al.* 2010).

24 By P. Audebert, L. Berling, and L.S. Schiettecatte (FAO).

Based on the Intergovernmental Panel on Climate Change (IPCC) methodology,[25] EX-ACT provides its users with a consistent way of estimating and tracking the impact of AFOLU investments and policies on GHG emission levels. EX-ACT is a free, open-source, Excel-based model and is available in all United Nations languages, as well as Bahasa, Vietnamese, Portuguese and German. EX-ACT is the primary GHG accounting tool for the World Bank, IFAD, FAO GEF and GCF projects, the French Development Agency (Agence Française de Développement, AFD) among others.

The EX-ACT methodology

Developed by FAO in 2009, EX-ACT aims to provide estimates of the mitigation potential of agriculture and forestry development projects, as the net carbon balance from GHG emissions and carbon sequestration. EX-ACT is a land-based accounting model, measuring carbon stocks, stock changes per unit of land, and methane (CH_4) and nitrous oxide (N_2O) emissions expressed in tonnes of carbon dioxide equivalent (tCO_2-e) per hectare and year. It provides estimations of the impacts of agricultural or forestry investments and policies on GHG emissions and carbon sequestration using different land-use scenarios as compared to a baseline scenario, i.e. without any intervention.

EX-ACT can be used for establishing and monitoring emission reductions in a wide range of projects, integrating climate change mitigation objectives into national policies and climate change commitments, such as Nationally Determined Contributions (NDCs), based on accurate and transparent estimates of GHG emission reductions using country or project-specific data.

EX-ACT results, i.e. the carbon balance, can be used in the economic analysis of a project to account for the value of mitigation project benefits based on the possible valuation options described above. Specifically, the tool can be used to evaluate the potential negative and positive impacts of a project in terms of mitigation, and account for the carbon balance in a classic EFA.

Data requirements

EX-ACT is the **only GHG accounting tool** to cover the entire AFOLU sector, integrated in specific modules:

- land use change (deforestation, afforestation and reforestation, other land-use changes);
- crop production (covering annual systems, perennial systems, rice cultivation);
- grassland and livestock management;
- forest and peatland management;

25 EX-ACT incorporates primarily the 2006 IPCC Guidelines, complemented by other existing methodologies, and augmented with the 2013 wetlands supplement to the 2006 IPCC Guidelines (IPCC, 2014). These equip EX-ACT with recognized default values for emission factors and carbon values – the so-called Tier 1 level of precision. EX-ACT is also based on Chapter 8 of the Fourth Assessment Report from Working Group III of the IPCC (Smith *et al.*, 2007) to account for more specific mitigation options not covered in IPCC 2006. Other required coefficients are taken from published reviews or international databases. For instance, GHG emission values for farm operations, transportation of inputs, and irrigation systems implementation are derived from Lal (2004). Electricity emission factors are based on data from the International Energy Agency (2013). In the fishery sector, fuel use intensity (FUI) data from the capture phase of target species at sea are taken from Parker and Tyedmers (2014).

Box 3.2.
GHG emissions associated with AFOLU sectors

The relevant GHG emissions associated with agricultural activities are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These gases have different global warming potentials (GWP), and their flows are converted into metric tonnes of CO_2 equivalent (tCO_2-eq) for accounting purposes, based on their GWP, i.e. CH_4 of 34 and N_2O of 298. The main emission sources in agriculture include:

- Cattle enteric fermentation [CH_4].
- Biomass burning [N_2O & CH_4].
- Production of flooded and irrigated rice [CH_4].
- Manure management [N_2O & CH_4].
- Application of fertilizer [N_2O & CO_2].
- Irrigation and farming machinery [CO_2].
- Change of soil organic carbon (SOC) content from land-use changes.

SOURCES: Authors.

- management of coastal wetlands, fisheries and aquaculture; and
- inputs and investments (use of fertilizers, pesticides, energy consumption and construction of new infrastructure).

Users will have to screen for the activity leading a change in carbon within the different compartments, in other words, above-ground and below-ground biomass, soil, deadwood pool and litter, and changes in GHG emissions. Such data require information on the different land uses and land-use changes (in hectares), management practices (e.g. no tillage, nutrient and/or residue management, organic amendment, improved agronomic practices), quantities of inputs used, livestock (head), energy consumption and investments in infrastructure.

If needed, several databases can help the user retrieve the necessary data, such as FAOSTAT, Earthmap, CIA (The World Fact Book), the Global Forest Resources Assessment (FRA) as well as UNFCCC submissions (GHG Inventory, National Communications, Nationally Appropriate Mitigation Actions (NAMAs), and National Adaptation Programmes of Action (NAPAs). Involving experts in the project formulation, implementation or evaluation is also an opportunity to offer a thorough analysis of a local context.

This project aimed to advance the conservation of healthy and functional forests and wetlands that are resilient to climate change, maintain carbon stocks, prevent GHG emissions, and generate sustainable and resilient local livelihoods in four Peruvian provinces. The project deployed field interventions in and around protected areas and indigenous territories. In particular, activities under the project were aimed at the following:

- preventing deforestation on more than 13 000 ha;
- improving the cultivation of traditional annual crops (including rainfed rice, fruits, cereals, etc.) and the residue management of perennial crops (notably coffee); and
- improving grassland management on 12 000 ha by reducing the grazing intensity, and land management on 14 000 ha of degraded tropical rainforest.

CASE STUDY DEFORESTATION-FREE COMMODITY SUPPLY CHAINS IN THE PERUVIAN AMAZON

All calculations done in the EX-ACT tool are reported in the results module of the tool. Table 3.6 provides an example summary of the GHG sequestered and the share of the balance[26] per GHG from the deforestation-free commodity supply chains investment in the Peruvian Amazon. It summarizes estimated gross fluxes and CO_2-e emissions and sinks from (a) the scenario without-project (left column), (b) the scenario with-project (middle column), and (c) the total balance (right column). The middle table details the carbon balance under project implementation, showing the GHG fluxes from the different modules. The right-hand column details annual CO_2-e fluxes for the different activities without- and with-project implementation, and for the carbon balance.

The highest carbon sinks resulted from the avoided deforestation of tropical rainforests (-9 419 406 tCO_2-e), followed by improved forest management (593 735 tCO_2-e), improved perennial crop management (-118 096 tCO_2-e), improved grassland management (-96 321 tCO_2-e), and annual crop management (-65 661 tCO_2-e). Overall, the project results for mitigation potential add up to about 10 293 219 tCO_2-e over 20 years, i.e. -2 tCO_2-e per hectare, per year.

Incorporation of mitigation benefits into project EFA

GHG mitigation actions produce substantial, far-reaching benefits, and contribute towards achieving the goals of the three – social, environmental and economic – pillars of sustainable development. Socioeconomic benefits can be valued in monetary terms using the "social cost of carbon" concept. By placing a value on carbon, this scheme seeks to encapsulate the overall economic implication (cost) of the emission of an additional unit of tCO_2-e to society. Thanks to the addition of quantifiable costs and benefits of such patterns of emissions, the value can provide information on the benefits of reduced warming in comparison to the costs of reducing emissions. The calculation methodology relies on internationally endorsed measures, such as the discount rate published by the IPCC (2014b) report. Despite the international recognition of the social costs of carbon, it is still contingent on a high level of uncertainty, most specifically the ones related to future capacity of adaptation and appraisal of non-market impacts, among others. However, as a consensus among international development organizations, it is recommended that the social value of carbon be used (in real terms) at USD 30 per tCO_2-e in 2015 to USD 80 per tCO_2-e, by 2050.

By establishing a BAU scenario and an alternative scenario with project implementation, EX-ACT can provide valuable information and complement an EFA to highlight the value-added and positive and/or negative externalities

26 The balance is the difference of GHG gross fluxes between the with- and without project scenarios. Results are given in tonnes of CO_2 equivalent (tCO_2-e). Positive numbers represent sources of CO_2-e emissions while negative numbers represent sinks.

Table 3.6.
EX-ACT screenshot of the GHG summary from the deforestation-free commodity supply chains in the Peruvian Amazon

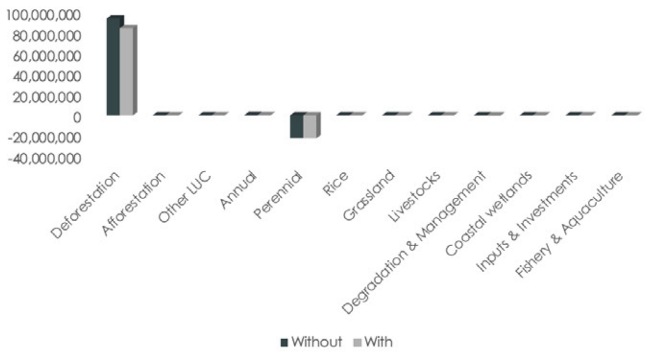
Project Name	*GEF Perú*	**Climate**	*Tropical (Wet)*	**Duration of the Project (Years)**	*20*
Continent	*South America*	**Dominant Regional Soil Type**	*LAC Soils*	**Total area (ha)**	*259012.83*

Components of the project	Gross fluxes			Share per GHG of the Balance					Result per year		
	Without	With	Balance	All GHG in tCO2eq					Without	With	Balance
	All GHG in tCO2eq			CO_2			N_2O	CH_4			
	Positive = source / negative = sink			Biomass	Soil	Other					
Land use changes											
Deforestation	94,194,059	84,774,653	-9,419,406	-9,419,406	0		0	0	4,709,703	4,238,733	-470,970
Afforestation	0	0	0	0	0		0	0	0	0	0
Other LUC	0	0	0	0	0		0	0	0	0	0
Agriculture											
Annual	229,170	163,509	-65,661	0	-45,609		-4,734	-15,318	11,458	8,175	-3,283
Perennial	-22,247,105	-22,365,202	-118,096	0	0		-61,546	-56,550	-1,112,355	-1,118,260	-5,905
Rice	0	0	0	0	0		0	0	0	0	0
Grassland & Livestocks											
Grassland	0	-96,321	-96,321	0	-96,321		0	0	0	-4,816	-4,816
Livestocks	0	0	0				0	0	0	0	0
Degradation & Management	0	-593,735	-593,735	-524,152	-69,583		0	0	0	-29,687	-29,687
Coastal wetlands	0	0	0	0	0		0	0	0	0	0
Inputs & Investments	0	0	0			0	0	0	0	0	0
Fishery & Aquaculture	0	0	0			0	0	0	0	0	0
Total	72,176,123	61,882,904	**-10,293,219**	-9,943,558	-211,513	0	-66,280	-71,868	3,608,806	3,094,145	-514,661
Per hectare	279	239	-40	-38.4	-0.8	0.0	-0.3	-0.3			
Per hectare per year	13.9	11.9	-2.0	-1.9	0.0	0.0	0.0	0.0	13.9	11.9	-2.0

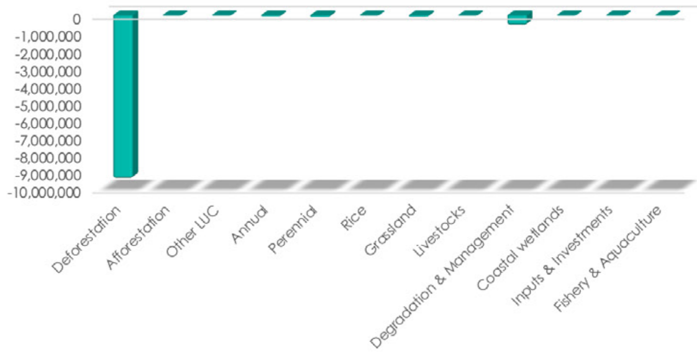
SOURCE: FAO. 2019. EX-Ante Carbon-balance Tool [online]. Rome. [Cited 15 December 2019]. www.fao.org/in-action/epic

Table 3.6. (continuation)

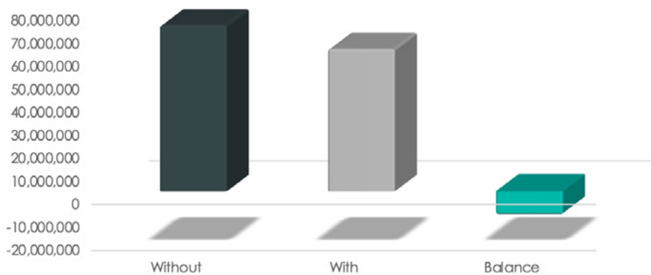
Fluxes per component



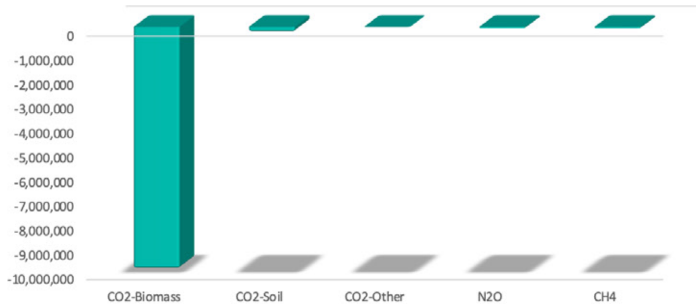
Balance per component



Total without and with project and balance



Share of the balance per GHG (plus origin for CO2)



of the project. Indeed, decision-makers may be informed of the typology of the project under scrutiny: either it generates benefits from GHG mitigation that are lower than implementation costs, unveiling no potential for carbon financing; or on the contrary, it generates mitigation benefits higher than implementation costs, creating an incentive for relevant implications from economic actors. Complementing an EFA with a carbon-balance assessment, coupled with a monetary value of carbon, presents more comprehensive and thorough results, as it captures the full benefits or costs of a project more accurately.

Carbon mitigation benefits in EFA:
The Family Farming Development Programme project

The Family Farming Development Programme (ProDAF) is an eight-year programme implemented in the Niger, more specifically in the Maradi, Tahoua and Zinder regions (IFAD, 2016a, 2016b). Several funding entities have participated in the programme (IFAD, OPEC fund for International Development, the Italian Cooperation, the Government of the Niger), totalling a sum of USD 207 million. Among others, the main programme objectives are to support the emergence of resilient family agriculture enterprises and to promote the economic development of agro-sylvo-pastoral production.

This programme's monetized benefits include:

- increased yields, generated through improved water management, more sustainable agricultural practices, Conservation Agriculture, natural resource degradation control, flood risk management;
- increased incomes, made possible due to increased yields as well as improved cropping systems and marketing in retail points;
- enhanced soil rehabilitation, facilitated by water management, Conservation Agriculture, natural resource management, flood risk management; and
- improved food security, due to increasing self-consumption of crops.

In addition to economic benefits, this programme will also induce carbon sequestration and reduce GHG emissions thanks to an increase of carbon in biomass and soils generated by improved practices (water management, sustainable crop systems, Conservation Agriculture, natural resource management, among others). These improvements can be considered positive environmental externalities of the programme.

In this example, the project EFA was complemented with a monetary value on the mitigation potential of the programme, which was estimated at (-) 28.9 tCO_2-e/ ha after 20 years [(-) 1.4 tCO_2-e/ha/year] by EX-ACT (see Table 3.6). Based on the social value of the carbon approach, the average cost per tCO_2-e in 2020 was USD 40, and will increase to USD 80 per tCO_2-e by 2050 (World Bank, 2017).

The productive and regenerating activity cash flows listed above were complemented by the economic benefits of GHG mitigation. The annual economic cash flows provide the basis for calculating the programme's internal rate of return (IRR) and net present value (NPV). The programme is economically justified when looking at the results over a 20-year period. Indeed, under the assumptions used in the analysis and after a period of 20 years, the economic IRR (EIRR) is 15.7 percent and the NPV (applying a 10 percent discount rate) averages USD 43.8 million.[27]

27 IFAD applied a fixed social cost of carbon of USD 20 and an exchange rate of USD 1 = 500 West African CFA*francs (CFAF).

Technical note 4 Estimating emissions from livestock, including manure management

This section[28] describes the application of GLEAM-i (Global Livestock Environmental Assessment Model-interactive) to the ex-ante assessment of project impacts on animal production and greenhouse gas (GHG) emissions.

This approach facilitates the calculation of the amount of carbon sequestered or not emitted through project interventions over the course of a project's lifespan, indicating savings of annual emissions in the sector as a result of project implementation.

The project

The "Carbon Sequestration through Climate Investment in Forests and Rangelands" (CS-FOR) project in Kyrgyzstan was designed to target critically climate-vulnerable areas of the country. The specific objective of the CS-FOR project is to increase carbon sequestration by supporting climate investments in forests and rangelands that will reduce the drivers of land degradation and GHG emissions through increased institutional support, participatory ecosystem-based sustainable management of natural resources, and green growth investments. The project will intervene in the four districts of Suzak, Toguz-Toro, Ak-Talaa and Uzgen, which are characterized by high climate change-related stresses and high risk of climate change-related hazards, and also represent different types of forest and grassland ecosystems in Kyrgyzstan.

The project contains three components: (i) strengthening of natural resource management governance; (ii) green investments for forest and rangeland rehabilitation; and (iii) climate-sensitive value chain development. The Project's interventions will contribute to the reversal of ongoing forest and pasture degradation, and start replenishing forest cover and improve pasture quality. In turn, this will enhance ecosystem and climate benefits, and – with technical and financial support for the development of green value chains – will create alternative economic opportunities, reverting the overdependence on livestock (cattle), and preserving the natural balance of sustainable landscapes in the project areas.

28 By Anne Mottet, Tommaso Alacevich, and Jacopo Monzini, with contributions from Anass Toudert (FAO).

Estimating net CO_2eq emissions from livestock practices

This document reflects a carbon *ex-ante estimation* of the project interventions with a direct carbon reduction potential from livestock activities. The intervention consists of improving the production efficiency of 849 226 head of cattle and other ruminants – 176 954 cattle, 623 417 sheep and 48 855 goats (see Table 3.7).

Table 3.7.
Project Structure – With-Project/Without Project

Project Structure	Activity	With-Project Scenario	BAU Scenario[29]
Component 2: Green investments for forest and pasture rehabilitation	Livestock management	849 226 head of cattle and other ruminants would be subject to improved herd management, improved feeding and improved manure management and could avoid -7 477.25 tonnes CO_2eq per year. -149 545 tonnes of CO_2eq avoided over 20 years.	No management practices improved and the number of livestock will increase by 20 percent.
Overall carbon balance	Integrated Natural Resources Management activities benefiting about 708 074 hectares with a potential **sequestration of -1 379 153.2 tonnes of CO_2eq per year.** For the entire duration of the project -27 583 064 tonnes of CO_2eq captured.		

Positive result means source, whereas negative result means mitigation.
GHG expressed in tCO_2eq.

SOURCE: Data adapted from FAO project design team calculations, 2018.

Emissions from livestock and manure management

The main sources of emissions from livestock are (i) methane (CH_4) emissions from enteric fermentation, (ii) CH_4 and nitrous oxide (N_2O) emissions from livestock manure management systems (direct and indirect), and (iii) N_2O emissions from managed soils (direct and indirect):

- ***Methane emissions*** [30] from manure management tend to be lower than enteric emissions, with the most substantial emissions associated with confined animal management operations where manure is handled in liquid-based systems.
- ***Nitrous oxide emissions*** from manure management vary significantly between the type of management system used, and can also result in indirect emissions due to other forms of nitrogen loss [31] from the system.

The methods for estimating CH_4 and N_2O emissions from livestock require definitions of ***livestock subcategories, annual populations*** and, for higher Tier methods, ***feed intake and characterization.***

29 Without the project scenario or baseline/business-as-usual scenario, which corresponds to a description of expected conditions in the project boundaries in the absence of project activities.

30 Cattle are an important source of CH_4 in many countries because of their large population and high CH_4 emission rate due to their ruminant digestive system.

31 The calculation of the nitrogen loss from manure management systems is also an important step in determining the amount of nitrogen that will ultimately be available in manure applied to managed soils, or used for feed, fuel, or construction purposes.

The procedures employed to define livestock subcategories, develop population data, and characterize feed[32] are available in the IPCC Guidelines for National Greenhouse Gas Inventories (NGGI-IPCC) to help estimate livestock-associated emissions.

GLEAM-i tool

The ex-ante assessment of the project's impact on animal production and GHG emissions is based on the tool GLEAM-i (or Global Livestock Environmental Assessment Model – interactive), developed by FAO. A description of the tool and full documentation is available on FAO's dedicated GLEAM-i web page.[33]

GLEAM-i is a user-friendly and interactive version of the FAO GLEAM, a biophysical model of livestock supply chains that calculates animal herd dynamics, feed rations, production and GHG emissions with Tier 2 methodology (see Box 3.3) and a life cycle approach (IPCC, 2006).

GLEAM identifies three main groups of emissions along production chains. Upstream emissions include those related to feed production, processing and transportation. Animal production emissions comprise emissions from enteric fermentation, manure management and on-farm energy use. Downstream emissions are caused by the processing and post-farm transport of livestock commodities. Three types of gas emissions are considered in GLEAM: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The latest available global warming potential from IPCC (2014b) are used to convert all emissions into CO_2 equivalent (298 for N_2O and 34 for CH_4).

GLEAM-i brings the core functionalities of GLEAM to the public in a web application. It allows the direct comparison between Baseline and Scenario conditions, and incorporates the 2010 default data from GLEAM. GLEAM-i is the first open, user-friendly and livestock specific tool designed to support governments, project planners, producers, industry and civil society organizations to calculate emissions from livestock supply chains using Tier 2 methods. It can be used in the preparation of national inventories and in ex-ante project evaluation for the assessment of intervention scenarios in animal husbandry, feed and manure management.

GLEAM-i works by default at country level for national herds and flocks, and proposes default parameters from national or regional GLEAM averages. In order to ensure a reliable analysis, it is recommended that the default parameters be updated with context-specific data.

Detailed analysis of GHG emissions from livestock and manure

Key project activities acting on GHG emissions

The project aims to improve the production efficiency of 849 226 head of cattle and other ruminants (176 954 cattle, 623 417 sheep and 48 855 goats) through **improved herd management, improved feeding and improved manure management:**

32 Suggested feed digestibility coefficients for various livestock categories have been provided to help the estimation of feed intake for use in calculation of emissions from enteric and manure sources.

33 See: www.fao.org/gleam/resources/en/

Box 3.3.
IPCC Tiers

The Intergovernmental Panel on Climate Change (IPCC) defines different methods that can be used to estimate emissions or removals from most sources and sink categories. The selection of a particular method will depend on the desired degree of estimation detail, the availability of activity data and emission factors, and the financial and human resources available to complete the inventory. In IPCC terminology, the lowest ranking or simplest method is "Tier 1", while more elaborate methods are "Tier 2" and "Tier 3".

Tier 1 methods typically utilize IPCC default emission factors and require the most basic, and least disaggregated, activity data. Higher tiers usually utilize more elaborate methods and source-specific, technology-specific, region specific and/or country-specific emission factors, which are often based on measurements, and normally require more highly disaggregated activity data.

Tiers 2 and 3 require more detailed data and/or measurements for their application. In cases where a national methodology exists, which is consistent with the IPCC Guidelines, it is highly advisable to use the national methodology. This methodology should be fully documented in order to allow the reader to understand why this particular method is better than the default proposed by the IPCC (UNFCCC, 2009: 9)

SOURCE: UNFCCC, 2009. UNFCCC Resource Guide Module 3: National greenhouse gas inventories. Bonn, Germany. 36 pp. (also available at https://unfccc.int/resource/docs/publications/09_resource_guide3.pdf).

- Improvements in herd management practices: include better care for animals, improved animal health and disease control, and more effective reproduction management, but controlling the growth of the herd that results from gains in productivity at herd level (mainly from improved fertility, reduced mortality and increase in average litter size for sheep).
- Improvements in feeding practices:
  - reducing fresh grass, hay and cereal straw in the ration to increase the proportion of grass-legume mix, alfalfa, and to a lesser extent, maize and cereals (1% to 2% increase) for cattle; and
  - increasing grains (+5% on average) and by-products (+3.5% on average) in the feed mix, while reducing crop residues for sheep.
- Improvements in manure management: increasing the proportion of manure stored in solid form with bedding while reducing the proportion of manure deposited in pastures, piled without bedding or burnt for fuel.

Without the project, a 20 percent growth in animal numbers is expected without any gains in productivity. The project could avoid emissions at an annual rate of -7 477.25 tCO_2-eq or -149 545 tCO_2eq for the entire accounting duration of the analysis.

Results provided by GLEAM-i

In order to perform the GLEAM-i analysis in the scope of the CS-FOR project, the baseline parameters for cattle and small ruminants, including herd, feed and manure management parameters were collected specifically by FAO in the project area. For the exercise, the GLEAM-i data collection spreadsheets were translated into Russian, and were verified by experts against national statistics as well as project-area specific data. They were also cross-checked by experts from the private sector to ensure that the project scenario was comparable to a fair representation of reality. As a result, significant changes were found compared to the default values, including in herd parameters (fertility and mortality rates, weights, milk yields, etc.), feed rations and manure management systems.

Table 3.8.
Results of GLEAM-i simulations for all ruminants and for cattle

Subsectors	Scenarios	Absolute values			Change compared to BAU			Change compared to current situation		
		Emissions (tCO_2eq/year)	Production[34] (t protein/ year)	Emission intensity (tCO_2eq / t protein)	Emissions	Production	Emission intensity	Emissions	Production	Emission intensity
All ruminants	Current situation	788 551	5 448	145	-17%	-17%	0%	-	-	-
	BAU (+20% herd)	945 779	6 537	145	-	-	-	20%	20%	0%
	Project – no herd control	930 825	7 372	126	-2%	13%	-13%	18%	35%	-13%
	Project + herd control[35]	838 034	6 635	126	-11%	1%	-13%	6%	22%	-13%
For cattle	Current situation	568 947	4 931	115	-17%	-17%	0%	-	-	-
	BAU (+20% herd)	682 760	5 917	115	-	-	-	20%	20%	0%
	Project – no herd control	587 536	5 648	104	-14%	-5%	-10%	3%	15%	-10%
	Project + herd control	587 536	5 648	104	-14%	-5%	-10%	3%	15%	-10%

SOURCE: Data adapted from FAO project design team calculations, 2018.

The business as usual (BAU) scenario was first run in GLEAM-i simulating baseline parameters and the animal numbers in the project area (176 954 cattle, 623 417 sheep and 48 855 goats. Several scenarios were considered for a project time frame of 20 years.

First, a BAU scenario was run as a continuation of past trends with a 20 percent increase in cattle, sheep and goat, without project implementation, which was assumed to result in no changes in management or productivity. Second, a scenario of the project with improved practices was modelled, without any control of animal numbers.

The improved herd management practices are summarized in Table 3.8 for a number of parameters in GLEAM-i, including fertility and mortality rates, animal weights and milk yields. Improvements in feed rations correspond to

34 Meat and milk.
35 Reduce reproductive female herd by 10%.

modest changes in the composition of the feed ration. For cattle, this was achieved by reducing fresh grass, hay and cereal straw in the ration and increasing the proportion of grass-legume mix, alfalfa, and to a lesser extent, maize and cereals (1% to 2% increase). For sheep, the improvements were similar, with an increase of grains (+5% on average) and by-products (+3.5% on average) in the feed mix, while crop residues were proportionally reduced.

Changes in manure management were achieved by increasing the proportion of manure stored in solid form with bedding while reducing the proportion of manure deposited in pastures, piled without bedding or burnt for fuel.

Finally, a third scenario was modelled which was based on implementing the project and improved practices, but controlling the growth of the herd that results from gains in productivity at herd level (mainly from improved fertility, reduced mortality and increases in average litter size for sheep). In trial runs, the number of adult females was reduced by 10 percent in each species compared to BAU, resulting in a 4 percent decrease in the total cattle herd, and a 13 percent decrease in the goat herd. Given the high gains in productivity at herd level in sheep production, the total number of sheep still increased by 20 percent despite the decrease of 10 percent in the number of adult females.

Results: between 149 545 and 1 077 451 tonnes of carbon saved over 20 years

Results are summarized in Table 3.8 for all ruminants and for cattle, as they represent the largest part of emissions and production. Business as usual results in an increase in emissions and production of 20 percent compared to BAU due to the growth in animal numbers without any gains in productivity.

With the project's improved practices, emissions increase by 18 percent and production increases by 35 percent compared to BAU, resulting in a 13 percent decrease in emissions per kg of protein. With the project, emissions are 2 percent below those without-project in BAU, while production increases by 13 percent due to gains in productivity.

If relative control in animal numbers is carried out to avoid this growth resulting from higher fertility and lower mortality, emissions would be only 6 percent higher than in BAU, but with a 22 percent increase in production, resulting in a decrease of 13 percent in emissions per kg of protein. Compared to BAU without improvement, implementing the project with a relative reduction in animal numbers (20%) would result in approximately the same level of production but an 11 percent reduction in emissions.

When projecting these results over the total lifespan of the project (20 years), and adding the differences in emissions and production for each year, implementing the project would save 149 545 tonnes of CO_2eq, and produce an extra 8 346 tonnes of protein. With relative herd control, the project would result in saving 1 077 451 tonnes of CO_2eq, with an extra 974 tonnes of protein produced. This corresponds to saving between 19 percent and 137 percent of the sector's annual emissions in the BAU scenario.

Technical note 5 Applying the MOSAICC methodology for adaptation planning in the agricultural sector in Malawi

This technical note[36] describes the application of the Modelling System for Agricultural Impacts of Climate Change (MOSAICC) to the development of Malawi's National Adaptation Plan in the agriculture sector (NAP-Ag).

MOSAICC was used for establishing a highly participatory process in identifying medium- to long-term projections of climate change impacts in the sector.

The evidence generated of climate impact provided grounds for the participatory prioritization of climate adaptation measures to be included in Malawi's National Adaptation Plan.

The context

Malawi has a sub-tropical climate, which is relatively dry and strongly seasonal. Although the country has diverse agro-climatic zones and abundant freshwater resources, its natural ecosystems are highly exposed to natural disasters, climate variability and climate change. These environmental pressures are exacerbated by socioeconomic factors, including population growth and agricultural intensification, which are increasingly degrading land and forest resources. As a land-locked least developed country (LDC) with no direct access to marine ports and marine natural resources, Malawi remains among the poorest countries in the world, with over half the population living below the poverty line. Eighty-five percent of Malawi's population lives in rural areas, where poverty rates are highest (World Bank, 2019).

Climate change acts as an incremental threat and risk multiplier, hitting the most vulnerable people and ecosystems hardest. Malawi is highly exposed to natural disasters, such as floods and drought, and as a predominantly agrarian country – where agriculture accounts for one-third of the gross domestic product (GDP) and nearly 80 percent of employment – it is crucial that the potential impacts of climate change on the agriculture sector are well understood and that adaptive measures are taken.

Adaptation planning in the agricultural sector in Malawi

The 2016 National Agriculture Policy of Malawi identifies climate change as a cross-cutting issue, and aims to enhance the "sustainable management of agricultural resources, increased agricultural exports and incomes, food security, and improved nutrition in the face of growing population pressure, urbanization, increasing global economic interdependence, and climate change."

Following the recommendations of the UNFCCC Least Developed Countries Expert Group (UNFCCC, 2012), taking stock of information and data are key components for laying the groundwork and addressing data gaps, but also for ensuring that the implementation of adaptation actions is enhanced

36 By M. Fujisawa, A. Gordes and A. Heureux, with inputs from T. Wong (FAO). Other contributors: J. Wolf, R. Ramstedt, and R. Vuolo (FAO).

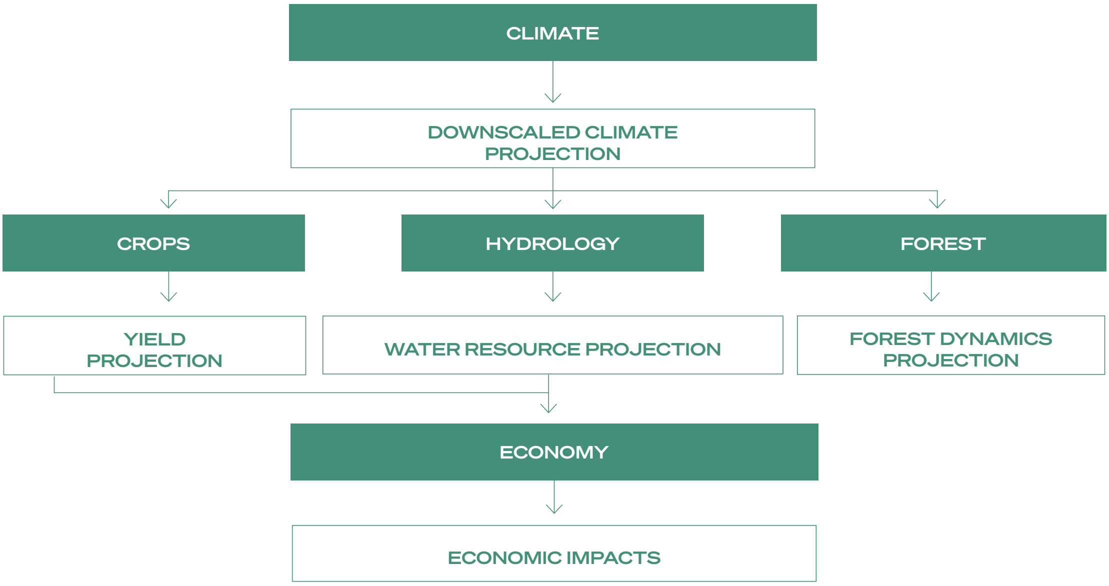


Figure 3.10.
Framework of MOSAICC model structure and data flow

SOURCE: FAO, 2015b.

by adequate coordination and capacity development for using and analysing climate data.

Malawi embarked on its National Adaptation Plan (NAP) process in 2014, including adaptation planning for the agriculture sector. For this purpose, a robust understanding of the current and expected impacts of climate change on the agriculture sector was essential to minimize damages and adverse effects for a large portion of the population. While climate studies and impact assessments were available, the scientific outputs often lacked the necessary links to policy-making and planning. Thus, building national capacity in climate impact assessments and establishing an evidence base were necessary for the country's National Adaptation Planning. The Modelling System for the Agricultural Impacts of Climate Change (MOSAICC) methodology was identified as a suitable tool and is summarised in Figure 3.10.

MOSAICC implementation

The MOSAICC implementation process broadly included:

- Collection and stocktaking of national data (i.e. weather station, crop yields, etc.)
- Design impact assessment based on the country interest (i.e. major sectors, time period, specific crops, etc.)
- Training of national experts by specialists in each area of interest
- Running models and production of results
- Technical report/policy brief by national teams
- Communication and application of results to planning and policy-making

Box 3.4.
National stakeholder engagement in MOSAICC implementation

Key national stakeholders, generally technical experts in climate and each impact area, are engaged at every stage in the MOSAICC process to ensure that the outputs exemplify national priorities and utilize local knowledge and expertise.

By bringing together national experts from across institutions during the project development stage, participants in the process can prioritize activities, taking diverse perspectives and objectives into consideration. National stakeholder engagement also ensures long-term sustainability and capacity development.

Upon completion of the initial MOSAICC process, local experts are left with the capacity to repeat the exercises if new information (i.e. emission scenarios or updated data) becomes available. In Malawi, the key national experts involved in the MOSAICC process were from the Lilongwe University of Agriculture and Natural Resources; the Department of Climate Change and Meteorological Services (DCCMS); the Department of Agricultural Research Services (DARS), and other Departments of the Ministry of Agriculture, Irrigation, and Water Development (MOAIWD).

SOURCE: Authors.

The implementation was organized along the following four steps:

Step 1: Engagement of stakeholders and assessment of national interest

Through bilateral meetings and an inception workshop with key stakeholders (Box 3.4), the interests of national experts and the status of the national capacity were evaluated. Participants included representatives from the Ministries as well as national and local research institutes, including those involved in policy-making, extension and research. In this context, the study design was discussed and decided, and the technical working group for the assessments was established. At this stage, a preliminary work plan was developed, and plans were introduced to consult a larger audience for the validation of the results.

Step 2: Identifying data availability and gaps in country data

With the working groups in place, the process began with the collection of country data (meteorological, crop yield data, etc.); this process also served as a ***stocktaking exercise to identify potential data gaps within the country.*** Climate data[37] (temperature max, temperature min, and precipitation) was collected from all available weather stations in the country for the years 1961–2015.

Table 3.9 shows the data gaps that were identified in the stocktaking exercise, including (1) chronological gaps in data records of climate (yellow cells), and (2) geographical gaps in station data for temperature (red cells).

For the crop component of MOSAICC, data were collected in a similar way, targeting the official historical crop yield statistics nationally and by province. Using local knowledge, the key crops for each province were select-

37 The MOSAICC methodology can be slightly adapted to the data available in the country.

ed by national experts. In the case of Malawi, yield and phenology data were collected for **maize, rice, sorghum, soya, common beans and groundnuts.**

Overall, this exercise identified the most useful datasets in the country as well as key limitations to be addressed in future exercises.

Step 3: Training – Strengthening national technical capacity

Capacity building is a core component of MOSAICC and ensures that lessons learned in establishing a system for climate impact assessment are sustainable. Through training and peer-to-peer learning, national experts in information technology (IT), climate and crop modelling (detailed below) are able to **continue analysis in the future as new information becomes available or the country interests and objectives change.** To run the models, the FAO MOSAICC team supports the installation of a physical server in the designated country. MOSAICC training – on each module of MOSAICC – is then carried out by FAO experts. In Malawi, the training focused on the IT, climate downscaling and crop components of MOSAICC (as described in detail below) and targeted the direct involvement of the focal points identified in the inception workshop.

Training 1: IT training

In order to support the MOSAICC interface and data management, IT experts in Malawi were trained on the configuration and codes used to run the models. The MOSAICC IT training included the installation of a physical server and training on the IT requirements for development and implementation of the other MOSAICC components – the objective being for the national IT experts to understand the architecture of the MOSAICC system and the overall objectives of the process. Participants were trained on maintenance of the server to continue the work in the country and troubleshoot throughout the process.

Training 2: Climate component – downscaling

The climate component of MOSAICC trained climate experts from universities and from the Department of Climate Change and Meteorological Services (DCCMS). The first step of the training provided an overview of the handling and analysis of historical climate data and trends collected for meteorological stations (as highlighted above). With this data, participants were trained to carry out statistical downscaling of climate data. This process entails using the outputs of General Circulation Models (GCMs) and downscaling these outputs to weather station level. The final outputs of this component are future climate projections at local or province level. The final stages of the training focus on quality control and analysis of the results.

Training 3: Crop component – yield projection

The crop component of MOSAICC aims to assess the impacts of projected climate change (outputs from the climate component) on crop yield projections for the priority crops chosen by the country experts. In the case of Malawi, the priority crops chosen were maize, rice, soya, common beans and groundnuts. The crop trainings introduced participants to one method of modelling future crop yields based on water balance parameters. The first stage of the training explained the analysis of historical crop yields from country data (discussed in the previous section). Subsequently, participants were trained to input crop-specific coefficients, growing season, and climate information into the crop-modelling component.

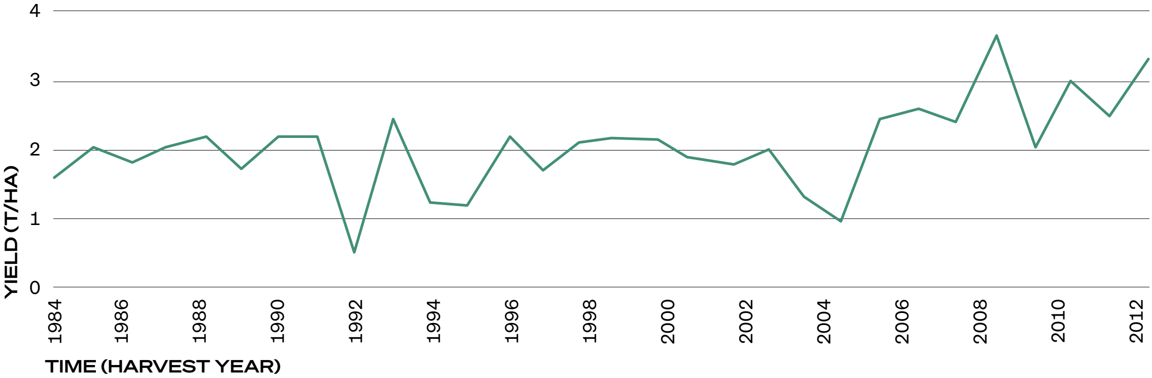


Figure 3.11.
Historical maize yield data from 1984 to 2012

SOURCE: Government of Malawi, 2018.

Table 3.9.
Tabulation of data by meteorological stations

ID	Station	Latitude	Longitude	Precipitation	Min Temperature	Max Temperature
3	Bolero	-11.02	33.78	1962–2015	1982–2015	1982–2015
4	Zombwe	-11.33	33.82	1961–1990		
5	Mzuzu	-11.43	34.02	1961–2015	1961–2015	1961–2015
6	Nkhata Bay	-11.6	34.3	1961–2015	1961–2004	1961–2004
7	Mzimba	-11.9	33.6	1961–2015	1961–2015	1961–2015
8	Dwangwa	-12.48	34.08	1972–2010		

SOURCE: Government of Malawi, 2018. FAO, 2020.

Step 4: Validation of results and completion of technical reports and policy briefs

The final outputs of MOSAICC in Malawi were medium- to long-term climate projections downscaled to local (weather station) level and projected crop yields, up to year 2070, for six major crops across eight provinces. The main outputs of MOSAICC in Malawi are summarized in Box 3.5.

The responsibility, management and ownership of the data, tools and results remained in the country, and the final results were presented to a wide range of stakeholders in a follow-up workshop held in Lilongwe. The working groups submitted technical reports, then proceeded to draft policy briefs summarizing the final results of the MOSAICC process.

Integration of MOSAICC into the planning process

Two national working groups were created under the framework of the NAP-Ag process in Malawi. The first is the core technical working group consisting of experts from the relevant ministries and researchers from the universities outlined above, tasked with the implementation of MOSAICC. The second working group is the larger group identified to apply the results, including those involved in policy-making from wider ministries. Throughout the process, the second group served as the consulting and validating body for the outputs of work. In the validation workshop, the MOSAICC results were presented to the larger working group and feedback was provided. By involving the technical experts as well as senior policymakers, the mainstreaming as well as the sustainability of MOSAICC are reinforced throughout the entire process. The aim of the working groups is to keep communication channels open to promote the technical outputs of the process in future planning and policymaking at all levels.

Key Lessons Learned

1 **Identifying inconsistencies and gaps in country climate data at the earliest stage is essential**

- Differences in the format of country-level data require capacity and time to harmonise for use in any data processing activity.
- Lack of systematic recording of planting dates and consistent information for irrigation in Malawi is a limitation for crop modelling.
- Different departments within the same Ministry of Agriculture use different descriptions of adequate rainfall when advising farmers when to plant.
- A physical server, based in the country, allows for (a) the use of MOSAICC without a strong internet connection, and (b) security of sensitive data – but in the case of Malawi, problems with maintenance of the physical server resulted in delays and difficulties using the system.

2 **Motivation of participants**

- Participants referred to the lack of human resources within the ministries as a limiting factor in maintaining momentum to complete the MOSAICC process.
- Motivation and engagement of the focal point to push the process forward is necessary to coordinate the various components and link the key participants.
- National experts performing the analysis should ideally have a professional interest in the MOSAICC methods and outputs (i.e. publications or research relevant to current work streams). The MOSAICC process should also highlight other methodologies used in these areas for possible future development.
- MOSAICC should be well integrated into the planning process and road map to ensure that the outputs are directly utilized. Technical working groups should include experts in climate, agronomy as well as relevant policymakers.

3 **Sustainability**

- Some countries are displaying MOSAICC results online and are utilizing the results for future research or climate-related objectives:
  - Morocco created an online portal that is used by researchers and governments: http://www.changementclimatique.ma/?q=en/node/19
  - In Peru, the National Drought Observatory used the outputs of MOSAICC in an online portal: http://ons.snirh.gob.pe/Peru/maproom/Forecasts/index.html#tabs-2
- Maintenance of the MOSIACC server is required to allow experts to access it and run the analysis again after the process is complete.

Box 3.5.
Main outputs of MOSAICC in Malawi

- Medium (2010–2040) to long-term (2041–2070) projections of **temperature and precipitation** downscaled to station level and interpolated to eight agricultural development divisions.
- Analysis of agro-climatic indices using climate outputs and agricultural parameters.
- Medium (2010–2040) to long-term (2041–2070) **crop yield projections** based on climate projections across the eight agricultural development divisions.
- Crops modelled: maize, rice, soya, common beans, sorghum and groundnuts.
- Final technical reports and policy briefs visualizing and summarizing final outputs (in progress).

Conclusion and recommendations

The main objective of the MOSAICC process is to build the national capacity of ministries and research institutions to handle climate data, produce medium- to long-term climate projections, and assess local impacts on key crops for national adaptation planning. The outputs of the process in Malawi, highlighted in this case study, were presented to relevant stakeholders and policymakers with the objective of incorporating a strong evidence base in policymaking.

As identified by the NAP stocktaking report, capacity constraints and/or lack of suitable climate information at ministry level may lead to decisions with only limited backing of data, making it more difficult to monitor the impact of the policies concerned. The activities described in this case study were undertaken to help address this issue. It is recommended that the outputs from this exercise, as well as other climate impact assessment initiatives and future work by national experts, should be integrated into the national planning process on an iterative basis. The technical working groups formed during the MOSAICC process should be continuously consulted throughout the NAP process and results can be modified according to new information or requests.

Technical note 6 Assessing household resilience to climate change

Measuring resilience in climate-smart investments is necessary to track results of their implementation.

Resilience Index Measurement Analysis methodology (RIMA) was applied on a pilot basis for a project to assess changes in household climate resilience in the target areas as a result of the project interventions.

The evidence provided was used to justify the choice of investment options at project design stage; it also established baseline data to quantitatively measure resilience and to allow its monitoring over time through the RIMA Resilience Capacity Index (RCI).[38]

Measuring resilience in climate-smart investments

International financial institutions place significant emphasis on monitoring the results of their investments. For example, the Green Climate Fund's (GCF, 2014) Performance Measurement Framework (PMF) requires that the adaptive capacity of vulnerable people – one of the fund's impact level results – be measured by the following predefined indicator: "increased resilience and enhanced livelihoods of the most vulnerable people, communities and regions."[39] However, while definitions of vulnerability, adaptation and resilience are widely recognized (see the Glossary Section), the methodologies and tools for measuring resilience remain debatable. Some suggestions refer to measuring resilience by an index, capturing aspects such as access to services and resources, vulnerability and risks, as well as production and productivity (GCF, 2016).[40]

This technical note illustrates the application of an FAO-developed Resilience Index Measurement Analysis methodology (RIMA)[41] that allows quantitative measuring of climate resilience and its changes over time.

38 Technical note 6 by S. Di Giuseppe, T. Alacevich, J. Monzini, and M. D'Errico (FAO).

39 Reference to GCF PMF's impact level indicator A1.0 (GCF, 2014).

40 The GCF position on the matter, summarized in GCF/B.13/26 (2016) states that: "[the abovementioned] indicator is envisioned to be measured in the form of an index, composed by a set of sub-indicators. The methodologies, to be developed, can be informed by similar indicators adopted by AF, LDCF/SCCF, PPCR, GIZ and ICF, among others. Sub-indicators composing this index would look at specific aspects of what constitute resilience and well-being, such as access (to services and resources), reduced risk of losses (economic, health, lives, etc.), and enhanced production/productivity (in agriculture, livestock, and other economic activities)."

41 References on RIMA are available at www.fao.org/emergencies/resources/documents/resources-detail/en/c/405048/.

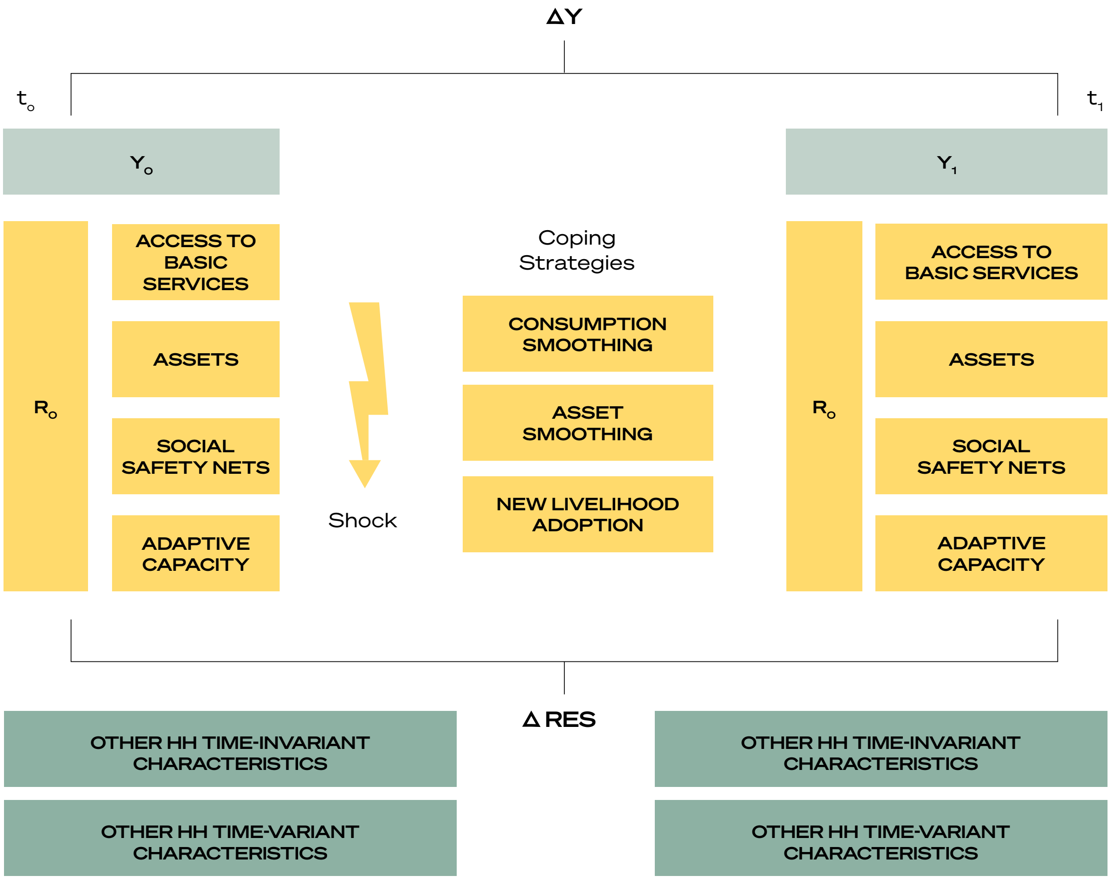


Figure 3.12.
Resilience conceptual framework

SOURCE: FAO, 2016c.

The case study

The "Carbon Sequestration through Climate Investment in Forests and Rangelands (CS-FOR)" project in Kyrgyzstan is aimed at establishing a national pattern for carbon sequestration, while increasing the climate resilience of vulnerable communities in the selected districts that are the most exposed and vulnerable to climate change.[42]

In order to measure the performance of the CS-FOR project against its contribution to climate-resilient sustainable development, FAO opted to pilot the use of the RIMA approach that allows for the comparison between different types of households in the project area. The approach also facilitates the analysis of how certain households are better able to cope with climate shocks and stressors. Resilience is defined as "the capacity that ensures adverse stressors and shocks do not have long-lasting adverse development consequences" (FSIN, 2014). Figure 3.12 describes a framework of the RIMA methodology (FAO, 2016c).

42 The geographic targeting was based on existing studies (IFAD, FIC and IEH, 2013) and government statistics, complemented by additional remote sensing analysis using EarthMap (platform available in beta version at https://beta.earthmap.org/), including variables such as Normalized Difference Vegetation Index (NDVI), Land Productivity Dynamics, and others.

In order to quantitatively measure resilience and to allow its monitoring over time, RIMA defines a Resilience Capacity Index (RCI) – normalized between 0 and 100 (100 being the highest possible value). Two steps are employed in the estimation. In the first step, a factor analysis[43] is used to identify the pillars that contribute to household resilience and the aggregate indexes for the household's climate sensitivity, starting from observed variables. This variable reduction technique relies on finding cross-correlations between the observed variables, identifying a number of (unobservable) factors that reflect correlations and predict the latent outcome (pillars and climate sensitivity index) as a linear combination of underlying factors. In the second step, a mixed-modelling technique termed "Multiple Indicators and Multiple Causes (MIMIC)" is used to estimate the RCI.[44]

The resilience analysis

The specific analysis used in support of the CS-FOR project design was based on the four typical pillars of the RIMA approach (FAO, 2019c), measured by a set of variables, which for this case, and included the following:

- *Access to basic services* (ABS), measured by the proximity to main services, proximity to water source, safe drinking water, sanitation and housing index.
- *Household assets* (AST), including per capita land used, financial assets, per capita number of livestock owned, household's wealth perception and agricultural wealth index.
- *Social safety nets* (SSN), capturing formal/informal transfers per capita, access to credit.
- *Adaptive capacity* (AC), summarized through diverse income portfolios, number of trainings attended by a household, crop diversification index, and household head with a university degree.

For the complementary aspect of household's sensitivity to climate change – specifically introduced for this case – the analysis used the following three main aggregates:

- *Climate anomalies*, measured by the coefficient of variation compared to the long-term trends of temperature and rainfall.
- *Environmental vulnerability* (as a proxy to exposure to risk of natural disasters affecting the area, such as landslides and mudslides), measured by total forest loss in the last 15 years (ha), percentage of village population with respect to total district population, and village altitude.
- *Socio-economic vulnerability*, measured by the number of migrants per household, share of household members at working, village Gini coefficient, poverty headcount ratio.

43 Factor analysis is a tool for investigating variable relationships for complex concepts such as socioeconomic status, dietary patterns, or psychological scales. It allows researchers to investigate concepts that are not easily measured directly by collapsing a large number of variables into a few interpretable underlying factors.

44 The MIMIC model is a procedure for the estimation of a model in which one observes multiple indicators and multiple causes of a single latent variable. The MIMIC model has both a structural component (relating pillars to resilience) and a measurement component linking resilience to households' climate sensitivity. The MIMIC model was defined in Karl G. Jöreskog and Arthur S. Goldberger, "Estimation of a model with multiple indicators and multiple causes of a single latent variable," *Journal of the American Statistical Association* 70, No. 351 (1975): pp. 631-639.

The two sets of variables simultaneously capture the levels of household resilience, after which they are summarized in the RCI.[45]

Findings of the analysis

Figure 3.13 summarizes the resilience levels resulting from RIMA. The analysis focused on two areas: project target area as the intervention area, and an area with similar economic and climate conditions as a control area. The two areas show little difference; the households in the control area show slightly higher resilience (RCI of 54.33), compared to the ones in the Project area (RCI of 51.69).[46]

Looking at how the resilience pillars contribute to the overall households' resilience (Figure 3.13[b]), **adaptive capacity** (AC) is the most influential pillar for both groups. For the households living in the Project area, the subsequent pillars in order of importance are access to basic services (ABS), social safety nets (SSN), and household assets (AST). For the control group, the subsequent pillars in order of importance are household assets (AST), access to basic services (ABS), and social safety nets (SSN). For both the intervention and control groups, the importance of adaptive capacity is mainly driven by the **high level of education** (household head with university degree, which accounts for almost 25 percent on the final RCI score), and the **diversification of income portfolios** (which account for almost 16 percent in the intervention group and 11 percent in the control group).

In fact, diversification is gaining recognition as one of the most effective adaptation strategies to mitigate the impact of climate variability. Concerning access to basic services, housing represents a major element in people's material living standards and is essential in providing shelter from weather conditions. Although housing conditions are good in both groups, the level of sanitation remains low. **Road access** also poses a significant problem and many of the roads in the country are not open all year round as a result of the harsh winter conditions in the mountains.

Regarding household assets (AST), **the level of well-being of the control group area is higher** compared to the intervention group, and **the level of vulnerability is lower** with respect to the intervention group. The difference in the two groups stems from the varying level of satisfaction (living standards and economic condition) and material status (used here as a proxy of the more general household well-being), with the control group being more satisfied with their material status.

The role played by livestock and agricultural activities is also multifaceted. Being more specialized in livestock and/or agricultural activities makes households more sensitive to extreme climatic events (such as drought resulting in water scarcity and insufficient water for use in irrigation and for livestock), whereas **having a differentiated livelihood makes a household more resilient to adverse climatic events**.

Concerning variables related to social safety nets (SSN), informal transfers (and remittances)[47] are the main drivers of the pillar for both groups, also considering the fact that since the mid-2000s, migration processes have considerably increased in Kyrgyzstan. Only 30 percent of the households in

45 For details and references, see "Resilience Analysis in the target areas of the CS-FOR", FAO (2019c).

46 See FAO (2019c) for the statistical tests used to check the significance of the difference.

47 According to the International Federation for Human Rights (FIDH, 2016), approximately 50 000 Kyrgyz leave the country every year to work abroad, mainly to seek employment in Russia and Kazakhstan.

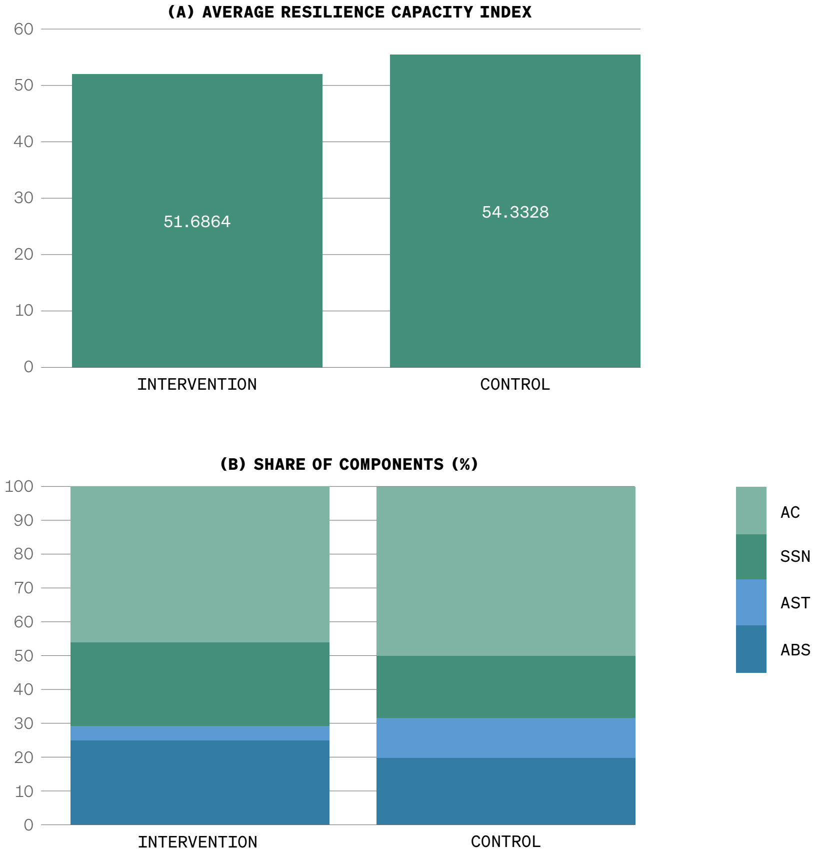


Figure 3.13.
Resilience Capacity Index (RCI) and its composition in CS-FOR analysis

Adaptive Capacity (AC); Social Safety Nets (SSN); Household Assets (AST); and Access to Basic Services (ABS).

SOURCE: FAO, 2019c.

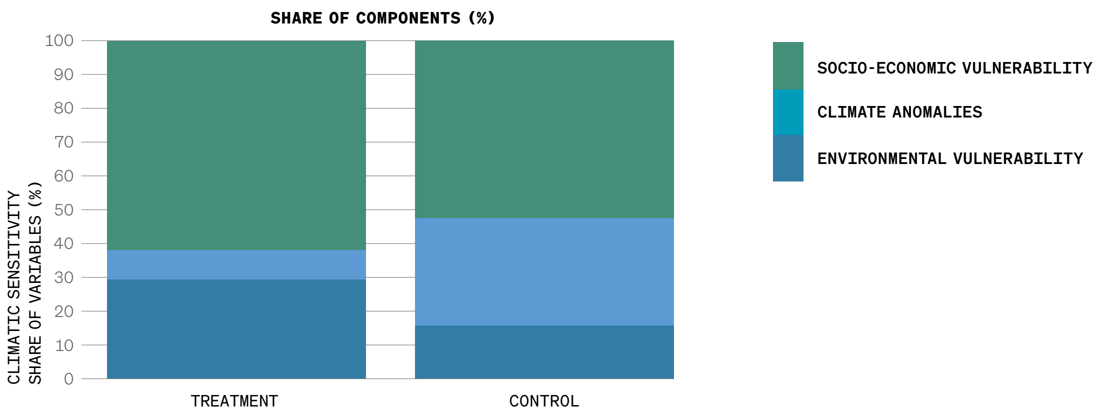


Figure 3.14.
Contribution of climate sensitivity to household resilience

SOURCE: FAO, 2019c.

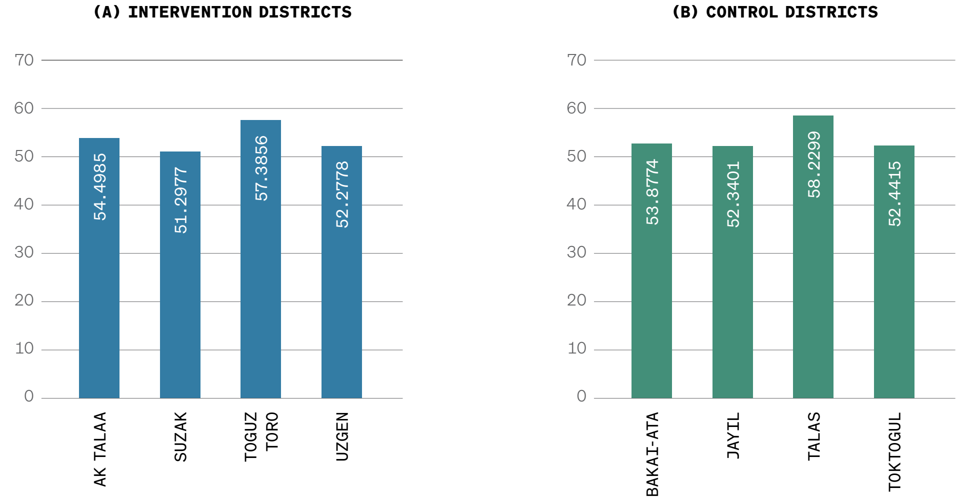


Figure 3.15
Average resilience index at district level

Source: Government of Malawi, 2018.

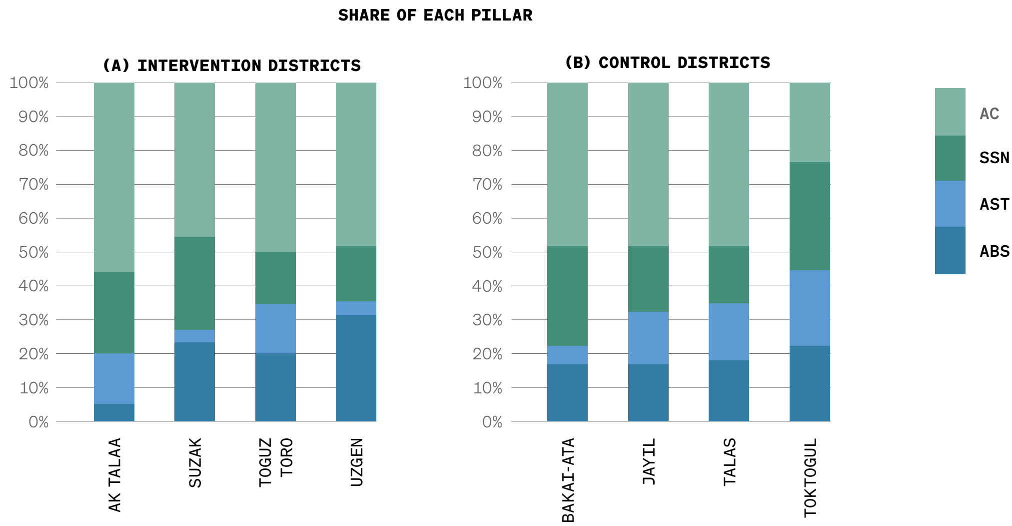


Figure 3.16
Contribution of the variables to households' resilience by district

Adaptive Capacity (AC); Social Safety Nets (SSN); Household Assets (AST); and Access to Basic Services (ABS).

SOURCE: FAO, 2019c.

both groups (30 percent for the treated group and 29 percent for the control group) have access to credit; **indeed, access to credit is one of the main constraints in the Kyrgyz Republic**. Formal transfers are higher for the treated group (USD 77 per capita) compared to the control group (USD 69 per capita).[48]

With regard to the climate sensitivity variables, the analysis found a higher impact of variation of the long-term rainfall (representing the degree of variation in the rainfall in the last 15 years) for the intervention group, while variation of temperatures was found higher for the control group. Looking at the structure of the climate sensitivity, the control group seems to be less vulnerable and less exposed to risk with respect to the intervention group, which is therefore more sensitive to climatic change (Figure 3.14).

Results by district

Considering the homogeneity of the intervention and control areas, which show the same resilience patterns and the same importance in the variables behind each pillar (described in Figure 3.15), it became important to take a closer look at the district level (Figure 3.15 and Figure 3.16).

Initial findings from the analysis showed heterogeneity among districts (both in the intervention area and in the control area). Figure 3.16 illustrates how adaptive capacity (AC) seems to be the main contributor to resilience, with the exception of Toktogul (control area), where the Social Safety Nets (SSN) pillar had a greater impact on the final RCI score. The level of resilience varied among the four districts in the Project area, with each district revealing the following characteristics:

- **Ak-Talaa** is the most resilient, showing the lowest climate sensitivity and exposure to climate change-related risks. Despite the limited access to basic services, the households' incomes and farming strategies are more diversified. Moreover, their high level of education is also an asset.
- **Toguz Toro** is the second most resilient district, but with higher climate sensitivity. Despite a relatively high Gini coefficient and headcount poverty ratio, the analysis shows a high adaptive capacity of this district's community, increasing its ability to manage extreme climatic events.
- **Suzak** shows the highest exposure to climate-related stressors and vulnerability to natural hazards (landslides and mudslides). Communities still rely on social safety nets, and when necessary, on migration. Training and education are also considered relevant tools to increase resilience.
- **Uzgen** is the least resilient district. The average household's climate sensitivity is the highest, with a high level of exposure and vulnerability. The district is subject to frequent landslides and floods. The great majority of households are livestock keepers (64 percent), and services are lacking – public assistance is insufficient, informal transfers are rare, and access to credit is still limited.

Box 3.6 highlights the key recommendations that were drawn from the above-mentioned resilience analysis.

48 For more details, see FAO (2019c).

Box 3.6.
Recommendations drawn from the analysis

Financial inclusion and access to credit
Given the limited access to credit, the study shows that households' resilience levels would benefit substantially from the introduction of new financial tools to promote green technologies. Green taxes and customs duties, green procurement practices and green investments in general represent possible options. Financial literacy also plays a substantial role, improving financial information, thus creating risk management and credit assessment skills.

Crop diversification and technology improvements
Recognized for being among the most effective tools for climate resilience, crop diversification and technology improvements are the most used for climate risk management strategies. Diversification needs to be coupled with technological improvements to increase yields, including livestock feeding efficiency, and to design and implement climate-smart solutions across sectors at the regional and sub-regional levels.

Development of green agri-food value chains
For rural and on-farm livelihoods in particular, strengthening the efficiency and inclusiveness of agri-food value chains (including for women and youth agri-entrepreneurs) represents a substantial opportunity to generate employment. These agri-food value chains can also decrease the pressure on, and degradation of, natural resources by promoting more efficient practices, thereby enhancing household resilience.

Diversification of income sources at rural level
Diversifying income sources at rural level could be a substitute form of risk management and a means of protecting households from climate change. Diversification enhances household economic stability, and this could be achieved by encouraging profit-oriented activities, and creating incentives and opportunities. In the context of the project, diversification from unproductive livestock systems also represents a way to ensure sustainability of the carbon sequestration investments (rangeland and forestry).

Livestock productivity
In the framework of climate change, promoting climate investment could help livestock farmers to increase climate adaptive capacity (especially as livestock-related livelihoods are most used by households in the area). Modernization of livestock production systems is crucial and can be achieved through improvements in animal husbandry as well as improved health services.

Agricultural wealth index
The diffusion and creation of the necessary agricultural practices and technologies could help households, especially farmers, to better adapt to extreme climatic events. Better road conditions and improved connections among isolated districts and villages can also reduce post-harvest losses.

Technical note 7 Innovative Land and Forest Monitoring Platforms and Tools

Through its global and country-level expertise, FAO supports the transfer of knowledge to countries using accessible, innovative and integrated tools, and novel learning environments which match country contexts and needs. For example, through its National Forest Monitoring Team, FAO has developed a range of innovative, modern technical tools and other technologies to assist countries in their efforts to measure, monitor and report on their forests, land use status and changes.[49]

These modern tools, particularly Open Foris (2019a)[50] and SEPAL (2019),[51] can enable the fast development of operational National Forest Monitoring Systems (NFMS) and their related capacities for Measurement, Reporting and Verification (MRV) of forest-related emissions and emissions reductions to serve as part of domestic and international reporting and decision-making needs. Countries are increasingly using these tools to set the baseline of their forest cover, land-use and related GHG emissions in order to demonstrate results on reducing emissions from deforestation and forest degradation and enhancement of carbon stocks (REDD+) as well as contributions to the achievement of the Paris Agreement, thereby fulfilling requirements to unlock related climate finance and investments.

Open Foris initiative, SEPAL, Collect Earth Online and upcoming Shiny tools

FAO has developed innovative solutions for forest and land monitoring under the Open Foris initiative (2019b) over the last 10 years, in collaboration with over 70 countries and partners. With over 20 000 installations, the initiative has already catalysed significant progress in the measurement and monitoring of forests. Open Foris has played a critical role in efforts to combat deforestation, lowering costs, removing barriers, and improving forest monitoring for many national governments, as for example in Ethiopia, Viet Nam and Peru. Open Foris tools are also applied in collecting environmental and agricultural information, as well as agricultural applications, such as dairy industry data collection in Kazakhstan, and animal production by pastoral communities in Chad and Mongolia.

With over 3 000 active users, SEPAL is one of the Open Foris suite tools, developed in collaboration with many institutions, including Google, NASA, universities and governments. SEPAL offers anyone, anywhere unparalleled access to satellite data and supercomputing power from their computer or mobile phone with modules for near-real time land cover disturbance, forest restoration monitoring, peatland monitoring, and forest degradation monitoring.

Collect Earth Online (CEO) is another solution, developed in collaboration with NASA, which provides a crowdsourcing feature that can change how we

49 Technical note 7 by J. Fox, L. Vesa, Y. Finegold and M. Koshoev (FAO).

50 See: http://www.openforis.org/

51 See the Open Foris and SEPAL FAO digital service flyer at www.fao.org/3/CA1085EN/ca1085en.pdf

collect data about the Earth. CEO is the streamlined online implementation of Collect Earth, eliminating the need for desktop computer requirements and installations. It allows multiple users to simultaneously collect sample-based data using high-resolution satellite images. CEO is suitable for a broad spectrum of applications, including landscape change and land cover monitoring, and deforestation studies (Box 3.7).

SEPAL and Collect Earth Online are fully integrated, therefore all visual sample-based data, once interpreted, can be immediately leveraged for many other geospatial applications inside SEPAL. These open and scalable technical solutions can transform forest and land monitoring more broadly into transparent and accurate information on the status and trends of the Earth's biophysical land mass, which is fundamental to achieving the Paris Agreement.

Looking towards the future, in 2018, FAO started the development of a new Open Foris Online, to be called ***OF Arena,*** funded by Norway and developed in collaboration with the Forestry Department Open Foris team, the Forest Resources Assessment (FRA/FAO) team, and the Information Technology Division (CIO/FAO). The aim is to keep current OF Arena tools functional, streamlined, and simpler to use. With the help of cloud applications that will be operational in 2020, OF Arena users can get easier access to the tools, without being burdened with software installations. OF Arena will join two tools, Collect and Calc, becoming a seamless cloud-based application. During the period 2020–2021, a new version of Collect Mobile will be developed and launched. The new system will offer ready-made templates for the most common forest inventory sampling strategies to make it even easier to get started.

The OF Arena development team will also facilitate the planning and implementation of National Forest Inventories and other types of forest inventories with new Shiny applications. The first Shiny applications (running under the SEPAL Toolbox) launched in 2019 will contain tools for the following two tasks:

1. Inventory grid design (also applicable for Collect Earth surveys); and
2. Examining reliability of sampling and number of required samples with bootstrapping techniques.

The third Shiny tool to be launched in 2020 will be an application for yield and carbon balance forecasting and forest planning following the principles of the MYRLIN toolkit (Alder, 2002). This tool will facilitate actions towards sustainable forest management (SFM). MYRLIN was applied in FAO-supported consultations in Tanzania in 2013, and in provincial level forest scenario planning in Zambia in 2016. The new Shiny application will update and revamp features of the MYRLIN toolkit.

SEPAL in use: making forest information faster and easier in Ethiopia

As changing land use is an important driver of deforestation, monitoring and predicting these changes is critical to understanding and halting negative changes, including deforestation and forest degradation. SEPAL has been used to generate data in Ethiopia, as well as in other countries such as Cambodia, the Democratic Republic of Congo, Ecuador and Zambia.

In Ethiopia, SEPAL was used to support REDD+ reporting requirements and became an integral part of the MRV national and regional operations. Eliminating the necessity for computer processing power and memory, satellite imagery is processed in the cloud to create analysis-ready data that is used for land cover and land cover change mapping. Wall-to-wall maps of

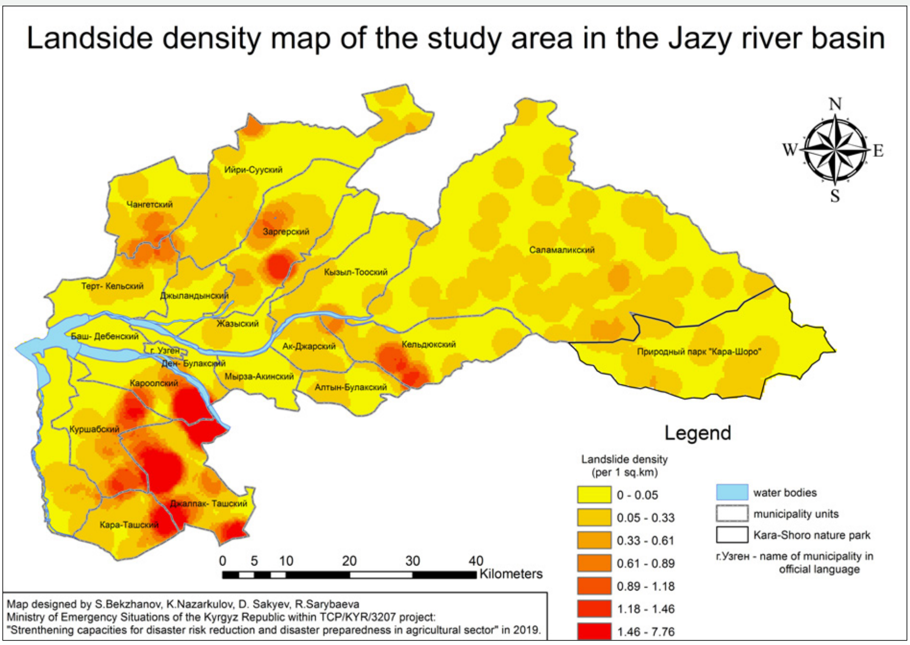
Box 3.7.
Geo-hazard mapping with Collect Earth in Kyrgyzstan

FAO has been providing support to the Ministry of Emergency Situations of the Kyrgyz Republic to strengthen evidence-based disaster risk reduction and climate change adaptation in the agricultural sector, according to the priorities of the national plan on disaster risk reduction and civil protection for 2018–2030. One of the project initiatives was the geo-referencing and identification of geo-hazards using Collect Earth tools, developed by FAO.

With these tools, the knowledge, skills and experience of local experts can be integrated with the latest advances in Earth Observation and internet technologies. So far, the government geo-hazard monitoring and forecasting agencies have been regularly monitoring less than 5% of the country's territory, essentially excluding agricultural lands and forest areas. Updating information on the types, location and characteristics of geo-hazards can hardly be overestimated in light of the susceptibility of agricultural lands to geo-hazards, the impacts of climate change, and the national SDG and NDC targets. Landslides, which represent the deadliest and most devastating geo-hazards, are widespread in Kyrgyzstan; therefore, they require priority mapping.

In 2019, a group of experts from Kyrgyzstan were trained by FAO in the use of the geo-hazard mapping module, attached to the Collect Earth tool. The Collect Earth geo-hazard mapping module allows users to (1) identify a geo-hazard location and its type, (2) assess the associated danger level based on such indicators, such as the relative age of the geo-hazard and its elements (origin, transit, accumulation zones), and (3) determine the distance to the nearest infrastructure object/agricultural land.

Over the course of three months, a group of trained experts collected and analysed information in 392 000 points/plots. As a result, maps of the distribution of all identified geo-hazards (18 types in total), with a twofold increase in accuracy, were created for the entire territory of the pilot Uzgen district. One of these maps showing the national landslide distribution density is shown in the map below. The results were presented at a regional seminar on land degradation issues for Central Asian countries and Turkey in Ankara, in September 2019.



SOURCE: Map designed by S. Bekzhanov, K. Nazarkulov, D. Sakyev, R. Sarybaeva Ministry of Emergency Situations of the Kyrgz Republic within TCP/KYR/3207 project: "Strengthening capacities for disaster risk reduction and disaster preparedness in agricultural sector" in 2019.

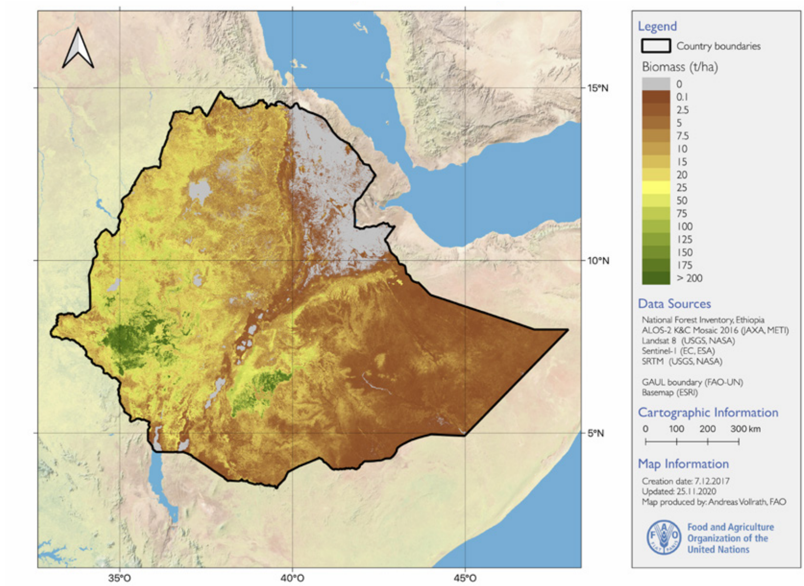


Figure 3.17
Biomass map of Ethiopia using Sentinel-1, Sentinel-2 and Landsat 8 imagery

SOURCE: Created by Andreas Vollrath, FAO, 03.12.2020.

tree forest biomass were created combining data collected through the national forest inventory and multi-sensor satellite imagery, including the European Space Agency's Sentinel-1 radar data and Sentinel-2 optical data, and NASA's Landsat 8 optical data. The satellite data needed to generate these maps can be accessed through a few clicks in the SEPAL interface, which produces time series analysis of Sentinel-1 imagery (Figure 3.17), and Landsat and Sentinel-2 mosaics.

SEPAL can be used in combination with other technologies for forest degradation assessment. Assessing forest degradation depends on better and more cost-effective technologies to allow for more consistent measuring and monitoring of emissions from this activity. A pilot study was carried out in collaboration with Wageningen University to test time series analysis and field data collection to monitor small-scale changes in remaining forests using BLAST (a data driven approach). Data can enable problem recognition, and once a problem is recognized, possible solutions can be identified, and targets can be set. The maps generated through this technology can inform national forest management plans, identify geographical areas of attention and be instrumental inputs for the preparation of national strategies, for example, to reduce emissions from deforestation and forest degradation, or in the prioritization of rural and public sector investments.

Sector note 1 Integrating climate change in fisheries and aquaculture projects

This section[52] discusses the main principles of the design and implementation of climate adaptation projects in fisheries and aquaculture. Adaptation tools and methods are suggested to advance the analysis of adaptation options.

Recommended adaptation responses in the fisheries and aquaculture sector can be grouped into three categories: (i) institutional and management; (ii) livelihood adaptation; and (iii) risk reduction and management for improved resilience.

Improving the current management of wild fish stocks, habitats and ecosystems and water resources will ensure better climate change preparedness and adaptation.

Introduction

Fisheries and aquaculture play an important role in food security and livelihoods for millions of people. FAO (2019d) reports that total fisheries and aquaculture production reached a record 173 million tonnes in 2017, with aquaculture representing 46 percent of the total. According to The State of World Fisheries and Aquaculture 2018 (FAO, 2018b), the total first sale value of fisheries and aquaculture production in 2016 was estimated at USD 362 billion, with both sectors combined supporting the livelihoods of between 10 percent and 12 percent of the world's population. About half of the global fish catches come from small-scale fisheries – a sector that employs more than 90 percent of the world's capture fishers and fish workers, about half of whom are women.

The effects of climate change on marine and inland fisheries and aquaculture are of particular concern, considering the dependency of countries on fish and fishery resources. Climate change not only affects aquatic systems, habitat and ecosystems, but it also has far-reaching, direct and indirect impacts on livelihoods, fisheries and aquaculture infrastructure, as well as demographics – e.g. changes in human density in coastal areas (see Figure 3.18).

The impacts of climate change on the growing aquaculture sector are likely to be felt most in developing countries, as climate change may result in unfavourable changes that could lead to suboptimal farming conditions and other perturbations, thus decreasing productivity.

The following section provides important insights into the main challenges of addressing climate change in fisheries and aquaculture. The focus is on existing adaptation and mitigation guidelines and toolboxes, with selected

52 By D. FernandezReguera, F. Poulain, S. FungeSmith, I. Monnereau, L. Dabbadie, G. Mair, F. Marttin, J. Valbo-Jørgensen, T. Bahri and M. Barange (FAO).

case studies in both fisheries – including marine and inland fisheries – and aquaculture.

Addressing climate change in fisheries and aquaculture

Climate change adaptation measures should emphasize the need to reduce poverty, strengthen resilience and increase food security in accordance with the Paris Agreement, the United Nations 2030 Agenda for Sustainable Development, and other guidelines and frameworks. In this context, specific measures should be contemplated in national adaptation plans – as part of a climate change adaptation strategy – to reduce poverty levels and to provide food security for coastal communities.

One particular characteristic of fisheries management is the need to address uncertainty, as information on the status of fishery resources (both inland and marine) is often highly fragmented. Climate change is expected to introduce additional sources of uncertainty; thus, it is crucial to incorporate uncertainty into management plans, and to communicate and explain to all stakeholders its potential impacts to avoid or minimize mistrust.

It is also important to emphasize that the cost of no-adaptation or maladaptation can be very high in both aquaculture and fisheries. A significant number of wild fish stocks are fished above safe biological limits and potential increased stress on these stocks or maladaptation to changes in stock distribution or productivity can jeopardize future yields and socioeconomic benefits from fisheries. An example is the allocation of erroneous catch quotas in places where stocks are increasing/decreasing, or the change of vessels/gear specific for stocks that are being displaced.

Adaptation in fisheries and aquaculture sectors is gradually evolving from being primarily reactive to becoming a planning and proactive endeavour. Adaptation should be understood as a continuous, flexible and iterative process that incorporates feedback from past experiences and intends to anticipate and reduce future risks. In this context, it is useful to determine early low- or no-regrets options while carefully planning and performing required analysis for long-term adaptation interventions.

According to Poulain, Himes-Cornell and Shelton (2018), both the design and implementation of adaptation projects in these sectors require a number of iterative steps:

1. Scoping and objective setting
2. Climate risk and vulnerability assessment
3. Development of climate adaptation responses
4. Implementation, monitoring and evaluation.

1 Scoping and objective setting

This first phase requires an understanding of the ecological functioning as well as the socioeconomic and institutional contexts of a given fishery or aquaculture system. If possible, this phase should be complemented by a risk analysis, which in turn requires the identification of hazards, exposure and an assessment of vulnerability. In addition, the activity or project should have a clear time frame (immediate actions, long-term policy, etc.), and an identification of the main stakeholders affected by the project. It is also important to identify the main interactions with other sectors, both as additional drivers, and as options for the diversification of activities where fishing or aquaculture activities are reduced. Uncertainty should be incorporated into the project design to facilitate the analysis in subsequent steps.

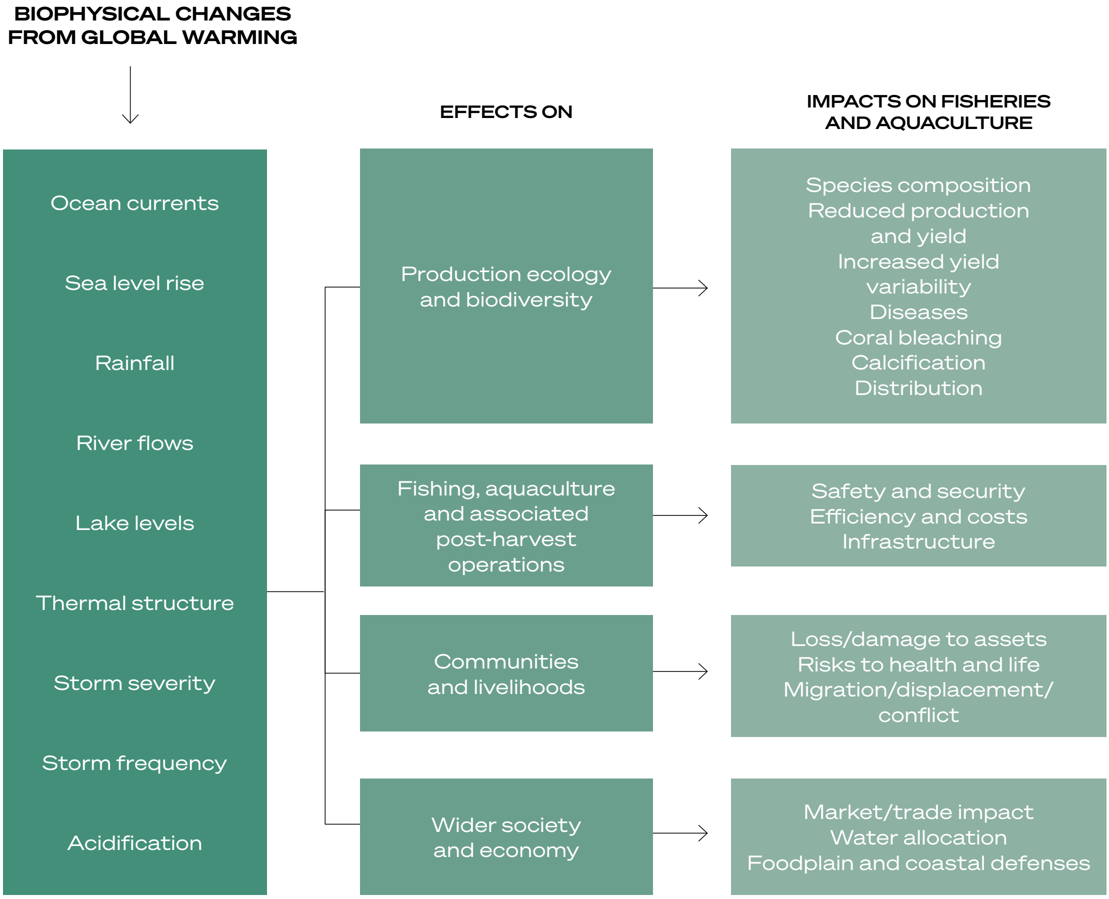


Figure 3.18.
Climate variability and change impact pathways in fisheries and aquaculture

SOURCE: Poulain, Himes-Cornell and Shelton, 2018. Adapted from Badjeck *et al.*, 2010.

Finally, it is crucial to take into account any potential barriers or difficulties to adaptation in order to ensure that final proposals emanating from the project are not only technically adequate, but also feasible to implement.

2 Climate risk and vulnerability assessment

Although vulnerability assessment is a crucial part of any project or initiative to plan for an adaptation strategy, its application in the fishery and aquaculture sectors is relatively new. In general, all vulnerability assessments involve the following steps:

1. identify current pressures and hazards;
2. predict, either qualitatively or quantitatively and with the help of models, future climate change impacts on any of the main components of fisheries or aquaculture systems; and
3. estimate the overall vulnerability of the sector, taking climate risks into account along with other potentially related risks, such as poverty or food security.

Cheung, Bruggeman, and Butenschön (2018) describe several modelling options to predict the impacts of climate change on catch potential in the world´s various exclusive economic zones (EEZs). Also using a modelling approach, Allison *et al*. (2009) applied a range of indicators to rank nations in terms of vulnerability of livelihoods dependent on capture fisheries to climate change; Handisyde *et al*. (2017) used geographic information systems (GIS) to represent a combination of qualitative and quantitative data on aquaculture at global scale. This approach was further developed to represent sensitivity, exposure and adaptive capacity, and provide an indicator of vulnerability.

For inland fisheries, Harrod *et al*. (2018a) analysed predicted changes in temperature and precipitation by river basins, and in combination with other stressors (including population growth, demand for fresh water from other sectors, and the construction of dams); they studied the potential future impacts on the sector for a total of 149 countries.

All of these examples use different modelling approaches to (a) simulate future effects under different climate scenarios, and (b) predict the potential impact on the fisheries and aquaculture sectors. The outcomes show important regional differences in the vulnerability of the fisheries and aquaculture sectors. They also highlight uncertainties and identify areas where improvements can be made:

- incorporating new knowledge on climate change effects;
- introducing potential effects along the value chain of fisheries and aquaculture products; and
- improving the predictive power of the analysis.

For inland fisheries and aquaculture, the interaction with other sectors is considered of particular relevance, and is therefore a crucial part of the assessment.

At regional scale, Barange *et al.* (2018) provide examples of the assessment of vulnerability of capture fisheries in up to 13 world regions, showing a range of approaches that depend on existing information as well as on the particular characteristics of each region's fisheries sector. Regional examples are also available for inland fisheries and aquaculture, where assessments tend to be done at national or watershed level.

Few comprehensive vulnerability studies have been carried out at national level; and only a few countries include fisheries and aquaculture in their Nationally Determined Contributions (NDCs). National assessments are often based on scaled down versions of Earth system models, capable of predicting major changes in national climate (e.g. in average ocean surface temperatures, precipitation), depending on the different IPCC scenarios assumed. On the basis of these predicted climate changes, an analysis of the effects on fisheries and aquaculture sectors is done, either using fish population models (mainly for capture fisheries), or analysis of suitable areas for aquaculture, coupled with a variety of other indicators, such as food consumption and market prices.

In addition to other countries in Latin America, the vulnerability of the aquaculture sector in Chile was assessed using models adapted from Allison *et al.* (2009) and contrasting IPCC scenarios. Exposure was estimated from simulations at different temporal periods, taking temperature or precipitation forecasts into account. The exposure estimation was in turn used to identify the main sectors (e.g. salmon or scallop farming) that are expected to be affected by climate change.

Of the three components of the vulnerability assessments, exposure at the local level is very difficult to establish due to the lack of high resolution models to understand local risks. In these cases, proxies such as knowledge of past extreme events as well as methods and tools that incorporate people's knowledge and involve their close participation (Soto *et al*., 2018) are often used. For example, for aquaculture, several adaptation options exist, but the challenge is to provide stakeholders or farmers with fine-grained vulnerability assessments to make better mitigation and adaptation decisions.

For inland fisheries, detailed studies are often carried out at watershed level, especially for areas of particular relevance due to their contribution in terms of volume of catches or socioeconomic outcomes, as well as areas where particular threats have been previously identified. Harrod *et al.* (2018b) provide examples of vulnerability and risk assessments in areas such as the Yangtze and Ganges river, where the importance of integrating potential anthropogenic threats other than climate change are emphasized. In both these examples, climate change is expected to be an additional stressor to systems that are already under stress because of deforestation, increasing modification of river floodplain habitats, economic and agricultural development, and more. Despite some uncertainty in the predictions of the effects of these combined stresses, in most cases the potential combined impact is expected to be large.

Results of existing projects highlight the regional and sometimes local differences in vulnerability: (1) emphasizing the need for dedicated vulnerability projects to help countries address adaptation; and (2) underscoring that vulnerability assessments must be set up as a regular and continuous process to identify priorities and allocate resources for adaptation.

3 Development of climate adaptation responses

Institutional adaptation

Many adaptations are responses to climate change impacts at the local level and are part of initiatives on mainstreaming climate change in fisheries and aquaculture planning and management. Some focus on vulnerability and risk assessment and include aspects of capacity building for local or national fisheries and aquaculture managers or individual communities of farmers and fishers. In addition, they recommend investment in research programmes and coordination between fisheries and research institutions to assist decision-makers in the timely implementation of adaptive measures.

There is growing recognition that climate change impacts will be much worse in fisheries that are not well managed; this underlines the need to improve fisheries management and to facilitate adaptation. An example of improved management increasing adaptation capability is the vessel day scheme (VDS), which is a sub-regional agreement between eight island countries of the Pacific. Using the VDS, countries conjointly approve to sell access to their waters at a mutually agreed price to distant water fishing fleets. This also covers and indirectly sets limits to the catch of fish over a large area, which favours the sustainability of their fisheries, thus countries are more able to respond to the natural variability of stock size and location (PNA Office, 2014). Other adaptive management measures provide benefits in the long term, such as mangrove planting for nursery habitat, shoreline protection, and carbon sequestration. The institutional adaptation often includes measures to improve information and knowledge generation, which inform policy, legislation and strategic interventions, and capacity building to plan and implement actions at local levels (Box 3.8).

Box 3.8.
Institutional adaptation actions in Inland fisheries in Malawi

Malawi is a landlocked country in southeast Africa. The fisheries sector is of great importance to its economy as a source of employment, food, rural income, export, import and biodiversity. Nationally, the fisheries sector directly employs nearly 60 000 fishers and indirectly over 500 000 people who are involved in fish processing, fish marketing, boat building and engine repair. Furthermore, nearly 1.6 million people in lakeside communities derive their livelihoods from the fishing industry.

Climate change is modifying the distribution of freshwater species. In general, warm- and cold-water species are being displaced and they are experiencing changes in the size and productivity of their habitats. Temperature changes also affect fish physiological processes, resulting in both positive and negative effects on fisheries and aquaculture. Seasonality of particular biological processes such as reproduction, food webs, diseases and invasiveness of species are affected.

The waters of Lake Malawi and Lake Malombe are heavily overfished and the over-exploited fisheries resources may not be able to cope with these additional impacts. The Government of Malawi aims to build resilience in the beleaguered fisheries sector through institutional climate change adaptation measures supported by the GEF.

This includes:

- Improving access to and use of information and knowledge regarding climate change and its implications in order to ensure a sound technical basis for policy work and field level activities;
- Introducing community-based management and governance of capture fisheries in Lake Malawi and Lake Malombe to improve the resilience of local fishing communities (beach village committees and district fishery management units);
- Strengthening capacities of fisheries professionals and other relevant stakeholders in the understanding of climate-related problems and options for addressing them;
- Mainstreaming of climate resilience into key policy and planning instruments of relevance to fisheries and fishing communities in order to create effective enabling policies, plans, and regulatory instruments to improve climate resilience among fishing communities;
- Promoting local level planning using the ecosystem approach for fisheries and the restoration of fish stocks through effective management, reduction of illegal gear and restoration of critical breeding habitats.

SOURCE: Adapted from Government of Malawi. 2012. *National Fisheries Policy 2012-2017,* Second Edition.

Livelihood adaptation

A common adaptation strategy is livelihood diversification, including diversification within the sector (e.g. changing the production or the post-catch processing and preserving systems), or outside the sector (e.g. shifting from fishing to terrestrial livelihood activities).

Adaptation strategies that support poverty reduction and increase food security are encouraged. When fisheries resources are overexploited, an initial reduction of catches may be needed. In such cases, diversification of activities, changes in the resources targeted, or improvement of the value chain can provide measures to alleviate poverty while allowing for resources to recover. Training and education, as well as close cooperation with stakeholders and administrations are often needed for the effective implementation of such measures.

In Small Island Developing States (SIDS), adaptation tools called fish aggregating devices (FADs) are often used. These devices facilitate access to pelagic species, including in coastal areas, and could in some cases reduce the pressure on inshore and coral reef habitats while allowing fishers to maintain a certain level of catches. Although FADs require appropriate management, training and monitoring, they can contribute to food security and sustainable, income-generating activities (CRFM, 2015).

As climate change will transversally affect all areas, particular attention should be paid to formulating adaptation strategies when changing sectors. For example, when catches declined as a result of the increasing frequency and intensity of cyclones in Madagascar (IRG, 2008), fishers switched partially or completely to farming livelihoods. However, agriculture and aquaculture (dominated by small-scale integrated rice-fish farming) in the area is also highly vulnerable to climate change due to erratic rainfall, floods, droughts, temperature changes and cyclones, all of which could compromise livelihoods and food security in the long term (IRG, 2008). Different types of farming methods, such as those integrating agriculture, aquaculture and livestock production, represent an option for increasing climate resilience (Box 3.9).

Risk reduction and management for resilience

In addition to the examples provided above, adaptation should also include tools to reduce the exposure and sensitivity to climate change risks, such as extreme events (storms, floods, and droughts) and related risks such as harmful algae blooms (HABs).

Data and information used to reduce exposure to extreme events can come from public research programmes, such as ClimaPesca[53] in Central America, ClimeFish[54] in Europe, or private companies offering commercial fishing forecasts. Moreover, early warning systems are used in aquaculture to reduce exposure. For example, an early warning system connecting researchers, fisheries organizations and policymakers was recommended in the Taiwan province of China to address the high mortality of cage aquaculture due to extreme cold events (Chang *et al*., 2013). Insurance provisions, co-financed by governments and relevant stakeholders, can be important tools to help fishers and farmers affected by extreme events. For example, government social protection tools in Viet Nam include insurance to help farmers cope with and recover from natural disasters and fish disease outbreaks (FAO, 2016b).

Other aspects of risk reduction, and in particular safety at sea, can be improved through investments in vessel stability, safety equipment and training. For example, in the Caribbean, fishers are provided with safety gear and GPS devices and trained in their proper use to reduce risks at sea due to extreme events (Box 3.10).

Adaptation tools and methods

Adaptation tools and methods can advance the analysis of adaptation. Figure 3.21 provides an example, illustrating how recommended adaptations have been grouped into three main non-mutually exclusive categories in the fisheries and aquaculture sector: 1) institutional and management; 2) livelihood adaptation; and 3) risk reduction and management.

Adaptation tools and approaches differ between capture fisheries and aquaculture. In Annex F, there are two toolboxes with examples of tools and methods that can be implemented in capture fisheries and aquaculture. In general, capture fisheries is more vulnerable to climate-related environmental

53 http://climapesca.org
54 http://climefish.eu

Box 3.9.
Agroecological fish farming in rural Guinea

Guinea is a country located along the west coast of the African continent. Twenty-six percent of the Guinean population experiences chronic malnutrition, and fish is an important source of food security, nutrition and livelihoods.

Climate projections for the country include a temperature increase of 1.1°C to 3.0°C by 2060, along with increased variability of rainfall and occurrence of droughts. The expected climate impacts include reduced availability of surface water, an increased demand for irrigation, food shortages, loss of ecological services, among others. The rural areas are also particularly vulnerable because 97 percent of cultivation is rainfed and thus highly exposed to changes in climate (IRG, 2008).

In order to deal with the local consequences of climate change, the Guinean government promotes agroecological fish farming projects. These projects build large water reservoirs at the head of unused valleys and dams with water outlet systems across the valley. The reservoirs are stocked with a polyculture combination of Nile Tilapia, African bonytongue, catfish and banded jewelfish (a carnivore to remove unwanted species and control recruitment). Over the years, the system has been refined by introducing floating rice culture inside the dam-ponds and by integrating animal farming, mostly swine (Figure 3.19).

This is a very basic extensive system, but it has proved to be very successful among farmers; the main benefits are as follows:

- The large water surface and effective polyculture allow for a significant volume of fish production.
- The rice and fish integration allows for synergies and improves the use of land and water.
- The fertile pond water can also be used to irrigate nearby crops.
- The pigs contribute to the recycling of farming and household by-products by producing an organic fertilizer.
- The resulting income is high, the additional work burden is limited.
- The reservoir also stores water in the surrounding water table, improving resilience to seasonal drought.

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Figure 3.19.
Fishermen working at a pond used to farm fish for personal consumption and for market use.

The image shows the dam dyke with a monk (outlet system) on the right, the dam pond with floating rice in the back and a multipurpose pond with pig stall at the front.

Table 3.10.
Examples of online tools for adaptation planning and implementation

UK Climate Impacts Programme Adaptation Wizard:	**www.ukcip.org.uk/wizard/**
CSIRO's Climate Adaptation Flagship best practices for engaging with stakeholders:	https://research.csiro.au/climate/wp-content/uploads/sites/54/2016/03/3_CAF_WorkingPaper03_pdf-Standard.pdf
Stockholm Environment Institute (SEI) – Climate change adaptation toolkit and user guide: a comprehensive guide to planning for climate change adaptation in three steps:	https://static1.squarespace.com/static/52045752e4b0330b6437dade/t/52dcdf39e4b032209173914d/1390206777083/UserGuide.pdf
EcoAdapt Climate Adaptation Knowledge Exchange:	www.cakex.org/
European Union's project ECONADAPT Toolbox provides easily accessible information on the economic assessment of adaptation:	http://econadapt-toolbox.eu/
Swiss Re Economics of climate adaptation:	https://www.swissre.com/our-business/public-sector-solutions/thought-leadership/economics-of-climate-adaptation.html

SOURCE: Poulain, Himes-Cornell and Shelton, 2018.

Table 3.11.
Example guidebooks and toolkits to guide the evaluation of adaptation in the fisheries and aquaculture sector

ADAPTME	www.ukcip.org.uk/wp-content/PDFs/UKCIP-AdaptME.pdf
DEFRA	Measuring adaptation to climate change – a proposed approach: http://webarchive.nationalarchives.gov.uk/20130403054913/http://archive.defra.gov.uk/environment/climate/documents/100219-measuring-adapt.pdf
CLIMAR	Evaluation of climate change impacts and adaptation responses for marine activities: www.belspo.be/belspo/fedra/proj.asp?l=en&COD=SD/NS/01A
USAID	Adapting to coastal climate change – a guidebook for development planners: www.crc.uri.edu/download/CoastalAdaptationGuide.pdf

SOURCE: Poulain, Himes-Cornell and Shelton, 2018.

Box 3.10.
Managing climate-related risks: Improving safety at sea of Caribbean Fishers

The seven countries participating in the Climate Change Adaptation in the Eastern Caribbean Fisheries Sector (CC4FISH) project in the Eastern Caribbean – Antigua and Barbuda, Dominica, Grenada, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, and Trinidad and Tobago – are highly dependent on the fisheries sector for food security, livelihoods and household income. The fisheries sector in these countries supports the socioeconomic viability of coastal communities by providing direct employment and benefits to over 15 000 fishers and their dependents. The sector also provides employment in seafood processing (especially for women) and ancillary services (e.g. boat building and repair).

Climate change stressors, such as sea level rise and increased frequency of severe hurricanes in the region, will continue to have significant negative impacts on the safety of fishers, fisheries infrastructure, boats and fishing equipment, and coastal fishing communities.

At the local level, the safety at sea for fishers is often compromised. Fishers have often only received limited training in safety-at-sea; have limited safety-at-sea equipment on board; have limited knowledge in the use of safety-at-sea equipment (e.g. flares); and have limited understanding of ICT devices that can support safety at sea – Very High Frequency (VHF) radio, Global Positioning System (GPS) and cell phones.

Under the CC4FISH project a number of activities are being carried out at various levels. With regard to improved safety at sea, the project supports the following activities to build climate resilience in the fisheries sector:

- Increased number of fishers are receiving safety at sea training. This relates to navigation skills and seamanship, safety-at sea training, ICT components, etc.;
- Training in the use of ICT devices that can support safety at sea: Very High Frequency (VHF) radio;
- Global Positioning System (GPS) and cell phones at various levels of ICT literacy amongst fisherfolk;
- Development of easy-to-read safety-at-sea manual for fisherfolk in the Caribbean;
- Strengthened capacities of fisheries professionals and other relevant stakeholders in the improved standardized safety-at-sea training materials;
- Provision of safety-at-sea equipment such as VHF radios and repeater systems; and
- Third party vessel insurance assessment in Trinidad and Tobago, Dominica, Saint Lucia, and Saint Kitts and Nevis in order to improve access to insurance for fisherfolk.

Figure 3.20.
Fishers training with VHF in Grenada and Dominica.

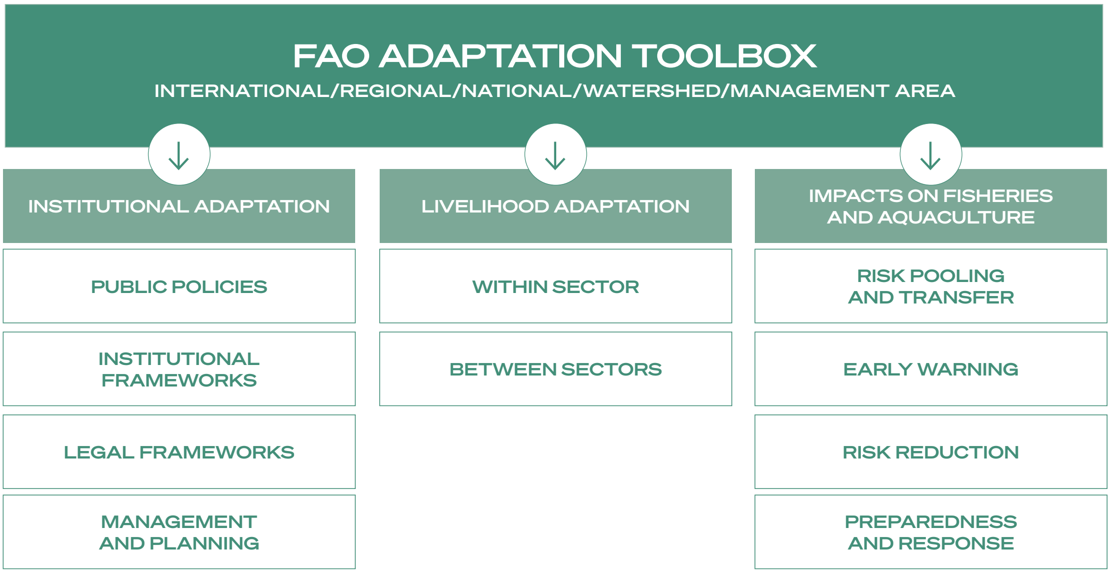


Figure 3.21
Categories of adaptation actions extracted from existing case studies

SOURCE: Poulain, Himes-Cornell and Shelton, 2018.

changes, while in aquaculture, some of these changes can be controlled or moderated. Table 3.10 provides examples of online adaptation tools and publications that can be used for adaptation planning in capture fisheries and aquaculture.

4 Implementation, monitoring and evaluation

Early low- or no-regrets measures that are feasible and agreed with stakeholders, and are easy to implement, should be initiated as soon as possible in the process of adaptation; other responsive measures identified through the steps above can be introduced more gradually. The evaluation of the effectiveness of the adaptation measure is very important in iterative processes, and it helps to improve current and future adaptations. Table 3.11 provides examples of guidelines and toolkits that can be used for the evaluation of adaptation in the fisheries and aquaculture sector.

Current adaptation projects in fisheries and aquaculture in developing countries are mainly framed as development projects, rather than climate-related investment projects. Among the existing projects, some focus on improving current understanding and providing a comprehensive vulnerability assessment, while others address adaptation directly based on existing knowledge. Cases of maladaptation have already been observed, where inaction or inadequate actions lead to increased risk of adverse climate-related outcomes, increased vulnerability to climate change or diminished welfare, now or in the future.

Conclusions

Climate change affects communities that rely on fisheries and aquaculture for their livelihoods. Small-scale fishers and small-scale aquaculture are particularly vulnerable, as they are more exposed to impacts, including extreme weather events and natural hazards. Adaptation strategies benefit from incorporating stakeholder participation, traditional knowledge and gender considerations into design and planning.

Interactions with other sectors that are also affected by climate change should be considered when designing and implementing adaptation responses. For example, inland fisheries are affected by policies and actions related to freshwater use in different sectors. Furthermore, coastal areas are subject to changes in freshwater runoff, agricultural intensification, growth in the industrial and energy sector, urbanization and transport, and the development of tourism. Aquaculture is also affected by policies regarding land and water uses, aquatic and terrestrially derived feeds, and the use of coastal space. Improving the current management of wild fish stocks, habitats and ecosystems and water resources will make both fisheries resources and fishers more resilient to climate change impacts, thus protecting livelihoods and the natural resources people depend on.

Sector note 2 Climate-smart crop production practices: case studies in Zambia, Sri Lanka and Angola

Agroecology and Conservation Agriculture represent climate-smart agronomic practices that can be adapted by farmers to improve their climate resilience.

Adopting these climate-smart crop production approaches requires an improved understanding of the climate risks that farmers are facing as well as the identification and prioritization of actions based on research, best practice experiences, and extensive farmer participation.

This section[55] discusses a four-step approach applied to the implementation of Conservation Agriculture interventions in Zambia and Sri Lanka. The case study in Angola discusses the implementation of agroecological solutions through farmer field schools (FFS).

Climate change has severe negative impacts on livelihoods and food systems worldwide. This is why best practices in climate change mitigation and adaptation are essential to ensuring food and nutrition security as well as improved livelihoods. Climate-smart crop production practices and technologies play an important role in addressing the impacts of climate change.

Producing food in a climate-smart way is possible for any farmer, including resource constrained smallholder farmers. Rather than adopting a one-size-fits-all solution, a range of proven agronomic practices can be adapted to address the needs and resource endowments of farmers to help them cope with climate change. Critical among such practices, are the following:

- using quality seeds and planting materials of

55 Case Study 1 (Zambia) was prepared by F. Beed, S. Corsi, M. Fujisawa, S. Kelly, J. Kienzle, M. Kokwe, M. Malik, A. Scognamillo, N. Sitko, M. Taguchi (FAO); P. Hamazakaza, N. Mutwale (ZARI); S. Scott (Grassroots Trust). Case Study 2 (Sri Lanka) - by S. Bandara (HARTI); F. Beed, S. Corsi, H. Kanamaru, J. Kienzle, M. Malik, J. Ni, C. Rizzo, A. Scognamillo, R. Vuolo (FAO); S. Hewage (HARTI). Case Study 3 (Angola) - by T. Basterrechea, A. Bicksler, and F. Escobar (FAO).

well-adapted varieties;
- growing a diversity of crop species and varieties in associations and/or rotations;
- adopting integrated pest management practices;
- implementing Conservation Agriculture and adopting sustainable mechanization to maintain healthy soils and manage water efficiently; and
- applying agroecological practices.

The adoption of climate-smart crop production practices and technologies requires: (a) knowledge of the type and extent of change in the climatic variables that affect crop production, (b) integrated research on crop, soil and water, and (c) the participation of farmers through system-wide activities to develop capacities.

Conservation Agriculture
Practices such as Conservation Agriculture can increase the productivity of land and water and mitigate the impacts of climate change, as well as its causes, through an optimal level of soil carbon stocks. Soil organic carbon improves soil and water productivity for climate change adaptation and reduces the release of greenhouse gases for climate change mitigation. In particular, Conservation Agriculture maintains healthy soils and manages water efficiently through the use of direct seeding, the maintenance of crop residues on the field, and the diversification of the crop system, growing adapted crops and varieties as crop mixes, intercrops and in rotations.

Conservation Agriculture, alongside sustainable crop systems (FAO, 2011), provides communities with the following benefits:
- sustainable mechanization for soil and water conservation;
- leguminous cover crops for weed control, building soil fertility, producing food and livestock fodder;
- quality seeds adapted to climate and pests; and
- precise fertilizer application and combined use of inorganic fertilizer and organic manures.

The combination of these practices is the cornerstone of climate-smart crop production. Although these practices have proven to be effective, they still require local promotion and piloting. Farmers need to be trained on how and why to use these practices, and they require incentives to adopt them. At the same time, governments need support in formulating policies that provide these incentives. Linking sustainable production practices to markets is a strategic way of creating traction for agronomic practices that are conducive to viable farm management systems and climate-smart stewardship of the environment.

The following four steps show how to develop crop systems that are best adapted to climate and markets:
- **Step 1: Assess climate risks**
  Advising farmers about what crop varieties to use in different locations and when to plant them requires a good understanding of the climate and whether new climate patterns have replaced old ones.
- **Step 2: Understand beneficiaries' needs**
  The prioritization of evidence-based actions requires a solid understanding of farmers' socio-economic and environmental constraints as well as how they can manage change. Understanding the key

factors that influence decision-making about the use and adoption of new practices and technologies at the farm level helps policymakers to develop targeted incentive mechanisms and the private sector to tailor their services to farmers' needs.

- **Step 3: Target agronomic solutions**
  In general, FAO promotes a form of crop production that does not rely on agrochemicals; rather, it encourages the use of cover crops instead of herbicides and fertilizers to achieve greater productivity and efficiency (FAO, 2011).

Specific agronomic solutions are devised based on: (a) the information obtained in step 1 and step 2, and (b) the availability of quality, locally adapted seeds for cover crops and main crop varieties. Weed management solutions for field crops need to take into account access to labour and mechanization. Plant nutrition is another important consideration that needs to be addressed according to soil characteristics, farmers' access to amendments, and the use of organic and inorganic fertilizer. With regard to paddy rice, agronomic solutions to reduce water withdrawal and control weeds require investments in developing knowledge of non-continuous water regimes, such as alternate wetting and drying, and access to improved technologies for transplanting (Aheyaar, 2012; Amarasingha *et al.* 2015; Somaweera, 2016; Weerakoon *et al.*, 2010).

- **Step 4: Scaling up**
  Farmers need to be able to access sustainable production inputs and climate-smart technologies. Linking climate-smart production to markets creates traction for sustainable agronomic practices conducive to a viable management of the farm and a climate-smart stewardship of the environment. In this step, it is important to prevent any discrepancies in the advice that farmers receive from the project, public and private extension advisors and the agro-dealers. For the selection and use of production inputs, farmers and all stakeholders working with them (such as public and private extension advisors, agro-dealers and service providers) require appropriate training as well as a shared understanding of sustainability.

The practical application of these key steps are illustrated in the following two case studies on maize- and rice-based systems in Zambia and Sri Lanka, respectively. To demonstrate how different interventions can be combined to create synergies on the ground for efficient and effective investments, Steps 1, 2 and 3 are implemented by the FAO project "Implementing the Save and Grow approach"; Step 4 is implemented by the project "Climate-smart crop and mechanization systems scaling-up". Both are selected from the portfolio of German-funded projects and are coordinated by the FAO Plant Production and Protection Division (AGP). The third case study focuses on agroecological solutions for climate change through farmer field schools (FFS) in Angola.

CASE STUDY

A FARM SYSTEM APPROACH FOR MAIZE- AND CASSAVA-BASED SOLUTIONS IN ZAMBIA

Zambian farmers face an array of production challenges. These include limited access to crucial agronomic production inputs and technologies, such as fertilizers, sustainable mechanization, and quality seeds of varieties that are better adapted to local climatic conditions. They also have limited knowledge of sustainable crop production practices which play a key role in building resilience and adapting to climate change.

Growing conditions for smallholder maize producers can be difficult. Drought is frequent, mid-season dry spells are prolonged, and rainfall distribution is irregular. In many areas of the country, the soil is highly degraded due to poor crop production practices. However, these farmers do not all face the same constraints. Nor do they have the same exposure and vulnerability to climate impacts, access to markets, knowledge-sharing networks, or information. For example, in the high rainfall agroecological region III of Zambia, farmers are confronted with high soil acidity, nutrient leaching and limited access to (a) mechanization, (b) inorganic fertilizers, and (c) seeds of locally adapted varieties. Farmers in agroecological region II are better connected to markets, although droughts and soil degradation push them to encroach on forest areas, including protected ones.

Two areas of Zambia were the focus of the FAO project: Mumbwa (in agro-ecological region II), and Kasama (in agroecological region III). By using the four steps, project teams identified sustainable solutions for the development of climate-resilient crop systems suited to local markets, and the outcomes are summarized in the sections below.

Addressing climate risks

A climate analysis is used to develop new crop calendars by assessing vulnerable areas within the country and areas in which historical climate has changed and the growing season has shortened. To help match suitable crop varieties and planting dates for each location, the crop calendars are presented in the form of suitability maps.

Understanding beneficiaries' needs

For an evidence-based prioritization of actions, farm households have been mapped and classified in farm typologies according to the quantity and quality of nitrogen applied and removed for farming. The amount of nitrogen that farm households return relative to the amount that they extract from their fields captures the interactions between agriculture and the environment (soil fertility on farms and pollution off farms) and the influence of agricultural policy, such as subsidises for the use of fertilizers.

There are four main farm typologies in Zambia:

- **Extractive** – Farmers return less nitrogen to the soil than the nitrogen removed. Also, they rely on hand tools for crop production, as they have limited access to both private markets and government social protection programmes.

Box 3.11.
Climate-smart practices to improve yields

Climate-smart practices for the "Balanced" farm typology include (a) Conservation Agriculture to minimize drought and soil erosion, (b) planting leguminous food crops (annual and biennial) to improve soil fertility, provide fodder and help suppress weeds, and (c) planting ***Gliricidia sepium*** trees to produce additional biomass, enrich soil, and fix nitrogen.

The average maize grain yield achieved was about 3 400 kg/ha in the mechanized system, and 4 500 kg/ha in the manual one. In terms of biomass, the farmer practice produced the least (6 728 kg/ha), despite having the highest maize plant population. In terms of financial returns to input investment, the maize-climbing bean intercrop gave the highest return on investment (ROI): USD 0.32 per unit input cost. The farmer practice (chitemene without the project) had the lowest ROI: USD 0.19 per unit input cost.

This result is very important because traditionally, farmers have a strong belief that millet can only be grown in chitemene systems. In addition to producing higher finger millet grain yields, the alternative farming methods provided a number of economic and environmental benefits to farmers: environmental, forestry, and soil micro- and macro-organism conservation; and labour-saving from cutting and slashing trees from large areas under chitemene.

For "Inorganic Nitrogen Dependent" farmers, integrating food and non-food producing nitrogen fixing species maximizes the biological nitrogen fixation, and with reduced and split doses of fertilizer, it improves nitrogen use efficiency. The following intercropping systems were demonstrated:

- maize/pigeonpea ***(Cajanus cajan)/Gliricidia sepium;***
- maize/cowpea ***(Vigna unguiculata)/Gliricidia sepium;***
- maize/velvet bean ***(Mucuna pruriens)/Gliricidia sepium***; and
- maize/kabulangeti bean ***(Phaseolus vulgaris)/Gliricidia sepium.***

Farmers were also trained in the application and management of manure; planting was demonstrated using a ripper and a two-wheel direct seeder. The maize grain yield from the experimental treatments ranged from 3 700 kg/ha to 4 000 kg/ha.

SOURCE: Authors.

- **Inorganic Nitrogen Dependent** – Farmers return to the soil a quantity of nitrogen greater than the quantity removed. More than 60 percent of the nitrogen that these farmers use is from inorganic sources because they rely on input subsidies, including fertilizers.
- **Organic nitrogen dominant** – Farmers return to the soil a quantity of nitrogen greater than the quantity removed. More than 85 percent of the nitrogen they return is from organic sources as they invest less in inorganic fertilizer. They live in areas threatened by high risk of crop loss due to adverse climate events, which disincentivizes them to invest in agronomic production inputs.
- **Balanced** – Farmers return to the soil more nitrogen than farming removes, and 40 percent to 85 percent of the nitrogen used is from organic sources. Inefficient nutrient cycling, plus a lack of money to invest in amendments and fertilizers, increase dependency on traditional systems, such as "chitemene" (a slash and burn method practiced to buffer the soil pH and release nutrients), and "fundikila" (grass, *Hyparrhenia rufa,* is buried in the topsoil before burning).

At the policy level, the farm typologies enable decision-makers to develop targeted incentive mechanisms to help move smallholder farmers towards more productive and sustainable outcomes. For the private sector, they are a mechanism for service providers to aggregate the needs of their customers. At the project level, dealing with a manageable number of farm typologies facilitates the task of developing combinations of climate-smart agronomic systems.

The Government of Zambia decided to prioritize project-driven solutions for two farm typologies – “Inorganic Nitrogen Dependent” and “Balanced” – based on their high potential to do farming as a business, and their potential to improve the economic and nutritional well-being of millions of Zambians. Representative sites have been selected in Mumbwa, Kasama and Chongwe districts.

Targeting agronomic solutions

For all farmers, important adaptive management practices include using the right crop varieties to match local conditions (such as drought tolerant, low-nitrogen maize varieties). These need to be planted before the not-to-exceed planting date calculated for each location at step 1 (Vanlauwe *et al*., 2015; Chikobola and Tembo, 2018). The “Balanced” and the “Inorganic Nitrogen Dependent” farmers’ communities have been trained on the leading practices of *Save and Grow* farming – tailored to farmers’ needs by farm typology (step 2) – through on-site demo trainings, field exposure visits and field days. The gross margins analysis shows the financial benefits that have been realized with the Save and Grow practices. However, significant improvements in crop yield and soil fertility can only be expected after at least three farming seasons.

Scaling up

To improve smallholder farmers’ access to markets, rural agri-business centres (Save and Grow hubs) have been established in selected cooperatives. These centres help farmers access the agronomic inputs and mechanization services they need to implement sustainable crop production practices as well as to bulk, store and sell their produce at a better price.

Training curricula have been developed according to farm typology to build the capacity of stakeholders with regard to climate-smart crop production. Frontal training to farmers, service providers, agro-dealers and extension advisors is provided through the *Save and Grow* hubs. In addition, farmers receive hands-on training through farmer field schools and extension advisors; agro-dealers and service providers receive residential training in selected training centres.

The management of crop residue (i.e. the plant material left in the field after the harvest) is essential to climate-smart farming, and it requires a community-centred approach. Follow up actions would need to also scale up sensitization activities involving community leaders – chiefs/chief representatives, ward councillors, village committees, among others.

CASE STUDY

SRI LANKA – A LANDSCAPE APPROACH FOR RICE- AND MAIZE-BASED SOLUTIONS

The combination of heavy rains, soil tillage, and poor nutrient cycling result in soil erosion and soil fertility loss in the uplands of Sri Lanka. This reduces productivity in upland farmers' fields and causes the siltation of water reservoirs, with negative consequences for irrigation systems and water productivity in the lowlands.

This case study describes the modalities to support a transition to more sustainable smallholder farm systems through integrated landscape planning and management that optimizes water, labour and machinery use, and distributes their demand more evenly and efficiently during the year between lowlands and uplands.

Assessing climate risks

In general, many people think that there is either little or no water scarcity in Sri Lanka. In reality, the high reliance on precipitation for agriculture and the spatial and temporal variations of water availability that result from the bi-monsoonal climatic pattern make large areas of the country drought prone.

Since the end of 2016, dry spells and droughts have become more prolonged. At the same time, rainfall has become more concentrated and high-intensity rainfall events have worsened the siltation of the water reservoirs, causing them to operate at suboptimal capacities. As a result, paddy rice production (planting area and yields) in the lowlands has decreased.

In 2017, seed paddy production was too low to meet the needs of the country; in the uplands, during the main agricultural season, only a small percentage of the agricultural area was used.

Understanding beneficiaries' needs

The priority of the Department of Agriculture is to support the population in the dry zone, which is most affected by climate change and has high potential for development. Farmers that live in these areas can benefit directly from production systems that improve efficiency.

In the lowlands, all farmers grow rice during the main season and most of them leave the land fallow during the minor season, whereas, most upland farmers grow maize in the main season and sesame in the minor one, or leave the land fallow.

These production systems are extensive, favour weed proliferation during the fallow, and rely on mechanization services that are rarely available at the right time. Delayed planting in lowlands increases the use of irrigation water during the main season (instead of rainfall), reducing its availability in the minor season when it is most needed. In the uplands, planting delays may lead to the inability to plant altogether, especially under heavy rainfall. Bare soil subsequently causes weed infestation and soil erosion, reducing fertility in the uplands and causing siltation in the lowlands.

Field demonstrations were implemented in the dry zone, in Anuradhapura district, and representative sites were selected in Meegassegama, Maradankalla and Palugaswewa villages.

Targeting agronomic solutions

The agronomic practices developed by the project for the lowlands aim to improve water productivity for rice production. They include (a) selecting the most adapted rice variety to climate (expected water availability for the season) and pests, (b) providing farmers with germinated seedlings to give them a better start and save seed material, (c) using the alternate wetting and drying technique to improve water management, and (d) using soil testing kits and leaf colour charts for more targeted fertilizer application.

Convincing farmers to initiate land preparation at the beginning of the rainy season was a key achievement in terms of water saving and efficient water management. Farmers usually wait for the water reservoirs to be filled and for the irrigation water to be released from the reservoir. Since the beginning of the project, all the farmers of the Meegassegama reservoir have adopted this practice. The Rice Research and Development Institute has calculated that this practice can save 20 percent of the total irrigation requirement for rice cultivation for one season; farmers can then use the water saved in the next cropping season.

Having received training in the alternate wetting and drying technique, farmers were able to save water during the main season and to expand the land under irrigation by 15 percent during the dry season compared to the average land extent cultivated in regular dry seasons. By combining early planting with the use of rainwater (instead of irrigation water), and the alternate wetting and drying technique, the community experienced the highest water capacity ever recorded at the end of the dry season.

The initial objective of the project was to intensify lowland production and grow a third crop of short duration and with low water requirements, such as green gram (*Vigna radiata*). However, in consideration of the extraordinary water availability, farmers preferred to privilege water use for domestic purposes (washing and bathing), animal husbandry (milk cattle and goats) and aquaculture (inland fisheries). Therefore, sunn hemp (*Crotalaria juncea*) was chosen instead. It was grown with the main purpose of controlling weeds between the two seasons (green fallow), and improving soil fertility thanks to its nitrogen fixation and soil decompaction properties.

By using cover crops, leaf colour charts and parachute trays, farmers have been able to apply fertilizer more precisely and reduce the quantity of fertilizer by 27 percent. In manual systems, at sowing, fertilizer is applied into the parachute trays instead of being broadcasted.

Plant pest and disease observation, identification and management was also introduced through these projects. For additional support, farmers can also contact the Rice Research and Development Institute (RRDI), extension officers of the Provincial Department of Agriculture and the Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI).

For the uplands, farmers traditionally plough the land before the manual planting of maize. This is the most labour-intensive and costly operation that also causes soil and water losses upstream and reduces the capacity of the water reservoirs for downstream water users. Through the projects, farmers learn how to use no-till seeders and implement Conservation Agricul-

DID YOU KNOW?

- In addition to improving the precision of fertilizer application, using **parachute trays** cuts down paddy seed requirements by 75 percent and increases the number of tillers per plant.
- Reducing weed infestations with this technique has a very low investment cost, which farmers easily recover by applying less herbicide.
- Rice planted with parachute trays is also more resistant to dry spells compared to rice that is broadcasted.

SOURCE: Authors.

ture systems (Dhanapala and Gunasekera, 1994; Dharmasena, 2007; Kumara and Karunathilaka, 2017; Werakoon and Schall, 1989).

To increase soil and water conservation, farmers are trained in the use of earth bunds, which they have also started using to grow drought-resistant perennials, such as dwarf moringa and pomegranate trees. In fields, farmers have grown sunn hemp (*Crotalaria juncea*) as a cover crop during the fallow period to control soil erosion and weed infestation, and to enrich the soil.

Scaling up

Scaling up requires building upon the existing institutional set-up, with local producers organized around existing farmers' organizations.

Improving the efficiency of these organizations requires a manager that coordinates the provision of services, agronomic inputs, and training. It also requires a public–private partnership to support private sector service providers and agribusinesses. This allows resource-poor smallholder farmers to have access to mechanization services, seeds and other agronomic inputs.

Finally, scaling up climate-smart crop production involves capacity building for farmers, so they can improve productivity through sustainable crop and mechanization systems. This is done through the establishment of agribusiness hubs through which farmers are able to access agronomic production inputs and mechanisation services; agronomic, mechanization and business curricula, and training guides; training for trainers; and opportunities for information and experience sharing for farmers.

CASE STUDY

ANGOLA – PROMOTING AGROECOLOGICAL SOLUTIONS FOR CLIMATE CHANGE THROUGH FARMER FIELD SCHOOLS

Addressing climate risks

The civil war in Angola (1975 to 2002) had devastating effects, including on the country's meteorological infrastructure. This has resulted in a lack of climate data in recent years, making it difficult to conduct a thorough analysis of climate change in the country.

There are many uncertainties, but climate projections indicate that surface temperatures in Angola could rise, along with the following possible impacts: increases in the occurrence of extreme climate events; expansion of arid and semi-arid regions; shifting seasonal rainfall patterns; rising sea level; increasing occurrences of wildfires; and changes in river flows. Available projections agree that there will be a decline in the length of the agricultural growing period in southern Angola and along the coast, while areas in the north that currently benefit from two growing seasons may in the future only experience one. If such predictions were to become true, given the rainfall dependency of most staple crops, combined with unsustainable agricultural practices and prevalent soil erosion, it would have severe impacts on smallholder farmers, who do not have the technical capacities to properly adapt to these changes. Climate change is also exasperating the spread of animal diseases, which thrive under certain conditions, such as warm temperatures and high humidity.

Angola's ecosystems are diverse and offer significant natural resources. However, the country does not have the proper legal framework to effectively manage and protect its forest resources. The weak natural resources governance has also led to the degradation of agricultural resources, in particular because of unsustainable farming methods and overgrazing.

Soil erosion and general land degradation in Angola has negative impacts on sedimentation in the fluvial basins, and leads to soil nutrient depletion in agriculture, affecting the industry and infrastructure sectors. Mineral extraction as well as wood and timber exploitation are common activities, despite leaving the ground bare without protection or vegetation cover, which aggravates the risk of soil erosion. Since the end of the civil war, the country has been chronically dependent on massive imports of cereals and horticultural products to meet their food needs. It is estimated that more than half of all grains and plant products consumed in Angola are of foreign origin.

In an effort to strengthen climate resilience in the country's agropastoral production systems, a project was set up in key vulnerable areas in the Provinces of Bié, Huambo, Malanje and Huila. The focus is on (1) mainstreaming Climate Change Adaptation (CCA) into agricultural and environmental sector policies, programmes and practices; and (2) capacity building and promotion of CCA through soil fertility and Sustainable Land Management (SLM) practices using the FFS approach.

In these four provinces, the majority of the population is involved in agricultural and agropastoral activities. Malanje, located in the sub-humid agroecological zone, is characterized by savannah forest and market-oriented cassava. Huila is mostly in a sub-humid, agroecological zone with some

Box 3.12.
The Farmer Field School Approach

Farmer field schools (FFS) is an approach to extension that is based on the concepts and principles of people-centred learning and was developed as an alternative to the conventional, top-down extension approaches. It uses innovative and participatory methods to create a learning environment, including learning networks, in which land users have the opportunity to learn for themselves about particular production problems, and ways to address them, through their own observation, discussion and participation in practical learning-by-doing field exercises. The approach can be used to enable farmers to investigate and overcome a wider range of problems, including soil productivity improvement, Conservation Agriculture, control of surface run-off, water harvesting and improved irrigation.

The FFS methodology promotes agroecological literacy through a participatory, learning-by-doing approach that promotes farm-based experimentation, group organization and decision-making. Participants enhance their understanding of agroecosystems through training, co-creation and sharing of knowledge, which leads to production systems that are more resilient to local conditions and optimize the use of available resources.

SOURCE: FAO, 2019e. *Introduction to Farmer Field Schools. A Reader for Institutions of Higher Learning*. Nairobi, FAO. www.fao.org/3/ca3605en/ca3605en.pdf

highland areas. In terms of production, it has livestock and maize in the south; central highland maize and beans in the north; and livestock, millet and sorghum in the northeast. Huambo and Bié are mostly highlands, with some sub-humid areas in Bié. In terms of production, they focus on central highlands maize and beans.

DID YOU KNOW?

- Rapid vulnerability assessments and resilience assessments complement agrometeorological systems, tailoring information to the needs of farmers and agropastoralists.
- Agrometeorological systems need to be upgraded to facilitate use by extension services and farmers.

Scaling up sustainable land management practices through farmer field schools

The project promotes agroecological techniques among farmers to adapt to climate change, including (1) improving soil fertility and integrated nutrient management through agroecological practices, and (2) agroecology[56] and environmental practices related to soil conservation, rational use of water and fertilizers, integrated nutrient management, and promoting integrated pest management.

Agroecology is a systemic approach that unlocks climate change adaptation and mitigation potentials in agriculture and food systems and builds resilience (FAO, 2018c). Fostering collaborations with civil society organizations within the FFS agroecology approach will contribute to the consolidation and systematization of existing knowledge and capacities in agroecology, thus ensuring long-term ownership by local communities of such models and practices. This approach aims at reinforcing rural populations' climate

56 Agroecology is a holistic approach for the transition to sustainable agriculture and food systems, from production to the organization of human societies, and involves the participation of a wide variety of stakeholders (countries, local authorities, intergovernmental organizations, civil society organizations, the private sector, research and academia, etc.).

change adaptation capacities. The concept is spread through the integration of new resilient practices, such as the use of meteorological data in farmer decision processes, the use of resilient seed varieties, integrated pest management, and more.

Through the project, 115 000 farmers and pastoralists are strengthening their resilience by adopting CCA and SLM practices. Using the FFS approach, communities are encouraged to use agroecological practices that are rooted and localized in their current agroecological systems and capacities. Examples include using locally available grasses for mulching to conserve soil moisture, and using soil organic matter to help reduce risks and increase resilience.

In order to help ensure long-lasting benefits of sustainable land management, participatory land delimitation is being conducted by communities in concert with the governments to provide more secure land tenure. Through these interventions, specific training tools on CCA, agroecology and SLM practices (including FAO CCA tools and SHARP[57]) are being carried out, targeting master trainers and facilitators that were recruited and initially trained through previous projects. In addition, capacity building for provincial governments includes training to become Master Trainers and Technicians for FFS in order to ensure sustainability once the project is finished. The project is also strengthening an existing network of 150 FFS by setting up new famer field schools in Huila Province. Through these FFS, smallholder farmers can benefit from hands-on experience in CCA and SLM practices, including agroecology and environmental practices related to soil conservation, rational use of water, fertilizers, integrated nutrient management and integrated pest management.

Scaling up

Angola has been implementing FFS for more than 10 years and the FFS approach has continued to evolve to adapt to changing societal and environmental realities, such as national economic crises and climate change. In 2019, the government requested FAO to support the institutionalization of FFS as the official mechanism of rural extension in the country. Integrating CCA and SLM practices into sectoral planning is essential to strengthen the adaptive capacity of governmental departments, civil society organizations, and farmers and to minimize climate risks in both agropastoral and agricultural production systems.

Agroecological mainstreaming in the FFS approach will play an increasingly important role as different ecoregions of Angola are affected by the impacts of climate change. Special attention is now given to knowledge management among public institutions, civil society organizations, non-governmental organizations (NGOs) and communities in order to make this paradigm change in rural development effective and sustainable.

57 For more information on SHARP, see: www.fao.org/in-action/sharp/en/

Sector note 3 Crop Water Productivity: A defining approach to the agricultural water challenge under climate change conditions

The Crop Water Productivity (CWP) indicator measures economic or biophysical gains from the use of a unit of water consumed in crop production. The CWP-based approach is suggested to address agricultural water scarcity situations that are often exasperated by climate change.

The CWP approach was applied to three small-scale irrigation schemes in Burkina Faso, Morocco and Uganda, including four main steps, and a bottom-up methodology. The AquaCrop growth model was used as a practical simulation tool.

Using the CWP approach in project design proved successful in implementing optimal farming practices; positive effects were achieved in terms of water productivity, crop production, and irrigation water use.[58]

Crop water productivity and climate change

Climate change poses a major threat to global food security. One of the defining challenges of the twenty-first century will be how to produce enough nutritious food to feed the world's growing population, while at the same time, not harming the environment. The links between climate and agriculture shape different agroecological zones, from humid to arid lands, where crops are produced. However, the impacts of climate change have already had significant effects on the weather conditions and the many factors that define the crop growth cycle, such as water availability, soil health, and air temperature. Climate variability greatly determines year-to-year crop production and affects all farmers, from smallholders to large-scale producers.

The effects of the climate crisis are becoming more evident with increasing competition over natural resources, such as water for use in agricultural production. In areas afflicted by water scarcity or by high competition over resources, the primary goal should be to sustainably increase production per water unit, rather than increasing productivity per land area unit. Thus, the concept of water productivity (WP) emerged to assess the efficiency of water use in crop production.

According to the so-called "more crop-per-drop" approach, the Crop Water Productivity (CWP) indicator is employed in the agricultural sector to measure the economic or biophysical gain from the use of a unit of water consumed in crop production. Initially, methodologies to assess CWP took only a land productivity indicator into account, but they have since evolved through field applications. The methods currently employed evaluate a set of indicators – such as water, soil and energy – according to the specific context to define required outputs. In addition to production and production-related gains, further outputs may be related to improved environmental conditions, reduced ecosystem costs, or enhanced ecological benefits.

58 Sector note 3 by M. Salman and S. Giusti (CBL, FAO).

Crop water productivity analysis

The impacts of climate change on agriculture are complex and often do not result in linear changes. For example, rainfall pattern variability associated with climate change can lead to reduced water availability for crop production, but in some cases – depending on the latitude and agroecological context – it can bring benefits. Consequently, crop yields are expected to increase in some areas and decrease in others, according to location and irrigation application. At the same time, climate change affects soil water balance, causing soil evaporation and plant transpiration, thereby affecting crop growth periods. While crop yields are sensitive to changes in temperatures, they are even more affected by precipitation. Therefore, soils with a high water holding capacity are more resilient to changes in water availability, and can maintain crop yields despite water scarcity.

Food security and water availability are deeply interlinked, and climate change is expected to exacerbate water scarcity in a growing number of countries and areas worldwide. According to FAO (2017e) estimates, while irrigated food production is expected to grow by more than 50 percent by 2050, water withdrawals for agriculture can only increase by 10 percent, provided that (a) irrigation practices are improved, and (b) yields are enhanced. Therefore, water productivity and efficiency rates need to be strengthened to avoid water scarcity in irrigated areas.

DID YOU KNOW?

- Reliance on irregular and unreliable rainfall is one of the major causes of low crop yields.
- Despite concerns about the technical inefficiency of water use in agriculture, water productivity at global level increased by at least 100 percent between 1961 and 2001. The major factor behind this was increase in crop yields.
- The achieved yield increases were different across regions. Yields of rainfed maize in sub-Saharan Africa have remained at around 1 tonne/ha in the past 50 years, while in Latin America and the Caribbean, yields have tripled from 1 tonne/ha to 3 tonnes/ha.

See: FAO. 2003. *Unlocking the Water Potential of Agriculture* [online]. [Cited 24 October 2019]. www.fao.org/3/y4525e/y4525e06.htm#bm06

Determining the potential effects of climate variability on crop production and water resources is necessary for effective agricultural project design. The adoption of bottom-up approaches would allow for a fair consideration of local environmental and climatic conditions. Furthermore, thorough appraisal of local contexts in terms of relevant climatic and environmental indicators should foster the inclusion of valuable adaptation strategies into project design as well as the application of crop growth models for the study of climate change impacts on crop growth.

Moreover, the definition of a comprehensive set of measures to increase CWP requires advance planning, tailored to local field conditions, in order to determine the most appropriate combination of agricultural water management (AWM) practices (water harvesting, water use efficiency, etc.), and thus maximize the benefits of CWP during project implementation.

Enhancing CWP, along with climate change-related considerations, is particularly effective at project level and can be achieved through multi-objective projects that are aimed at implementing a number of AWM practices:

- Optimizing the use of rainwater for increased crop production;
- Maximizing the utilization of existing irrigation schemes in a sustainable manner;
- Designing new irrigation schemes in a sustainable manner; and
- Developing practical tools to enhance CWP under any irrigation condition.

ENHANCING CWP AT PLANT LEVEL:

most significant improvements come from breeding programmes to develop appropriate growing cycles

↓

ENHANCING CWP AT FIELD LEVEL:

crop selection, planting methods, minimum tillage, synchronized irrigation, nutrient management, improved drainage, etc.

↓

ACCOUNTING CWP AT SYSTEM AND BASIN LEVEL:

land-use planning, improved irrigation scheduling, conjunctive management, etc.

↓

POLICY TOOL TO ADDRESS CWP:

government intervention, sufficient operation and maintenance, policies and incentives, etc.

Figure 3.22.
Evolution of the Crop Water Productivity Approach

SOURCE: FAO, 2019f.

CASE STUDY STRENGTHENING AGRICULTURAL WATER EFFICIENCY AND PRODUCTIVITY IN AFRICA

On average, agriculture accounts for 70 percent of global freshwater withdrawals (FAO, 2017e). Yet, further development of irrigation is imperative in developing countries, both to improve food security and to support commercial farming. Strengthening water productivity and efficiency for irrigation purposes will not only enhance the sustainable use of water resources, but it will also contribute to a certain extent to alleviating pressure on water resources, especially where water is scarce due to climatic conditions.

The rural sector in the African continent accounts, on average, for 17 percent of the gross domestic product (GDP), and it employs about 60 percent of the total labour force. The vast majority of smallholders in particular are highly dependent on rainfed production for their livelihoods. Improved agricultural water management practices are therefore essential, especially considering the increasing unreliability of rainfall caused by climate change.

Stemming from these considerations, the project was carried out in three countries in Africa – Burkina Faso, Morocco and Uganda – with the aim of reducing hunger and poverty by focusing on improved AWM practices and mainstreaming the CWP approach into national frameworks and policies. In particular, the project focused on enhancing capacity for improved crop water productivity in small-scale agriculture through the development of capacity building and knowledge sharing activities:

- Training programmes addressed all stakeholders – from farmers' representatives and extension agents (micro-level), to research institutes and academia (meso-level), to regional and national decision-makers (macro-level) – on the use of tools for water productivity.
- Calibration and application of water productivity tools were performed to assess farming conditions for rainfed and irrigated agriculture and evaluate changes in management practices.
- Information and communication materials were disseminated to illustrate and promote good practices in water management.

In line with the directive of the NEPAD-launched Comprehensive Africa Agriculture Development Programme (CAADP), the project highlights the central role that agriculture and sustainable water management play in food and nutrition security, and poverty alleviation; it also takes into account the urgent need for effective responses to climate change, such as adaptation and mitigation strategies.

During the project design phase, the selection of target countries was based on the emergence of climate variability and its effects on the agricultural sector, with the aim of introducing best practices for irrigation water management and effective measures to enhance water productivity in each country. In Burkina Faso, rainfed agriculture production, typically performed by traditional smallholders, represents about 70 percent of national produce. The dependence on climate variability in the country was evident in 2012, when cereal production fell by 20 percent compared to the previous year due to severe drought, which caused a 154 462-tonne cereal deficit (FAO, 2012c).

Given the insufficient food production at national level, with more than half of rural households being poor and without land and only few animals, many farming families consumed their seed stocks of cereals and beans, leaving them with fewer seeds to plant during the next season. The development of the water sector is therefore of key importance to cope with water scarcity and increasing food demand; it can be achieved through different approaches by enhancing the availability and improving the efficiency of water use for crop production.

In Uganda, the agricultural sector, characterized by small- and medium-scale farmers, employs about 77 percent of the active population and accounts for around 33 percent of the GDP. Nevertheless, almost 34 percent of the population is undernourished, mostly due to the very low level of productivity. Optimizing the sustainable use of water resources, as recognized by the national Agriculture Sector Development Strategy and Investment Plan (ASDSIP), is vital for improved water productivity for food production, especially considering recurrent drought episodes (1993/94, 1998/99, 2006), localized dry spells (2008, 2009, 2010, 2011), and frequent rainfall deficits, all of which are expected to increase.

The key objective of water productivity enhancement can be reached regardless of whether the crop is grown under rainfed or irrigated conditions, and it can be estimated at plant, field and basin level. Moreover, the definition of water productivity is particularly meaningful and applicable in developing countries where the use of surface irrigation is widespread, but the systems have low efficiency levels – in terms of irrigation water application, distribution and uniformity – associated with high evapotranspiration rates.

Through a case study approach, three small-scale irrigation schemes (one per country) were selected from different cases in the African continent, for the implementation of a water productivity methodological approach, which outlined a context-tailored method to assess and improve the on-farm CWP in the selected sites.

The implementation approach

The project implementation followed four main steps and adopted a bottom-up methodology:

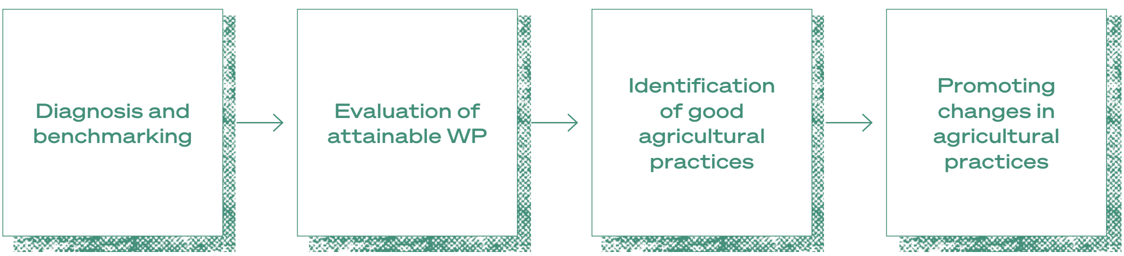


Figure 3.23.
Project implementation - four main steps

SOURCE: FAO, 2019f.

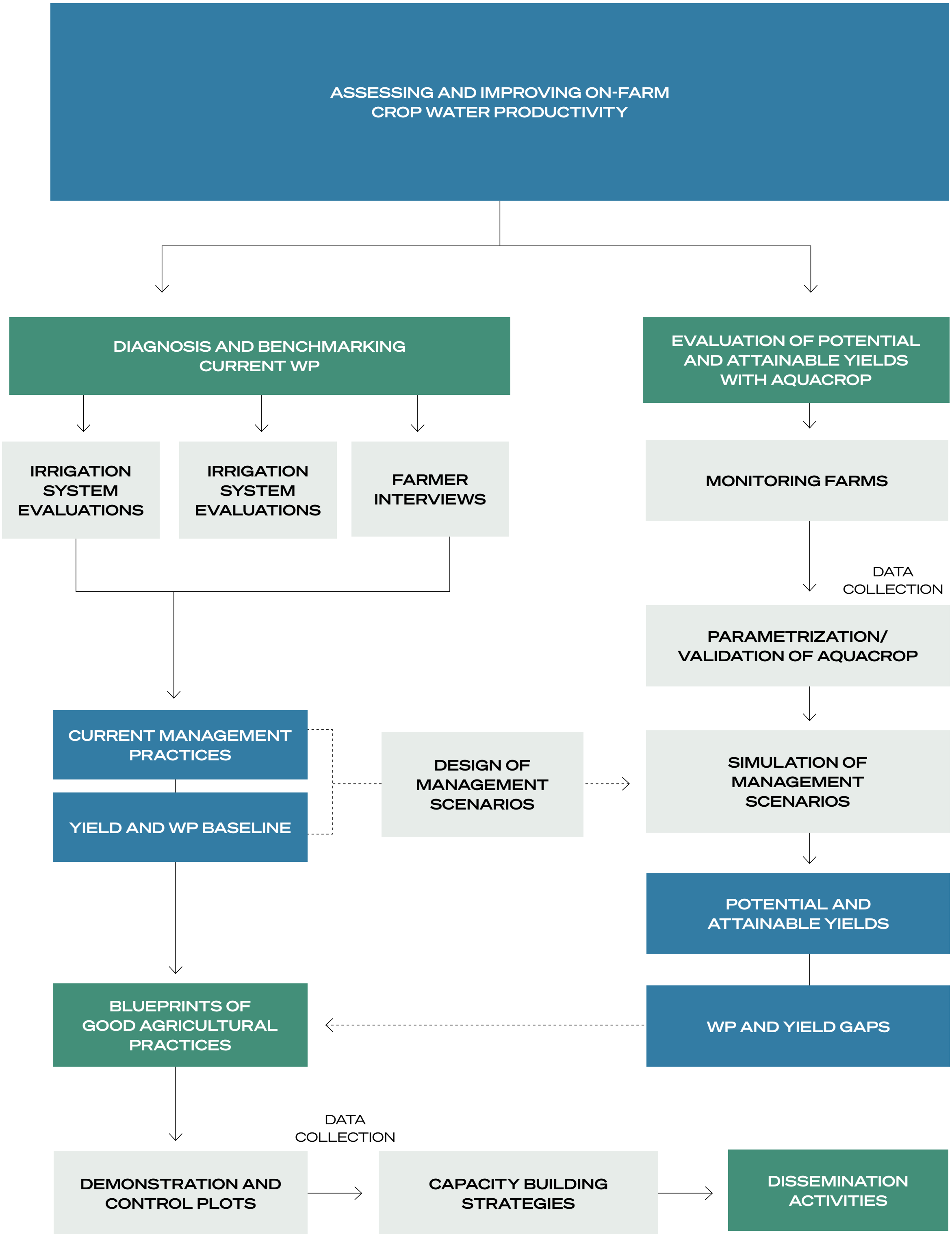


Figure 3.24.
Application of the CWP methodology and AquaCrop tool to project design

SOURCE: FAO, 2019f.

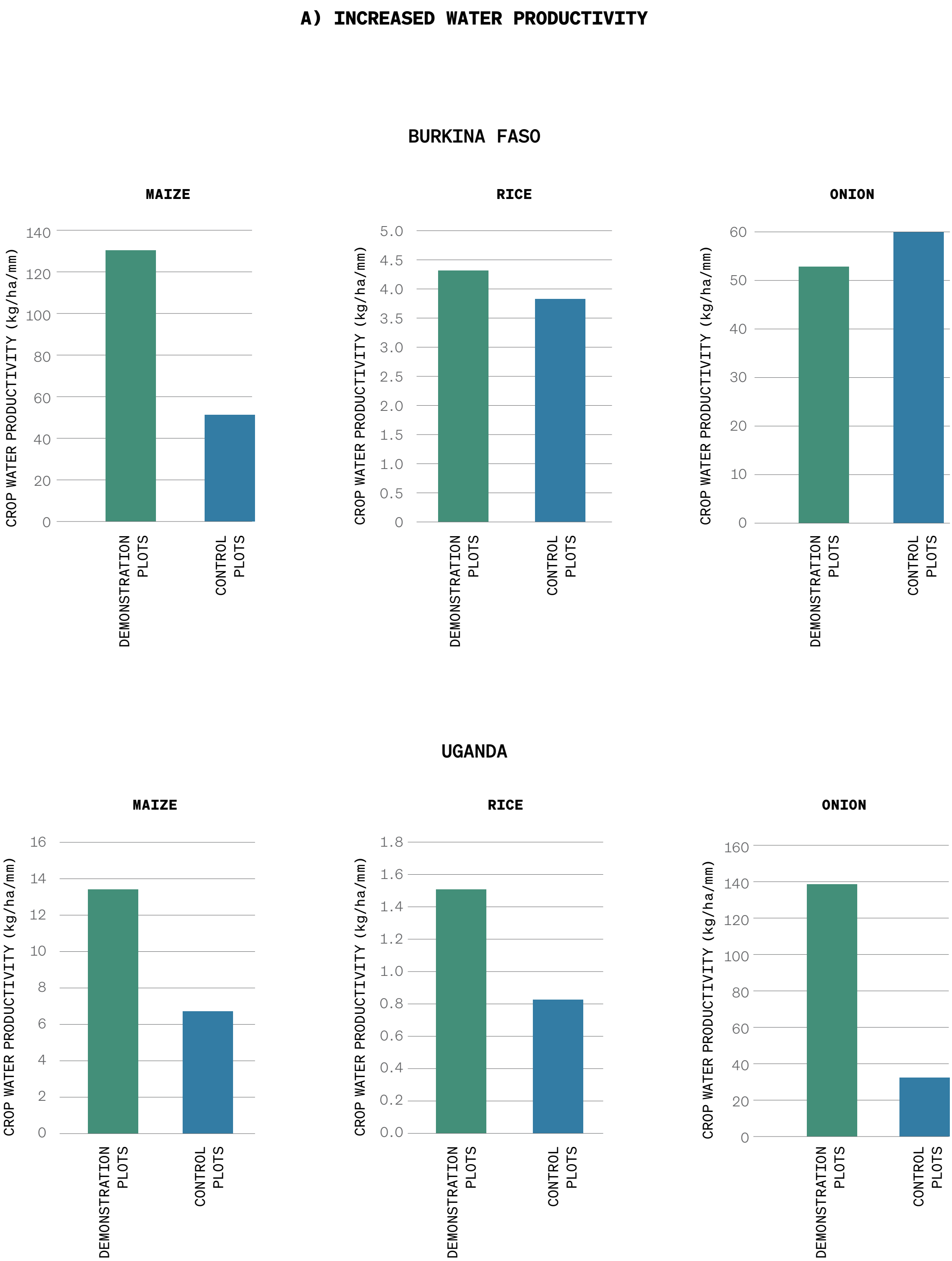


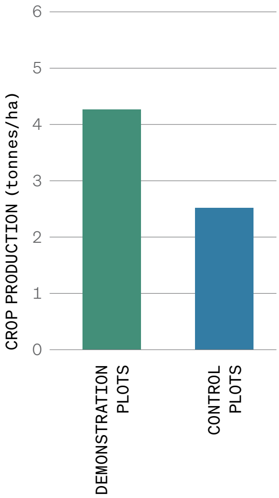
Figure 3.25.
Implementation results for maize, rice and onion plots in Burkina Faso and Uganda

SOURCE: Salman *et al.*, 2020.

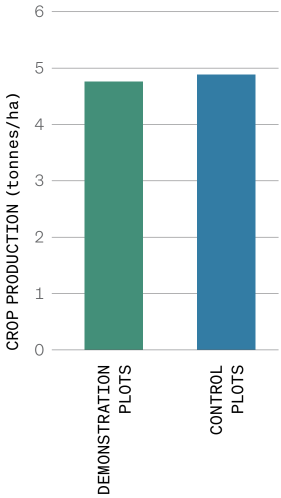
B) INCREASED CROP PRODUCTION

BURKINA FASO

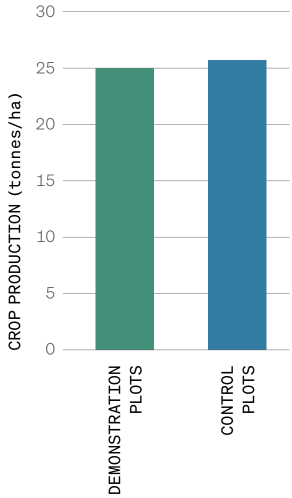
MAIZE



RICE

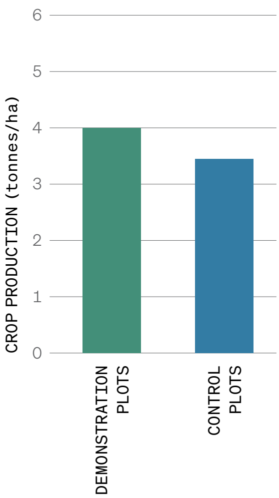


ONION

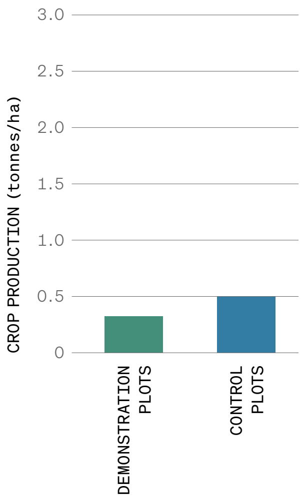


UGANDA

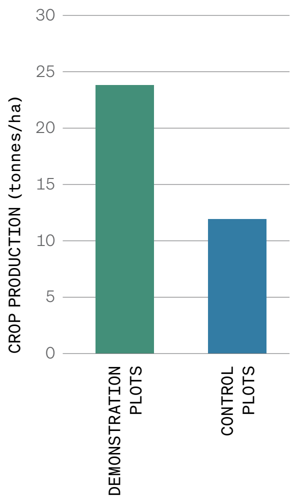
MAIZE



RICE

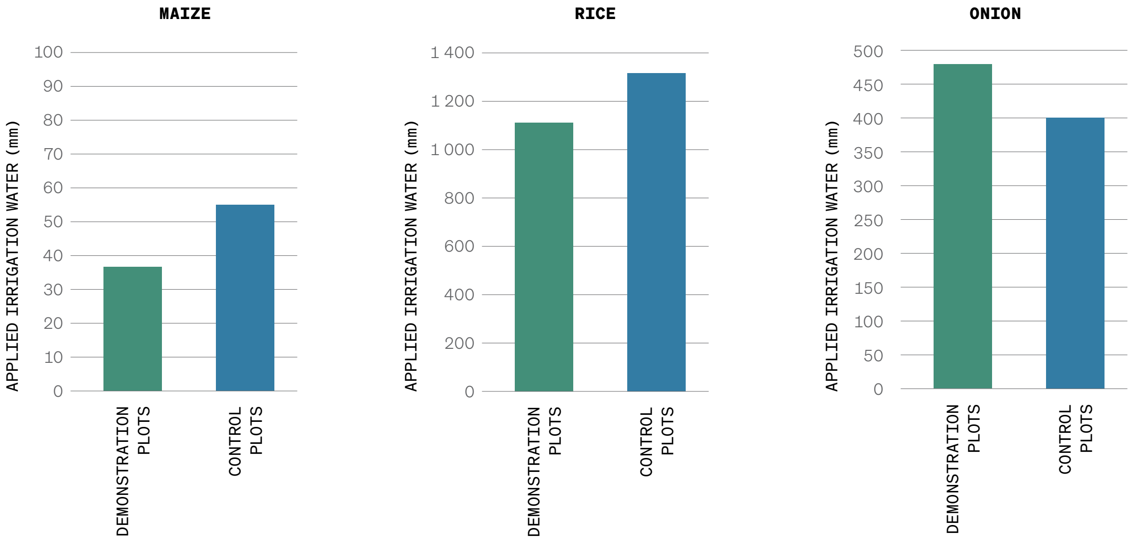


ONION

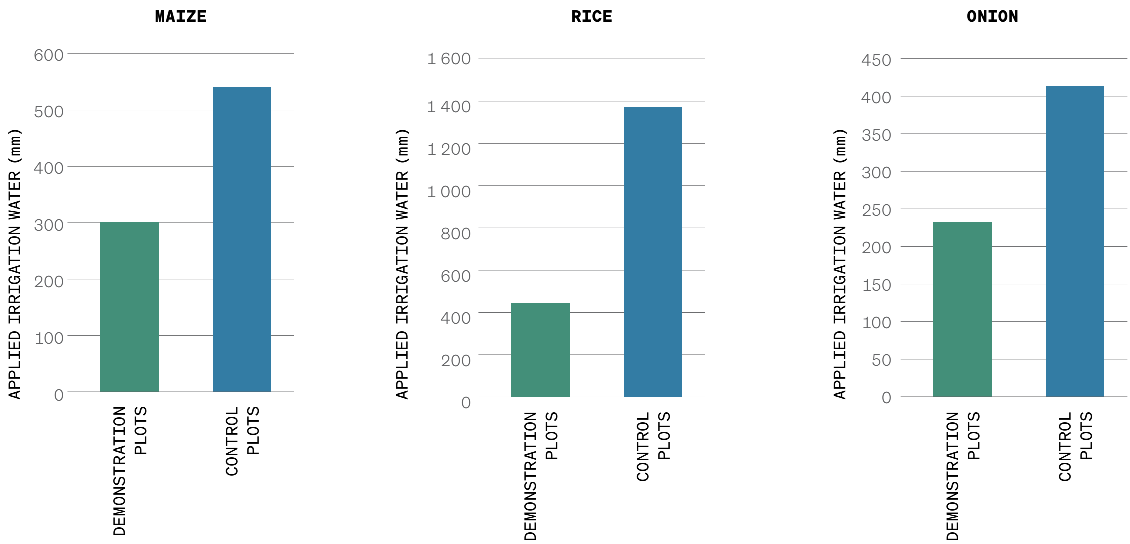


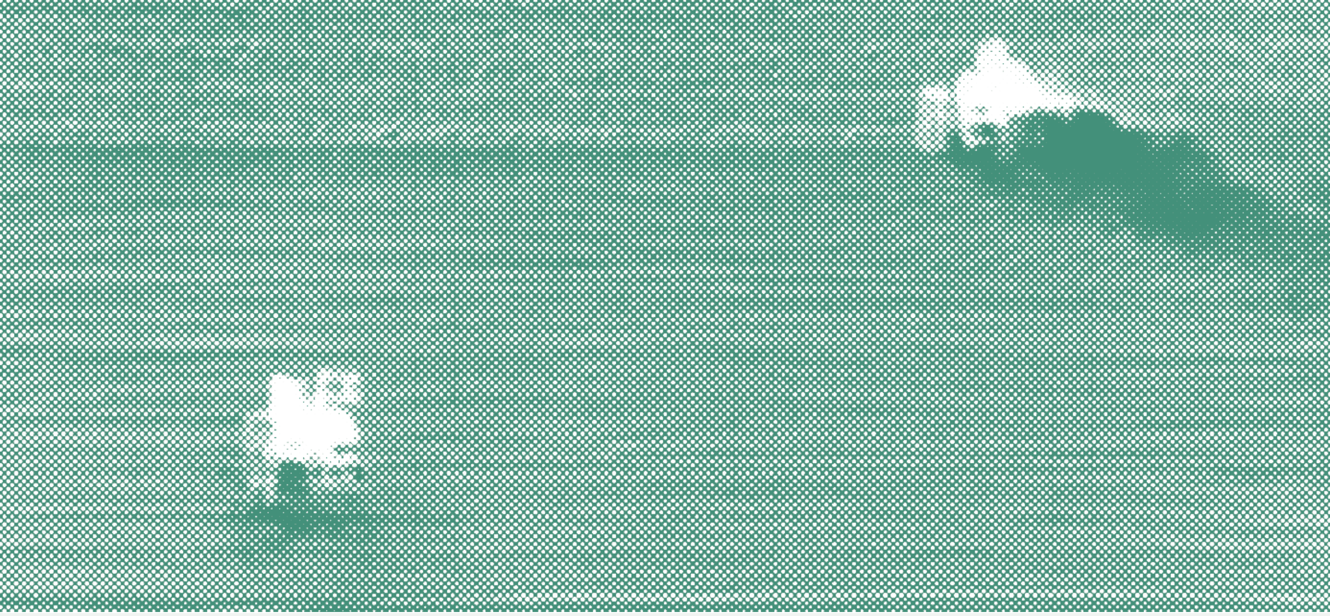
C) REDUCED IRRIGATION WATER USE

BURKINA FASO



UGANDA





Box 3.13.
AquaCrop simulation model under climate change

AquaCrop is a simulation model designed to account for the features that are expected to occur under climate change, namely, increased temperatures, variations in rainfall, and most importantly, elevated CO_2 concentrations, all depending on the different scenarios formulated by the IPCC. In AquaCrop, the crop production engine depends on the concentration of CO_2, and the crop response to elevated CO_2 is simulated for future CO_2 concentration levels. Following the results of more than three decades of research, AquaCrop has built in a recommended response to elevated CO_2 in future climate, which the user may adjust according to the different climate change scenarios. In fact, AquaCrop is one of the most advanced simulation models in this regard, and it has already been used for the simulation of future global wheat production under climate change.

SEE: www.fao.org/aquacrop/en/

The project approach recognized the impacts of climate change on irrigation and agriculture, thus the need to promote the most efficient use of water resources for crop production, while taking into consideration a number of environmental factors. It employed the AquaCrop growth model[59] as a practical simulation tool to evaluate the effects of both environmental conditions, and different management practices on crop production.

The AquaCrop tool was applied in selected, small-scale irrigation schemes to (a) evaluate attainable yields, and (b) to compare potential yields to actual production and diagnose yield gaps of selected crops. In the follow-up phase, the tool was then embedded in the overall project design according to different country cases; it was also used to support the formulation of possible alternatives in crop water management practices for the improvement of CWP (Box 3.13).

59 For more information on the AquaCrop growth model, see: www.fao.org/land-water/databases-and-software/aquacrop/en/

The AquaCrop tool was tailored to suit environmental conditions at the pilot level, and activities were designed to meet project targets, providing a comprehensive evaluation of the water productivity level and identifying possible pathways to increase it. The procedure followed at each step is summarized in Figure 3.24.

Implementation results

Outcomes of the project designed with the use of the CWP approach proved successful in the implementation of optimal farming practices, and positive effects were achieved in terms of water productivity, crop production, and irrigation water use. Figure 3.25 shows implementation results for maize, rice and onion plots in Burkina Faso and Uganda.

Bearing in mind that the project applied a case study approach, the methodology may be applied to other irrigation schemes, taking into account their particular features. In this regard, the approach was not developed as a rigid framework, but rather as one that can be adapted to different contexts. The approach applied in the case study allowed for a detailed evaluation of the socioeconomic and environmental conditions existing at pilot level. Follow-up actions for each country have been identified, including interventions in irrigation water supply, irrigation water management, and agricultural practices.

Conclusion

Climate change poses a serious threat to water and crop water productivity, mainly due to the imbalances it triggers in the hydrological cycle and in natural ecosystems at the regional and global scale. The increasing recurrence of extreme weather events and the alteration of rainfall patterns affect a number of components of the hydrological cycle, such as soil moisture or evapotranspiration, thereby limiting countries' capacities to deal with these challenges.

Decision-makers and planners in the agricultural sector are encouraged to promote the sustainable management of water resources, and to embrace effective and context-tailored approaches, with the aid of the CWP methodology, to improve water productivity and optimize farming practices.

Sector note 4 — Reducing emissions from deforestation and forest degradation: REDD+ process

This sector note[60] presents REDD+ experiences in Ecuador and Equatorial Guinea in designing and implementing projects aimed at reducing emissions from deforestation and forest degradation, in combination with sustainable management of forests, and the conservation and enhancement of forest carbon stocks.

Through the REDD+ process, Ecuador has enhanced the government's and key stakeholders' technical capacities, strengthened and set in place a fully operational National Forest Monitoring System, and submitted its Forest Reference Emissions Level (FREL) to the UNFCCC.

In Equatorial Guinea, five pilot investment projects were selected as "integrated local programmes" of the National REDD+ Investment Plan. The outputs contributed to (a) improving information on forests and deforestation processes; (b) increasing recognition of the value of the forests; and c) mobilizing complementary funding to meet Equatorial Guinea's REDD+ commitments.

REDD+ Process

Reducing emissions from deforestation and forest degradation, plus the sustainable management of forests, and the conservation and enhancement of forest carbon stocks (REDD+),[61] is an essential part of the global efforts to fight climate change.

Forests play a fundamental role in climate change mitigation by removing carbon dioxide (CO_2) from the atmosphere and storing it in biomass and soils. When forests are degraded or converted into other land uses, stored CO_2 is released, and forests become a source of greenhouse gas (GHG) emissions. It is estimated that globally, forestry, agriculture and other land uses are responsible for just under a quarter (~10–12 $GtCO_2eq/yr$) of anthropogenic GHG emissions, mainly from deforestation and agricultural emissions from livestock, soil and nutrient management (see IPCC AR5, Smith *et al.*, 2014).

The role of land use, land-use change and forestry in mitigating the effects of climate change is widely recognized in the Paris Agreement. FAO (2016d) reports that mitigation actions in this sector are referenced in 83 percent of all countries' Nationally Determined Contributions (NDCs).

Undertaking actions to reduce or to even halt forest loss is considered a relatively cost-effective, high-impact approach to reducing global GHG emissions. These actions also have the potential to generate important co-benefits, such as adaptation to climate change, enhanced livelihoods, food

60 By S. Fortuna, M. B. Herrera, P. Rosero, J. Armijos, A. Moreno and M. Ruiz-Villar (FAO).

61 The UN-REDD Programme is the United Nations Collaborative Programme on Reducing Emissions from Deforestation and forest Degradation (REDD+) in developing countries: www.un-redd.org

security, and economic growth. Forests not only offer a nature-based solution towards reducing emissions to the atmosphere, but they also represent a key natural instrument to enhance carbon sinks. The potential of forest restoration – one of the five main activities of REDD+ – as a climate drawdown strategy is increasingly gaining traction, with reinforced actions to be put in place during the upcoming UN Decade of restoration. For example, forest restoration enhances the absorption of carbon from the atmosphere, thus creating added synergy when combined with efforts to tackle deforestation and forest degradation, which prevent new carbon emissions and conserve existing biodiversity.

Countries pursuing REDD+ follow a phased, step-wise approach. Throughout the last decade, countries have made significant progress in the *REDD+ readiness phase*, strengthening or building the four main elements needed to be eligible to participate in the process – REDD+ strategies, forest monitoring systems, forest reference (emissions) levels, and REDD+ safeguards information systems. This progress is linked to the support countries receive, such as from FAO, which often works in partnership with UN-REDD[62] or the Forest Carbon Partnership Facility (FCPF).

Although much still remains to be done, several countries have increasingly recognized the importance of cross-sectorial coordination at multiple levels – from the national level, down to regional and local levels. Countries have also been working towards creating an enabling environment to achieve sustainable and long-term results: (a) identifying triggers for transformational change; (b) strengthening forest governance and tenure; and (c) recognizing the important role of women, local communities and indigenous peoples as contributors and rights holders in the fight against climate change.

To achieve the ambitious goal of net-zero emissions by 2050, countries now need to turn the political commitments reflected in their NDCs into actions. After intense years of work, many countries are now ready to (1) start putting mitigation actions (defined in their REDD+ strategies) into practice, and (2) to monitor, measure and report the results of these actions.

At least 64 countries have moved towards completing readiness and starting the implementation of REDD+ strategies. Through different initiatives and donors (CAFI; CIF; GCF; REDD+ Early Movers; SIDA; NORAD; UN-REDD; the World Bank BioCarbon Fund, etc.), countries were able to start receiving compensation or financial support to pilot actions on the ground to reduce emissions (*REDD+ phase 2*).

Emission reductions results are increasingly being submitted to the United Nations Framework Convention on Climate Change (UNFCCC). As of February 2020, the UNFCCC had received 13 REDD+ results submissions[63] from ten countries (Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Indonesia, Malaysia, Papua New Guinea and Paraguay). Together, the results amount to 8.84 billion tonnes of CO_2 emission reductions (ERs) obtained between 2006 and 2017, though the large majority of these ERs (93 percent) are from Brazil (FAO, forthcoming).

REDD+ represents an opportunity. Moving along its path and phases, countries strengthen technical capacities within their governments, institutions and stakeholders, and through rigorous UN-backed technical evaluation, they can reach the final phase (*phase 3*) of results-based payments. Some of these countries have started receiving payments for the results achieved so far; Brazil and Ecuador were the first, followed by Chile and

62 See: https://www.un-redd.org/

63 Brazil's latest BUR contains a technical annex with REDD+ results for the Amazon (2016-2017) and a technical annex with REDD+ results for the Cerrado (2011-2017), considered here as one REDD+ results submission.

Paraguay, and a growing list of countries (mainly from Latin America), to enter the Green Climate Fund (GCF) REDD+ results-based payment pilot programme pipeline.

In addition to this central climate finance avenue, the private sector is increasingly looking to integrate nature-based solutions, such as REDD+, into corporate social responsibility actions that contribute to the global fight against climate change. An example is carbon offsetting, such as the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Given its ability to innovate, rapidly adapt to changing conditions, and leverage capital for new market opportunities, the private sector can indeed play a key role in helping countries meet the Sustainable Development Goals (SDGs) and their climate commitments, such as NDCs and REDD+.

The importance of the agriculture and forestry sectors in many NDCs and the broad adherence to REDD+ have created a global momentum to drive private capital in sustainable land-based investment opportunities, carbon markets, green bonds and specialized private equity funds. The New York Declaration on Forests (NYDF), a global commitment by governments, companies and civil society to halt forest loss, has further boosted efforts by international corporations (e.g. Barclays, Cargill, Unilever) to adopt responsible investment practices that contribute to forest protection. In its latest progress report, the NYDF (2019) notes that the private sector has invested USD 2.7 billion since 2010 in sustainable commodity production and forest conservation in developing countries affected by deforestation, while international and national public investments have amounted to USD 11.8 billion.

Although these figures are encouraging, they fall short of the estimated USD 200 billion needed to shift land-based investments and achieve deforestation-free commodity production. Unlocking the investment power of the private sector is essential to meet this ambitious financial target and achieve REDD+ objectives.

REDD+ in Ecuador: from Readiness to Results-Based Payments

REDD+ country level activities cover various thematic areas: forest monitoring, identification and assessment of drivers of deforestation and forest degradation; government and local community support to enhance forest and land-use management; and the identification of key climate finance opportunities.

Ecuador was one of the first two countries to reach the REDD+ results and related results-based payments. Over the past 10 years, FAO – in collaboration with other partners – has been working with the government and a wide range of stakeholders to achieve this important milestone and to submit to the UNFCCC all the elements needed to progress in this process.

Ecuador is a megadiverse country, with 91 ecosystems, of which 65 are forested. Forests correspond to about half of the continental national territory (around 12 600 000 ha); one-third of the forested area (4.8 million ha) is protected by the National System of Protected Areas, and another 20 percent (1.6 million ha) is under the Socio Bosque agreement.

Since 2008, Ecuador – supported by FAO and other sister agencies in the framework of the UN-REDD programme – has been working on strengthening the technical capacities of a wide range of key actors (from government to local communities), on the main REDD+ elements. Three main highlights will be mentioned here: (1) establishing a database and emissions monitoring system; (2) developing an action plan to reduce emissions while enhancing local livelihoods; and (3) achieving results-based payments and implementing related actions to further reduce carbon emissions.

1 Better forest data and reporting systems: building up foundations for enhanced decision-making and for monitoring emission reduction results

In the *first phase of REDD+*, while collaborating and contributing to the achievement of all four elements, FAO's support to Ecuador mainly focused on the two key technical ones: the National Forest Monitoring System, and the Forest Reference Emission Level (FREL).

These elements are essential for a country to monitor the changes in forest cover and related carbon emissions/absorption. The information gathered is then used for (a) domestic decision-making, (b) measuring the effectiveness of the actions being put in place to reduce deforestation, and (c) reporting to the UNFCCC (i.e. progress towards achieving forest-related commitment as per the country's NDC), or other conventions. The functioning and operationalization of these elements are also essential for *REDD+ phase 2* (implementation) and *phase 3*, where countries – as in the case of Ecuador – can receive payments for the emission reduction results achieved.

As a result of the cooperation with FAO, Ecuador has not only strengthened technical capacities in the government and in key stakeholders, but it now has a fully operational National Forest Monitoring System, with measuring, reporting and verification (MRV) functions in line with the UNFCCC decisions.

In addition to all the data, process and capacity strengthening generated by the different NFMS technical pillars, Ecuador also managed to advance its FREL – a benchmark for assessing a country's performance in implementing REDD+ activities. Ecuador's FREL was submitted to the UNFCCC in December 2014, accomplishing a second REDD+ key element.

Ecuador's NFMS components (satellite land monitoring system, national forest inventory and assessment, and GHG inventory) are reported below:

Satellite land monitoring system

The work included the generation and automation of methodological processes, using new and innovative tools and platforms, such as Google's Earth Engine (GEE), and the System for Earth Observation Data Access, Processing & Analysis for Land Monitoring (SEPAL). Ecuador is the first country in the world to have incorporated the SEPAL platform into its national forest monitoring systems:

- building satellite imagery and mosaics in multiple time periods;
- carrying out land cover and land-use classification; and
- detecting changes to monitor deforestation processes.

Special attention was also given to enhancing NFMS institutional arrangements to ensure long-term sustainability.

National forest inventory and assessment

One of the pillars that provides part of the data needed for the NFMS is the National Forest Inventory and Assessment. This technical work started in 2009 as an initiative led by the Ministry of Environment – in collaboration with FAO and thanks to the financial support of the Government of Finland. In this process, FAO strengthened technical capacities, provided backstopping and supported the coordination of work, from the methodological design of the inventory, to the field work, to data interpretation and analysis. FAO has continued to provide support in this domain through the UN-REDD Programme, and the country is now implementing the Second National Forest Inventory and Assessment in the Amazon region.

Greenhouse gas inventory: national communications, biennial update reports

Another key pillar generating the data needed for the REDD+ process (but also for domestic decision-making and for commitments under the Paris Agreement), is the GHG inventory. As part of the commitments made by the country to the UNFCCC, Ecuador submitted the First National Communication (NC) in 2000 and the Second National Communication in 2012. Through these instruments, the country reports periodically on (a) its sources of GHG emissions and absorption, (b) actions and measures aimed at reducing the emissions and adapting to the changes, and (c) any other information relevant for the achievement of the Convention objectives.

In 2017, also thanks to the technical collaboration of FAO (UN-REDD and MICCA programmes), Ecuador elaborated and submitted the third NC, including the following information:

- progress for the period 2011–2015;
- GHG inventory for 2010 and 2012; and
- updates on the GHG inventory for 1994, 2000 and 2006.

FAO supported (a) the development of the inventory for the Agriculture, Forestry and Other Land Use (AFOLU) sector, and (b) the design of the overall National GHG Inventory System for the five sectors on which Ecuador reports. This inventory system will facilitate the generation of GHG data in a coordinated manner and with a step-wise approach of continued technical and technological improvement.

2 REDD+ strategy and safeguards: identifying key actions to reduce emissions while enhancing livelihoods

In collaboration with UN-REDD and other relevant initiatives, Ecuador has taken action on many levels:

- developing a REDD+ Action Plan, "Forests for Good Living" 2016 – 2025;
- designing a REDD+ safeguards information system; and
- submitting its first safeguards information summary to the UNFCCC, thus fully completing its REDD + readiness phase.

3 Moving into implementation and achievement of results-based payments

The successful completion of *REDD+ readiness (Phase 1)*, and the related strengthening of technical capacities in the country, allowed Ecuador to move towards *phase 2* of this international process: the implementation of the country's REDD+ strategy actions. According to GCF (2019), this also allowed the mobilization of further funding and investments totalling USD 41.2 million, with the approval in 2016 of the first project from GCF on REDD+ implementation, "Priming Financial and Land-Use Planning Instruments to Reduce Emissions from Deforestation," supported by the United Nations Development Programme (UNDP).

In 2018, FAO and UNDP joined forces to operationalize REDD+ in the country, collaborating on the implementation of the "Integrated Programme for Forest Conservation and Sustainable Production in the Amazon" (PRO-

Amazonía), in particular on technical issues related to forest policies, governance, sustainable forest management, and forest and land-use monitoring.

It is important to stress that, while the country was advancing in its *REDD+ readiness* in the piloting phase (Phase 2), it also started achieving important results on emission reductions, reporting a 28 million tonne reduction in CO_2 emissions between 2009 and 2014 (UNFCCC, 2016b), moving towards REDD+ *phase 3*. This important progress was internationally recognized and praised; Ecuador's Results-Based Payment proposal to the GCF REDD+ RBP pilot programme was the second to be approved by the Fund (following Brazil's).

In its proposal for the GCF, Ecuador offered the Fund the total REDD+ results achieved in 2014. After a thorough process of approval, the Fund granted a total of USD 18.6 million to the country (GCF, 2019) to be used to achieve further emission reductions in the country. Furthermore, in 2018 the country received compensations from the REDD+ Early Movers (REM) programme for the emission reductions achieved in the period 2015–2016.

While the journey of REDD+ in Ecuador carries on, with further results expected to be achieved in the upcoming years, the country has also moved forward in the larger context of the Paris Agreement, with a concrete NDC for the Agriculture and Land-use, land-use changes and forestry sectors. The preparation of the NDC was led by Ecuador's Ministry of Environment, with the collaboration of FAO, and the financial support of UN-REDD. Strengthening capacities in all the REDD+ and NDC processes not only creates a more enabling environment for public and private sector investments, but it also contributes to the achievement of food security and the 2030 Agenda for Sustainable Development.

Equatorial Guinea's National REDD+ Investment Framework: An opportunity for sustainable development

Within the framework of national development objectives, its commitment to the global fight against climate change and in particular REDD+, Equatorial Guinea is committed to halting and reversing GHG emissions linked to forest loss, as well as to improving the management of its territory and forests, contributing to sustainable development and the well-being of the population. The vision of Equatorial Guinea for its forests is rooted in its National REDD+ Strategy:[64] "to contribute to the global fight against climate change and to the development of the country to achieve the well-being of the people of Equatorial Guinea through REDD+, with an approach based on competitiveness, sustainability, integrated land management, food security, and social and gender equity" (MAGBOMA, 2019).

The National REDD+ Investment Plan (NIP-REDD+) presents the implementation priorities of the EN-REDD+ for the next ten years (2020–2030). It establishes, as a principle, orderly and sustainable economic growth that safeguards the country's valuable natural capital, promotes social participation and inclusion, and improves the living conditions of the population, ensuring equal access to services and resources. The NIP-REDD+ proposes to make the REDD+ vision a reality through two main impacts, combining environmental and socioeconomic benefits:

64 Structured around 4 sectors and 4 cross-cutting issues, the Strategy aims to: reduce GHG emissions by 20% by 2030; maintain the current forest cover of 93%; and reduce the annual forest degradation rate from 0.9% to 0.45% (see https://www.cafi.org/content/cafi/en/home/all-news/equatorial-guinea-launches-national-redd--strategy-.html).

- reducing the country's emissions from deforestation and forest degradation, and increasing, conserving and managing forest carbon stocks; and
- diversifying production with a sustainable approach and integrated land management that improves livelihoods.

Specifically, the NIP-REDD+ aims to reduce the country's emissions from deforestation and forest degradation by 100.6 million tonnes of CO_2 equivalents by 2040, including the implementation (2020–2030) and capitalization (2030–2040) periods. A total budget of USD 185 million is needed to achieve this impact.[65]

In 2018, five pilot investment projects were selected, and it was decided that they will constitute the "integrated local programmes" of the NIP-REDD+, where drivers in a specific jurisdiction are addressed with an integrated and inter-sectoral approach, so as to reduce forest loss and promote sustainable development.

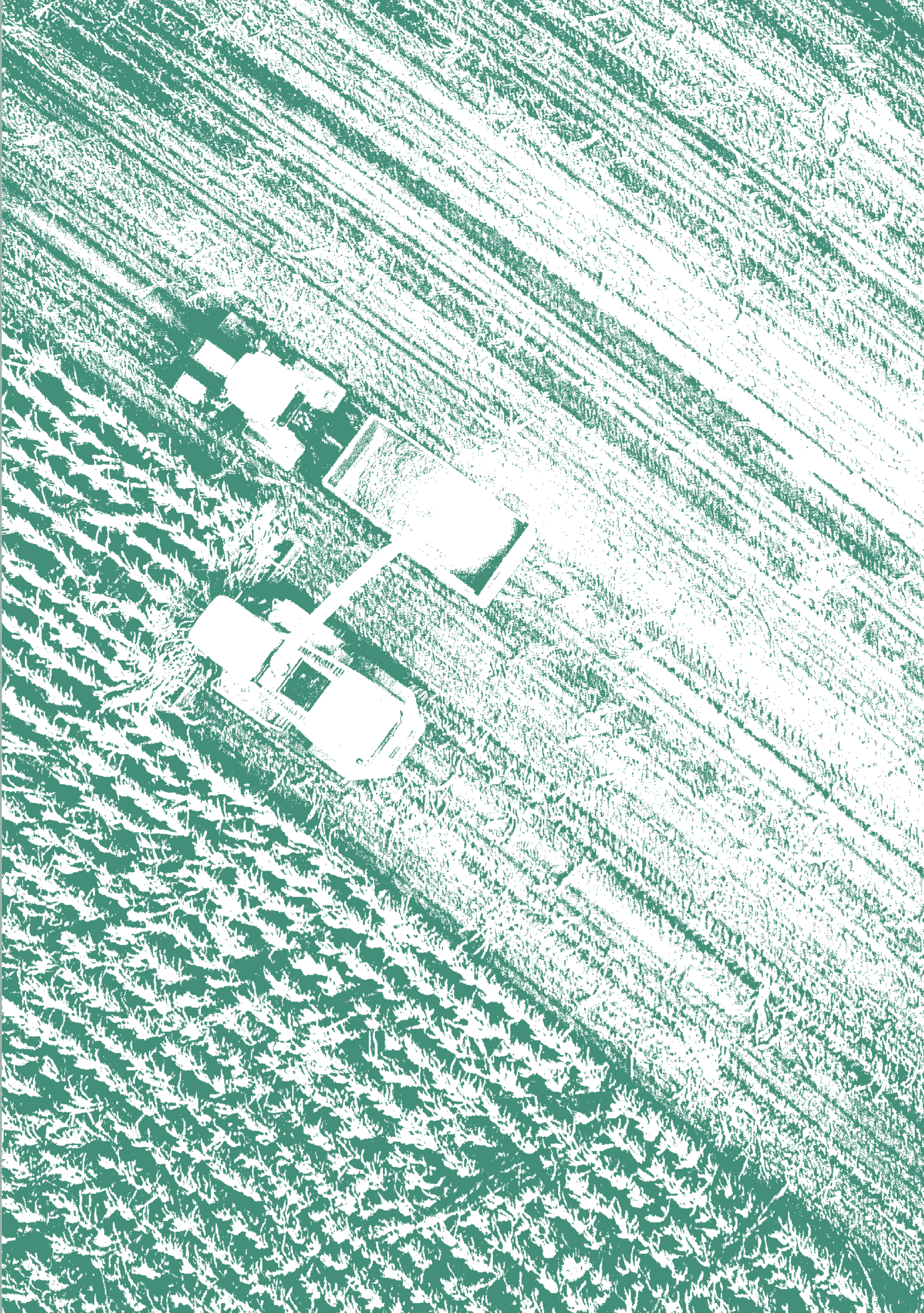
The NIP-REDD+ has been developed with the support of national and international experts on the basis of updated data and studies, including participatory consultations with more than 450 people (63 percent men and 36 percent women), with financial support from the Central African Forest Initiative (CAFI) and technical support from FAO. Technical support from FAO has helped Equatorial Guinea make significant advances in their national forest monitoring systems, allowing them to collect an unprecedented wealth of data on forests and generate detailed maps, statistics and studies on forest use that were previously not possible.

Thanks to the technical support received, Equatorial Guinea has been successful in developing the two REDD+ strategic documents that will guide and facilitate the REDD+ process. Other important aspects were also developed and achieved, such as political and institutional support, the creation of a steering committee, and an extensive, participative and open consultative process. This has allowed the country to (a) improve the information on forests and deforestation processes, (b) increase the recognition of the value of the forests of Equatorial Guinea, and (c) play a catalytic role in mobilizing complementary funding to meet Equatorial Guinea's REDD+ commitments.

These commitments are ambitious, multisectoral and cross-cutting, and include the mobilization of national budgets, multilateral cooperation, bilateral cooperation and public and private investments. For the first investment cycle in the period 2020–2030, the sources of funding identified as priorities are CAFI, GCF, the GEF, and the national budget.

The relative weight that sustainability has acquired in the strategic plans of Equatorial Guinea has substantially increased through this cooperation. The resolutions of the Third National Economic Conference, held in May 2019, reaffirmed the national commitment to a sustainable development model that respects the environment. Unlike previous national development plans, the resolutions of the Third Conference consider forests and forest management as priority aspects of environmental sustainability.

65 For more information see: https://www.undp.org/content/dam/cafi/docs/EG%20documents/Equatorial%20Guinea%20CAFI%20Leaflet%202016%20Final%20ONLINE.pdf



Module 4
Climate financing options and mechanisms: opportunities and experiences

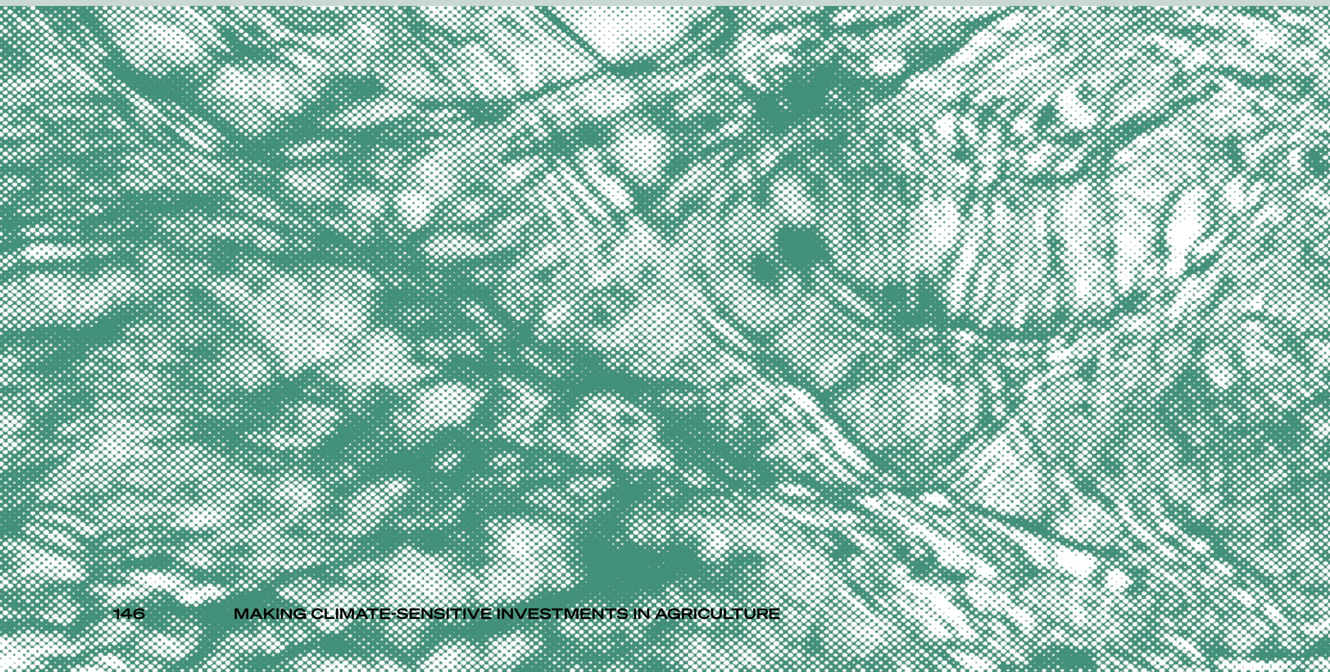
The climate finance landscape is complex and continuously evolving, featuring different funding channels (public and private,multilateral and bilateral, international and national).

The available options increase the possibilities for developing countries to access funding so as to achieve their NDC targets in the agricultural sector. Considerable opportunities are available with the Green Climate Fund (GCF) and the Global Environment Facility (GEF).

While opportunities exist, low capacity in developing projects is a major constraint limiting countries' access to financing for climate-smart investments in agriculture. Public climate finance can play a catalytic role in addressing these capacity constraints through the targeted "readiness" and preparatory support programmes.

This section[66] presents examples and insights from recent FAO experiences in assisting countries with GCF- and GEF-related agricultural project preparation.

66 By R. Dankova, J. Schlickenrieder, E. Wieben, and N. Azzu (FAO).



The Paris Agreement was the main outcome of the 21st Conference of the Parties (COP21) of the UNFCCC and explicitly linked food production and food security to its objectives. It laid the foundation for global action on adaptation and mitigation in agriculture by explicitly recognizing that agriculture is critically affected by climate change, though it is also one of the major contributors to the climate crisis. Nationally Determined Contributions (NDCs) are at the heart of the Paris Agreement and agriculture is included in the majority of them. At the time of writing, 184 Parties have submitted their NDCs to the UNFCCC. Based on analysis of the NDCs, all of the submissions referred to mitigation commitments in agriculture and 134 countries included adaptation actions, out of which 127 countries (67 percent) refer to agriculture as an adaptation priority (FAO, 2016d).

While data on the financing requirements is limited and estimates in literature vary considerably, it is widely accepted that the amount of financing required for the implementation of NDCs for priority adaptation and mitigation interventions in the agricultural sectors far exceeds the funds pledged so far for this purpose (Box 4.1). Considerable additional financing will be necessary to achieve climate targets for agriculture set by developing countries.

4.1 TYPES OF CLIMATE FINANCING MECHANISMS

The climate finance landscape is complex and continuously evolving. It features many different funding channels with different objectives and eligibility criteria. Although this process is made more complicated, these options increase the possibilities for developing countries to access climate finance. The emergence of these options necessitates strategic uses and combinations of traditional development assistance and dedicated climate finance mechanisms.

There are public and private sources of climate finance. Public financing sources include bilateral aid agencies, climate funds and multilateral, bilateral and national development finance institutions (DFIs). Government budgets are also considered as public capital. Private funding sources include private financial intermediaries, such as commercial financial institutions, private equity, venture capital, infrastructure funds, and institutional investors. Private capital also comes from households, private and multinational companies, and project developers.

There are a number of windows currently available for accessing funds for financing climate adaptation and mitigation efforts in agriculture. Multilateral climate funds are provided by multilateral institutions, such as multilateral development banks, United Nations (UN) agencies, and the financial institutions that have been created within the framework of the UNFCCC itself. UNFCCC climate funds include the Adaptation Fund (AF), the Global Environment Facility (GEF), the Least Developed Country Fund (LDCF), the Special Climate Change Fund (SCCF), and the Green Climate Fund (GCF). An overview of the main multilateral climate funds that finance adaptation and mitigation action in agriculture (in AFOLU sectors) is summarized in Table 4.1. More detailed information about these funds' financing priorities and access can be found in ACT Alliance's 2018 publication: *A Resource Guide to Climate Finance: An orientation to sources of funds for climate change programmes and action* (ACT, 2018).

4.2 OPPORTUNITIES WITH THE GREEN CLIMATE FUND

The Green Climate Fund plays a unique role as the largest international fund dedicated to supporting developing countries' efforts to limit or reduce their greenhouse gas emissions and to adapt to the impacts of climate change. The Fund provides financial support to developing countries to promote a paradigm shift towards low-emission and climate-resilient development pathways. In order to achieve maximum results, GCF aims to catalyze funds, increasing and multiplying the effect of its initial financing.

The Fund supports adaptation and mitigation action in all main economic sectors, including such areas as energy, infrastructure, food and water security, health, ecosystems, transport and cities. With regard to agriculture, a recent analysis of the GCF project portfolio found that, of the 77 projects approved between the 13th and 19th GCF Board meeting, over 25 percent of projects focused primarily on one or more of the agriculture sub-sectors, corresponding to 12 percent of total GCF Funding. In addition, the analysis found that 31 percent of projects (29 percent of GCF funding), included some agriculture-related component (FAO, 2018d). Aligned with its investment framework, and the draft *Updated Strategic Plan for the Green Climate Fund: 2020–23,*[67] GCF is currently in the process of finalizing sectoral guidance[68] for the eight GCF result areas, outlining potential for high impact interventions including in agriculture, forestry and other land use; ecosystem and ecosystem services; energy; health, food and water security; and livelihoods of vulnerable communities. This guidance is expected to define GCF's priority interventions in these areas, and to set the scope of the paradigm shift and transformations that need to be achieved to move towards climate-resilient and low-emission agricultural development. The sectoral guidance will provide orientation of how GCF can complement other sources of climate finance and catalyse private investments following the first replenishment, to be concluded in 2020. It will also guide countries and GCF Direct Access Entities, international Accredited Entities and partners through the priorities for the projects the GCF wishes to support in the agriculture sector.

The GCF Initial Investment Framework was adopted at the 7th meeting of the GCF Board (Decision B.07/06) to support the GCF Secretariat, iTAP and Board to assess the relative merits of different funding proposals and provide a basis for funding decisions. The investment framework comprises the six criteria against which all funding proposals are assessed: climate rationale and the potential for adaptation and mitigation; theory of change/transformational change applied to a project; sustainable development potential; country ownership; needs of the recipient; and efficiency and effectiveness (Box 4.3).

Proposals on agriculture and food security projects already represent a considerable percentage of the current GCF pipeline, and their share is expected to increase. It is essential to ensure that they represent high-quality projects that promote climate-smart approaches, innovative technologies, and practices and techniques that ensure agricultural intensification while preserving the environment and biodiversity. It is recommended that proposals promote effective climate adaptation, which help build the resilience of millions of poor family farmers, and contribute to the mitigation of GHG emissions (Box 4.4).

67 GCF/B.25/09.

68 Decision B.17/08 and approved Work Programme of the Secretariat for 2018 and 2019.

Box 4.1
Indicative estimates of financing needs for climate adaptation and mitigation in agriculture

- Estimates for achieving food security are a net USD 83 billion a year in developing countries and USD 11 billion in sub-Saharan Africa alone. Sub-Saharan Africa is particularly vulnerable to climate change impacts, with annual costs for climate change adaptation between 2010 and 2050 estimated at USD 18 billion, with more needed for low-carbon development.
- According to the 2018 Climate Policy Initiative (CPI) report, out of the USD 463 billion invested in climate change (average of 2015–2016 figures), only USD 5 billion flowed to adaptation and USD 4 billion to mitigation in the agriculture, forestry, land use and natural resource management sector. Official Development Assistance for the "agricultural development sub-sector" has gone down since 2014 – from around USD 2.8 million to USD 2.5 million in 2017.

SOURCES: FAO. 2019h. *AIDmonitor* [online]. [Cited 22 October 2019]. www.fao.org/aid-monitor/analyse/sector/en/; Climate Policy Initiative (CPI). 2018. *Global Climate Finance: An Updated View 2018.* (also available at https://climatepolicyinitiative.org/wp-content/uploads/2018/11/Global-Climate-Finance-_-An-Updated-View-2018.pdf).

4.3 OPPORTUNITIES WITH THE GLOBAL ENVIRONMENT FACILITY

The Global Environment Facility (GEF) serves as a Financial Mechanism of the United Nations Framework Convention on Climate Change (UNFCCC). The GEF's programming, its policies and operations on climate change are guided by the UNFCCC Conference of Parties (COP). Through the GEF Trust Fund, developing countries can access resources for climate change mitigation activities and the GEF administers two separate funds (LDCF and SCCF), dedicated to finance climate change adaptation.

The GEF model relies upon eighteen GEF Agencies to work with countries to develop project proposals and then oversee their implementation by country partners. The Operational Focal Point (OFP), together with relevant government ministries, decides which GEF Agency is suited to develop and implement projects. The Agency submits project proposals to the GEF Council on a semi-annual basis; it also provides support to eligible governments and NGOs to develop, implement and execute their projects.

GEF climate projects are designed in alignment with national priorities as identified in relevant policies and plans, such as the Nationally Determined Contributions (NDCs), National Adaptation Programmes of Action (NAPAs), Nationally Appropriate Mitigation Actions (NAMAs), National Adaptation Plans (NAPs), as well as other climate change strategies where they exist. GEF-funded climate action initiatives are also encouraged to promote synergies across the different GEF focal areas.

The GEF Trust Fund: Climate Change Mitigation Focal Area in GEF-7

The GEF's 7th and current funding cycle – referred to as GEF-7 – runs from 2018 to 2022 and is based on voluntary contributions, replenished by donor countries every four years. In order to ensure the highest impact of the resources dedicated to mitigation efforts, climate change mitigation resources have been channelled into two priority areas for the GEF-7 programming: Impact Programs and energy transformation.

Table 4.1.
Selected Climate Funds and Initiatives

FUND	PRIORITIES	FUND AVAILABILITY	ELIGIBILITY
GCF	Support developing countries to limit or reduce their GHG emissions and adapt to climate change impacts.	USD 10.24 billion announced and signed (as at 30 April 2019).	Countries most vulnerable to the effects of climate change, especially SIDS, LDCs and African States.
AF	Support to adaptation projects and programmes in developing countries — party to the Kyoto Protocol.	Over USD 546 million allocated. In September 2019, the AF Board approved 63 million in new projects, including First Innovation and Scale-Up Grants.	Countries party to the Kyoto Protocol.
GEF	Support to projects that address global environmental challenges, including climate change.	The GEF provides funding to projects with CCM objectives, including UNFCCC enabling activities. By 30 June 2019, USD 6.2 billion in GEF funding had been invested in 972 projects on CCM.	Developing countries and countries with economies in transition (CEIT)
LDCF (administered by GEF)	Support to adaptation priorities identified in NAPAs, NAPs and NDCs.	Total USD 1.3 billion; the LDCF holds the largest portfolio of adaptation projects in LDCs.	Least Developed Countries.
SCCF (administered by GEF)	Support to adaptation priorities identified in NAPAs, NAPs and NDCs.	More than 340 million of voluntary contributions from donors.	All developing countries; priority for SIDS.
Forest Carbon Partnership Facility (FCPF) (Administered by the WB)	Global partnership. Focus on reducing emissions from deforestation and forest degradation; forest carbon stock conservation.	The FCPF supports REDD+ efforts through its (i) Readiness Fund (USD 400 million), and (ii) Carbon Fund (USD 900 million).	Currently 47 developing countries https://www.forestcarbonpartnership.org/countries

SOURCE: Authors.

Table 4.1. (continuation)

ACCREDITED ENTITIES	FUNDING MODALITY	FURTHER INFORMATION
Private, public, NGO, subnational, national, regional, international. Currently, there are 88 Accredited Entities (AE). See: https://www.greenclimate.fund/how-we-work/tools/entity-directory	Grants (including REDD+ Results-Based Payments), concessional debt financing, equity and guarantees. Access modalities: Direct Access and International Access. Approved list of GCF Accredited Entities, conditions apply.	https://www.greenclimate.fund/home
Full list and status as at 15 March 2019: https://www.adaptation-fund.org/wp-content/uploads/2019/04/Accreditation-status-of-the-Implementing-Entities_March-2019.pdf	National (NIE), Regional (RIE) and Multilateral Implementing Entities (MIE), Readiness for Climate Finance Programme (small grants), Innovation Facility (small grants).	https://www.adaptation-fund.org Programme on Innovation: https://www.adaptation-fund.org/apply-funding/innovation-grants/ Climate Finance Readiness Programme: https://www.adaptation-fund.org/readiness/
18 GEF Implementing Agencies (IA). https://www.thegef.org/partners/gef-agencies	Grant financing. Full-Sized Projects (over USD 2 million) or Medium-Sized Projects (up to USD 2 million).	http://www.thegef.org/topics/climate-change-mitigation http://www.thegef.org/sites/default/files/documents/gef_report_unfccc_cop25.pdf
18 GEF Implementing Agencies (IA). https://www.thegef.org/partners/gef-agencies	Grant financing. LDCF projects generate adaptation benefits. Full-Sized Projects (over USD 2 million) or Medium-Sized Projects (up to USD 2 million).	https://www.thegef.org/documents/gef-climate-change-adaptation-results-framework-gef-7 https://www.thegef.org/sites/default/files/publications/23469_LDCF_1.pdf
18 GEF Implementing Agencies (IA). https://www.thegef.org/partners/gef-agencies	Grant and concessional financing. Full-Sized Projects (over USD million) or Medium-Sized Projects (up to USD 2 million).	https://www.thegef.org/sites/default/files/publications/23469_LDCF_1.pdf http://www.thegef.org/sites/default/files/documents/gef_report_unfccc_cop25.pdf
REDD Country Participants/FCPF participant countries.	The Readiness Fund is grant based. Within the Carbon Fund, funds are delivered in exchange for emission reductions.	Carbon Fund https://www.forestcarbonpartnership.org/requirements-and-templates Readiness Fund https://www.forestcarbonpartnership.org/requirements-and-templates

Impact Programs

The Impact Programs (IPs) form a core part of the wider GEF-7 strategy to shift from fragmented and often stand-alone investments towards more integrated and systems-based programmes. These global programmes aim to catalyse transformation in key economic systems by tackling drivers, both on the supply and demand side, that lead to environmental degradation and increased GHG emissions. Three major economic and natural systems, which all offer significant opportunities to cut GHG emissions, have been prioritised for the GEF-7 Impact Programs through a system-wide approach: food systems, land use and restoration; sustainable forest management (covering key forest biomes spanning the Amazon, Congo Basin and Drylands); and sustainable cities.

All three IPs are expected to catalyse transformative shifts towards sustainable growth by reducing or avoiding GHG emissions (otherwise associated with these economic systems), and increasing carbon sinks through the reversal of deforestation and land degradation.

In GEF-7, the Impact Programs remain the main opportunity for countries to programme their climate change mitigation allocation in the AFOLU sector, in addition to the Capacity Building Initiative for Transparency (CBIT).

DID YOU KNOW?

- The Agriculture and Other Land Use (AFOLU) sector represents the second largest source of emissions after the energy sector. Globally, the sector accounts for up to 21% of emissions; in developing countries, it accounts for up to 50%. At the same time, the agriculture sectors are highly climate-sensitive and are increasingly impacted by climate change and variability. This is also reflected in NDCs, in which countries frequently refer to the agriculture sectors.
- AFOLU-related GHG emissions are expected to continue growing due to the increasing global population, development trends and food demands. However, the lack of data in the AFOLU sector and particularly for agriculture remains a limiting factor for addressing transparency requirements.

See: https://www.thegef.org/sites/default/files/project_documents/08-03-17_PIF_Request_Document_revised_SN_0.pdf

Capacity Building Initiative for Transparency (CBIT)

Transparency constitutes an essential part of the Paris Agreement, as it is a precondition for raising climate ambitions and is key for tracking and reporting progress on Parties' contributions to the Paris Agreement (the NDCs) as well as building collective trust and confidence in accountability. As part of the Paris Agreement (Article 13), Parties agreed to an Enhanced Transparency Framework (ETF) for action and support. However, many developing countries still lack the capacity to effectively monitor and report progress towards their NDC commitments. At COP 21 in Paris, Parties requested that the GEF support the establishment and operation of the Capacity-building Initiative for Transparency (CBIT). Its objectives are to (i) enhance national institutions on transparency-related activities in line with national priorities; (ii) provide relevant tools, training, and assistance for meeting the provisions stipulated in Article 13 of the Agreement; and (iii) assist in the improvement of transparency over time (see Table 4.1).

Almost 30 percent of the approved to-date CBIT projects include a specific component for enhancing measurement and transparency of GHG emissions from the AFOLU sector (see Box 4.5). This provides an indication of the importance of emissions stemming from the AFOLU sector, particularly among developing countries including the Least Developed Countries (LDCs). It also reflects the challenges in the sector when it comes to quantifying and reporting on emissions and removals due to limited data as well as the need for technical capacities for the quantification and projections of AFOLU-related emissions, compared to other sectors.

Box 4.2.
What is climate finance?

Climate finance refers to the flows of capital from both public and private sources that support and finance climate-smart investments and aim to achieve climate change adaptation and mitigation objectives.

Climate finance is considered to be a source of capital for climate-smart investments that has demonstrated its ability to unlock additional public and private capital, such as from domestic national budgets, the private sector, bilateral and multilateral actors, DFIs, and institutional investors.

SEE: Sadler *et al.* 2016. *Making climate finance work in agriculture.* Washington, DC, World Bank Group. http://documents.worldbank.org/curated/en/986961467721999165/Making-climate-finance-work-in-agriculture.

The GEF's Climate Change Adaptation Trust Funds

As an operating entity of the financial mechanism to the Paris Agreement and the UNFCCC, the GEF administers the Least Developed Countries Fund (LDCF) and Special Climate Change Fund (SCCF), which are dedicated to providing adaptation finance to reduce vulnerability and build resilience to climate change in developing countries (please see Table 4.1 for more details). The GEF, which was the first global source of funds for adaptation, channels support to climate adaptation efforts primarily through the LDCF and SCCF. The LDCF is dedicated to financing activities exclusively for the Least Developed Countries (LDCs) that face challenging circumstances to adapt to the impacts of climate change. The LDCF remains the only fund entirely dedicated to supporting adaptation action in LDCs. The SCCF, on the other hand, has been designed to finance activities, programmes and measures related to climate change adaptation and technology transfer to all eligible developing countries.

The GEF-7 Adaptation Strategy provides the framework for LDCF/SCCF programming for the period 2018–2022 (GEF, 2018). The overall goal of the GEF-7 adaptation strategy is to strengthen resilience and reduce vulnerability to climate change in developing countries, and support their efforts to enhance adaptive capacity. This is fully aligned with the long-term adaptation goal of the Paris Agreement, stipulated in Article 7. The strategy outlines three strategic objectives to achieve the abovementioned goal: (1) reduce vulnerability and increase resilience through innovation and technology transfer for climate change adaptation; (2) mainstream climate change adaptation and resilience for systemic impact; and (3) foster enabling conditions for effective and integrated climate change adaptation. Figure 4.1 provides an illustration of the LDCF strategic objectives and entry points under each objective.

The adaptation strategy also emphasizes complementarity and partnerships among financing entities, including the GCF, to mutually enhance effectiveness and impact, and ultimately offer more sustainable solutions to countries. In addition, private sector engagement is considered an integral part of the efforts to deliver on the three objectives of the strategy. A particu-

Box 4.3.

Preparing GCF project proposals: insights

The process of developing a Green Climate Fund (GCF) concept note into a high-quality GCF project funding proposal could require 6 to 18 months of preparation time. This will depend on the country and project, as well as the available information and foundation upon which the proposed investment project builds.

Climate Rationale

GCF is first and foremost a climate change fund, and thus will only support projects that have a narrative, rationale and theory of change rooted in the response to climate change. GCF is interested in supporting projects that enhance natural resources management, poverty reduction, and nutrition; but these should be framed as sustainable development co-benefits, rather than as a primary project objective. In this context, the GCF has also stressed that this climate focus needs to be reflected explicitly in the narrative and short title of a project.

Theory of change

It is recommended that a project be developed by starting with the climate impacts identified for the project location by a group of beneficiaries. A project's underlying theory of change should start from the imperative of addressing climate change impacts. This discussion should be followed with activities to be implemented. Interventions to be supported through a proposed project should be clearly linked to the specific climate challenges/needs identified in the baseline scenario, and the relevant barriers that are otherwise inhibiting action to effectively respond to these specific challenges and needs. This should be substantiated by methodologically sound project annexes as well as relevant support studies, such as climate risk and vulnerability assessments, feasibility studies, economic and financial analyses, among others.

Financing for GCF projects should be reasonable and fully justified:

- Funding requests should be linked to the needs of the recipient country. For example, middle-income countries may have more difficulty justifying requests for highly concessional funds given the resources they already have at their disposal.
- Funding requests should constitute an efficient use of scarce GCF resources. Where possible, GCF funds should thus be used in an innovative way to catalyze and unlock additional public and private investment.
- Projects should request appropriate concessionality for the activities being proposed.
- Co-financing needs to correspond to the particular country and context, and arrangements made with co-financiers before submitting a particular funding proposal to the GCF.

Implementation arrangements

Project implementation and execution arrangements should be clear and (to the extent possible) simple. Overly complex and unclear implementation arrangements may complicate project delivery and affect the final GCF funding decision on financing granting. The GCF Secretariat and iTAP have indicated a preference for projects that include a strong role for national counterparts in project execution. This is partly because such arrangements are seen as vital to enhancing national ownership and capacity, and thus sustaining support after projects are complete.

Government involvement/National ownership

Access to GCF funding is a country-driven process, coordinated and overseen by the National Designated Authority (NDA). The project's country ownership needs to be demonstrated by extensive information provided on stakeholder consultations and involvement, and the submission of a clear plan of how engagement will continue during implementation.

SEE: https://www.greenclimate.fund/documents/20182/239759/Investment_Framework.pdf/eb3c6adc-0f24-4586-8e0d-70aa6fb8c3c8 lar focus is on the involvement of local micro, small-, and medium-sized enterprises that have the potential to contribute to increasing climate resilience in vulnerable populations and rural communities.

The LDCF provides support to projects that address adaptation priorities identified by LDCs in their NAPAs, NAPs and NDCs, including the following priority areas/themes: agriculture, water, disaster risk management, climate information systems, sustainable land and forest management, urban development and infrastructure, energy, health, and coastal zone management. Common threads help address these priorities:

- climate proofing major components of national economies and sustainable development plans;
- protecting livelihoods and enhancing adaptive capacity;
- achieving and safeguarding food and water security;
- enhancing ecosystem structures and functions; and
- supporting and enhancing human health and safety.

In addition, private sector aspects, such as value chains, market development, risk transfer and sharing mechanisms, insurance/re-insurance and eco-tourism, are also relevant. Box 4.6 illustrates examples of climate-sensitive GEF-7 projects in the rice sector.

4.4 NON-UNFCCC CLIMATE FINANCING

Non-UNFCCC financial institutions include development banks and other UN agencies. Examples include the Forest Carbon Partnership Facility ([FCPF] see Table 4.1), which is a global partnership of governments, businesses, civil society, and indigenous peoples' organizations focused on reducing emissions from deforestation and forest degradation, forest carbon stock conservation, the sustainable management of forests, and the enhancement of forest carbon stocks in developing countries (these activities are generally referred to as REDD+). The United Nations Program on Reducing Emissions from Deforestation and Forest Degradation (UN REDD Program), which is a collaborative program of the Food and Agriculture Organization of the United Nations (FAO), the United Nations Development Program (UNDP), and the United Nations Environment Program (UNEP), was created in response to the UNFCCC decision on the Bali Action Plan and REDD at COP13 in 2008. UN REDD aims to reduce emissions from deforestation and to enhance carbon sinks from forests while contributing to sustainable development at the national level.

Other examples of non-UNFCCC financing include those coming from GEF's Small Grant Programme (SGP), the World Bank (e.g. Forest Investment Programme), the International Fund for Agricultural Development (IFAD) and banks such as the Asian Development Bank, the Inter-American Development Bank (IDB), and the African Development Bank. Providers of bilateral climate finance include the European Union and national governments (usually through official development cooperation). Many countries are particularly active in the global climate finance arena: Germany, Japan, Nordic countries, Switzerland, the United Kingdom of Great Britain and Northern Ireland, and the United States of America. Regional and national funds in developing countries are also available (e.g. the Amazon Fund). Lastly, there are also numerous non-governmental finance mechanisms, including foundations, philanthropic institutions and faith-based organizations (GEF, 2019).

Box 4.4.
GCF FAO El Salvador: Upscaling climate-resilience measures in the dry corridor agroecosystems of El Salvador (RECLIMA)

The five-year USD 127.7 million RECLIMA project seeks to strengthen the resilience of smallholder farmers, who are on the frontline of climate change impacts, by promoting climate adaptation measures. The Green Climate Fund will allocate USD 35.8 million to an FAO-designed project in El Salvador's Dry Corridor aimed at building climate change resilience in farming systems. In addition to the GCF grant, the project will receive USD 91.8 million from the Salvadorean Government and the Initiative for the Americas Fund (FIAES).

El Salvador, located in the dry corridor of Central America, is one of the most vulnerable countries to climate risks in the world. Climate change projections show that there will be reductions in water availability of between 35% and 63% in El Salvador, and IPCC predicts that rising temperatures will reduce the country's yields of main crops by 30% by 2050, mainly through recurrent droughts. Agriculture contributes 11% to the country's GDP. Smallholder family farmers, who account for 82% of all agricultural producers in the country, are particularly vulnerable to climatic stresses, as they are largely dependent on rainfed production systems. Climate change will therefore have direct implications on food security, especially in the dry corridor of the country, where it has been estimated that 86% of the population is vulnerable to climate change.

The project objective is to improve the resilience of the livelihoods of the vulnerable population of El Salvador's dry corridor to the effects of climate change, through adaptive agroecosystem management. This GCF-FAO project will implement a landscape approach to adaptation throughout the Dry Corridor by transforming the Government's existing nationwide Social Protection and Development Programme – especially the "Agricultural Package", which is an input based package focused on increasing productivity and fertility among poor and vulnerable family farmers through non-resilient productive options. It will be transformed into a Paquete Agricola++ that will integrate off-farm restoration and on farm-level adaptation measures:

- scaling up the use of resilient open-pollinated seed varieties;
- introducing resilient agricultural practices;
- restoring and reforesting degraded ecosystems;
- enhancing water access and water efficiency; and
- enriching extension methodologies.

This GCF investment will shift practices from the current non-sustainable agricultural production system in the country to a resilient, sustainable food system and will climate-proof existing national programmes and planning instruments that by Law have public funding allocations, offering a unique opportunity for scale up and replication.

The implementation of the RECLIMA project is expected to result in an average 10% increase in yields over current levels. This will help farmers to transition to a state in which they are no longer dependent on subsidy support, and reach levels of income and resilience that make them more attractive to banks and other financial service providers.

SEE: FAO, FAO's work on climate change: *United Nations climate change conference 2019* (Rome, 2018: p.28).

Box 4.5.
FAO Global CBIT AFOLU project

The project aims to strengthen developing countries' technical and institutional capacity – through the coordinated dissemination of knowledge – to meet Enhanced Transparency Framework (ETF) requirements when implementing priority actions in the AFOLU sector and to contribute towards the achievement of their respective NDCs. The implementation of activities will allow the global CBIT-AFOLU project to deliver a combination of stand-alone tools designed to help countries to overcome the challenges posed by the ETF in the agriculture sectors; pilot actions aimed at validating and refining the tools while stimulating country-level capacities to comply with the ETF in the agriculture sectors; disseminate knowledge and tools across a wide range of platforms and networks; and coordinate with other transparency practitioners to ensure a broad outreach.

4.5 THE CATALYTIC ROLE OF PUBLIC CLIMATE FINANCE

It is estimated that only a small portion of total climate finance flows into agriculture. In addition to the limited funds available, there are a number of constraints that limit countries' capacities to access financing for climate-smart investments in agriculture as well as to implement them. The main constraints relate to (i) low level of awareness of climate adaptation needs and relevant sources of funding; (ii) low capacity in developing projects that meet requirements and standards of potential financiers; (iii) limited climate knowledge and data availability; (iv) lack of coherent policies and legal and regulatory frameworks; and (v) lack of clear priorities for climate-smart investments in agriculture at national level (OECD, 2019). Once funds are received, difficulties also exist with the low absorptive capacity of low-income countries' public financial systems (FAO, 2016b). These capacity constraints have already been addressed by some climate finance providers, such as GCF's targeted Readiness and Preparatory Support programme (see Box 4.7).

Activities funded by public finance can have a strong catalytic effect, encouraging the mainstreaming of climate change considerations into national sustainable development plans and programmes, and sectoral development strategies. Public funding should support the development of an enabling environment that is conducive to scaling up climate-smart agriculture and to attracting increased public and private financing for the agriculture sectors. This also includes the development of policies and institutions that support the prevention and management of climate risks and vulnerabilities based on improved climate services. For climate-related policies to be successfully implemented, climate change needs to be fully integrated into domestic budgets for agricultural investments and in public expenditure reviews, with climate change strategies and plans realistically prioritized and costed.

Available estimates suggest that the private sector has the largest potential to finance agricultural investments that could be directed for climate change adaptation and mitigation efforts in the sector. Most agricultural investments are financed through domestic public and private resources, with only a small share flowing from international sources. As all investments in agriculture today need to be climate smart, both public and private investors in the sector will need to support the transition to low-

Box 4.6.
FAO-GEF project examples in GEF-7: Climate change mitigation and adaptation in the rice sector

Food systems, land use and restoration (FOLUR) Impact Program in Viet Nam
Rice plays a vital role in Viet Nam's agricultural sector, with a significant number of smallholder farmers depending on it for their livelihoods, particularly in the Mekong Delta. The Delta is home to 17 million people, 60% of whom are engaged in rice cultivation. It produces 50% of Viet Nam's rice and 95% of its exported rice, and is one of the world's largest rice producing areas. The emphasis on increased production has come at the expense of the environment, with methane emissions from paddy fields contributing to climate change. Fragmented land-use planning with extensive use of agro-chemical inputs has caused human health issues, land degradation, water pollution, and loss of biodiversity. Furthermore, rice production is responsible for approximately 17% of the country's total GHG emissions.

The FOLUR project in Viet Nam will adopt an integrated, multisectoral and multilevel approach, addressing key sustainability and social inclusion issues in rice production landscapes – both on-farm and off-farm. Climate change mitigation activities include scaling up climate-smart farming practices and diversification through the application of agreed local, national and international rice standards. A mix of proven participatory approaches also enables industry stakeholders and relevant actors to enhance sustainable value chains and products. The project will also develop monitoring frameworks for agricultural GHG mitigation, including indicators and monitoring, reporting and verification (MRV) tools that can serve as blueprints at the national level for farmer participation in the carbon market.

LDCF: Promoting Climate-Resilient Livelihoods in Rice-Based Communities in Tonle Sap Region, Cambodia
Rice production in Cambodia is mainly based on smallholder farmers, who cultivate less than two hectares of land. Much of the country's rice area is rainfed, making it highly dependent on seasonal rainfall and associated flooding conditions of the Mekong River and its key tributaries, including the Tonle Sap. As a result, rice yields are significantly lower when compared to some other Southeast Asian countries with more extensive irrigation-supported production systems. Furthermore, the lack of access to appropriate supply chain infrastructure and value-adding technologies is preventing smallholders from participating effectively in market systems. In addition to being an LDC, Cambodia is also ranked as one of the most climate-vulnerable countries in the world. The impacts of climate change are already negatively affecting rice-based landscapes and the productive output of the supply chain, thereby further increasing the current vulnerability of rural households in Cambodia.

This recently approved LDCF project will benefit Cambodian smallholder farmers and value chain actors in the Tonle Sap region, whose livelihoods and food security particularly depend on rice. Through its activities, the project will employ an ecosystem-based and market-driven approach to reduce the climate vulnerability of rice-based communities and increase their resilience to climate change. By targeting the local private sector, the project will develop mechanisms to incentivize the uptake of climate-resilient practices and investments in adaptation techniques and technologies along the value chain. This includes the promotion of approaches, such as Participatory Guarantee Systems (PGS) and the Sustainable Rice Platform (SRP) assurance scheme to create stable market opportunities and increase value addition for climate-smart agricultural products, which will create further incentives for farmers to continue with climate-resilient practices while also improving investment in post-harvest infrastructure.

SOURCE: Authors.

Box 4.7.
GCF Readiness and Preparatory Support Programme

The GCF Readiness and Preparatory Support Programme (the Readiness Programme) is a funding programme to enhance country ownership and access to fund resources. The Programme provides resources for strengthening the institutional capacities of National Designated Authorities (NDAs) or focal points and Direct Access Entities (DAEs) to efficiently engage with the Fund. Resources may be provided in the form of grants or technical assistance.

All developing countries can access the Readiness Porgramme, and the Fund aims for a floor of 50 percent of the Readiness support allocation to particularly vulnerable countries, including Least Developed Countries (LDCs), Small Island Developing States (SIDS) and African States. Up to USD 1 million per country per year may be provided under the Readiness Programme. Of this amount, NDAs or focal points may request up to USD 300 000 per year to help establish or strengthen an NDA or focal point to deliver on the Fund's requirements. Up to USD 3 million per country can be allocated for the formulation of national adaptation plans and/or other adaptation planning processes by NDAs or focal points.

This support can facilitate the development of National Adaptation Plans, which set national priorities for measures to address adaptation to climate change. Furthermore, GCF can provide capacity building for national or regional organizations (DAEs) that are nominated by their NDAs. Support can be provided to enhance the ability of an entity to seek accreditation with the Fund, including for the fast-track accreditation process (pre-accreditation support). Support can also be provided to build the capacities of DAEs that are already GCF accredited (post-accreditation support). In each case, Readiness funds will be allocated in coordination with, and with the approval of, the relevant NDA. FAO is currently implementing 29 Readiness projects, including three projects under the National Adaptation Plan (NAP) process.

SEE: www.fao.org/climate-change/international-finance/green-climate-fund/en/

OBJECTIVES

1 — Reduce vulnerability and increase resilience through innovation and technology transfer for climate change adaptation

- ↗ Innovation in priority sectors, themes & private sector
- ↗ Climate security
- ↗ Incubation and accelerator support

2 — Mainstream climate change adaptation and resilience for systemic impact

- ↗ Mainstream adaptation across GEF focal areas and IPs
- ↗ Innovative partnerships
- ↗ Support for NAP process

3 — Foster enabling conditions for effective and integrated climate change adaptation

- ↗ Support for NAP process
- ↗ Support for LDC work programme
- ↗ Support for enabling activities

Figure 4.1.
Overview of the GEF-7 LDCF strategic objectives and corresponding entry points

SOURCE: GEF internal communication, 2019.

carbon and climate-resilient agriculture, and adopt innovative ways to attract additional capital to the agricultural sector.

New and innovative financing mechanisms have emerged. For example, *Public-Private Partnerships* (PPPs) contribute to catalyzing additional capital from public and private sectors. PPPs can also help to accommodate the interests of a wide range of actors with different risk-taking levels, desired investment returns, and leverage a variety of capacities and expertise. Partners in PPPs can include public donors, international and non-governmental organizations, foundations, research institutions, UN organizations, development and international financial institutions, private companies and impact or institutional investors. Innovative *blended finance* is the strategic use of catalytic capital from public sources to mobilize additional private sector investment. Typical blended finance is structured around four approaches for raising private capital: 1) grants at project design stage; 2) technical assistance funds; 3) guarantee/risk insurance; and 4) concessional loans (Table 4.2).

An example is a weather index-based guarantee/insurance fund that is based on weather variability rather than on crop damage, offering major benefits to producers and, at the same time, giving the private sector the assurance of a risk mitigation framework in place (Box 4.8).

Table 4.2.
Climate finance instruments common for supporting agricultural projects

Climate finance instrument	Examples of support areas
Grants	· Technical assistance for policy development · Capacity building of farmers and government institutions to address climate-related constraints · Strategies and guidelines development to support adoption of climate-smart agriculture principles and practices
Concessional loans	· Innovative climate-smart investment projects · Facilitation of access to private finance through PPP and other entities · Development of climate information and climate-smart advisory services
Guarantees	· Risk sharing with lenders to promote investments in climate-smart investments and in more remote rural areas · Credit guarantee schemes to replace collateral requirements and expand lending to farmers · Premium in agricultural insurances (weather and commodity price) to extend insurance services to farmers
Equity	· Equity funds to respond to climate-smart investment opportunities
Performance-based mechanisms	· Funding for measurable and previously agreed upon results; introduces performance incentives in the delivery of services (both at a project or an institutional level)
Green bonds	· All of the funds invested in green bonds are used for funding projects that are environmentally friendly and climate-responsible

SOURCE: Authors.

Box 4.8.

Crop Insurance in the Philippines: Climate de-risking with CARD Pioneer

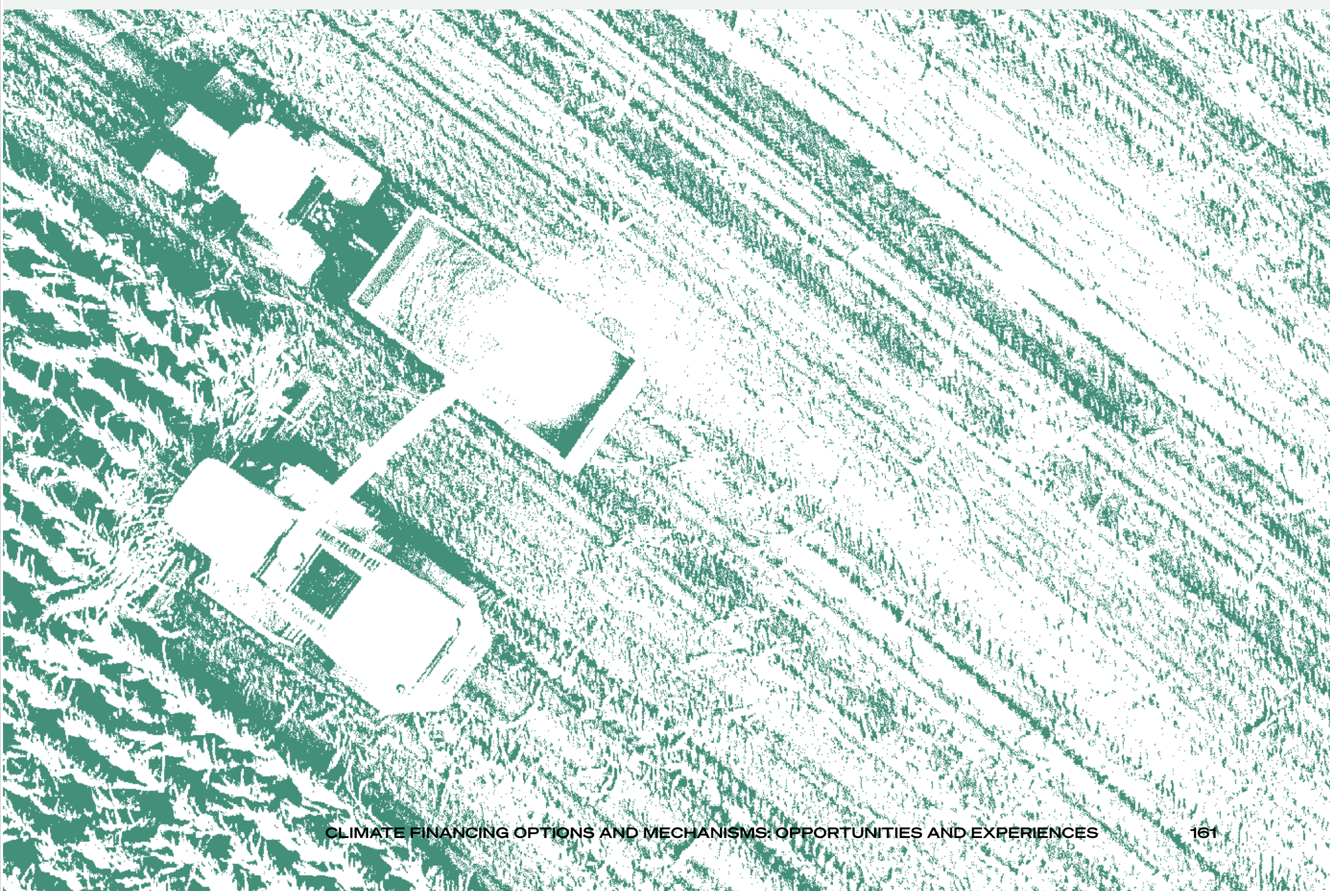
In 2014, the Center for Agriculture and Rural Development (CARD), the largest microfinance and microinsurance group in the Philippines, formed a joint venture with Pioneer Insurance, a leading private insurance company in the country, to tackle the challenge of providing affordable and sustainable microinsurance to farmers who are considered high risk. The venture was named "CARD Pioneer Microinsurance Inc. (CPMI)."

CPMI went on to provide the first ever private sector-led crop insurance product against typhoons and tropical depressions in the Philippines, launching the product in 2016 and rolling it out in 2017. The product is targeted for rice and corn farmers, has an average dispersal time of two-to-five days (never longer than two weeks), and currently retails with no premium subsidy support from the government. With a more efficient claims process and extensive distribution points, CPMI has been able to target farmers scattered in remote areas across the country, reaching well beyond the main urban centres.

To date, 14 000 smallholder farmers in 12 provinces have purchased the insurance product, bundled with microfinance loans through CARD's NGO microfinance institution. The product's effectiveness has attracted more farmers to purchase the product and encouraged repeat purchases for those who have made and received claims. The product also increased the confidence of lenders to provide more financing to smallholder farmers and CARD is planning to expand distribution further to two of their own banks.

CARD Pioneer is now working with IFC to develop an insurance product for drought-prone farmers. So the next phase of IFC engagement is to find a model for using donor funds to set up a partial stop loss facility at the reinsurance level so that CPMI can expand their coverage, without having to increase premiums that farmers have to pay. The theory is that as the private market grows, and local technical capacity is built, premiums can be kept at a reasonable/competitive price.

SOURCE: Prepared by A. Gage (FAO) and U. Saoshiro (IFC), 2019.

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References and additional information

INTRODUCTION AND MODULE 1

References (in-text citation)

Asian Development Bank (ADB). 2012. *Guidelines for climate proofing investment in agriculture, rural development and food security.* Mandaluyong City, Philippines, ADB. (also available at www.adb.org/sites/default/files/institutional-document/33720/files/guidelines-climate-proofing-investment.pdf).

FAO. 2008. *Climate Change and Food Security: A Framework Document*. Rome. 110 pp. (also available at www.fao.org/3/k2595e/k2595e00.pdf).

FAO. 2012a. *Incorporating Climate Change Considerations into Agricultural Investment Programmes.* Rome. 148 pp. (also available at www.fao.org/3/i2778e/i2778e.pdf).

FAO. 2012b. *Identifying Opportunities for Climate-Smart Agriculture Investments in Africa.* Rome. (also available at http://www.fao.org/3/an112e/an112e00.pdf).

FAO. 2013. *Climate-Smart Agriculture Sourcebook* (1st edition). Rome. 570 pp. (also available at www.fao.org/3/i3325e/i3325e.pdf).

FAO. 2015a. *The impact of natural hazards and disasters on agriculture and food security and nutrition: A call for action to build resilient livelihoods.* Rome. 16 pp. (also available at www.fao.org/3/i3325e/i3325e.pdf).

FAO. 2016a. *The State of Food and Agriculture: Climate Change, Agriculture and Food Security.* Rome, Italy. 190 pp. (also available at www.fao.org/3/a-i6030e.pdf).

FAO. 2016b. *Climate Change and Food Security: Risks and Responses.* Rome. 110 pp. (also available at www.fao.org/3/a-i5188e.pdf).

FAO. 2017a. *The future of food and agriculture – Trends and challenges.* Rome. 180 pp. (also available at www.fao.org/3/a-i6583e.pdf).

FAO. 2017b. *Addressing agriculture forestry and fisheries in national adaptation plans (supplementary guidelines).* Rome. 116 pp. (also available at www.fao.org/3/a-i6714e.pdf).

FAO. 2017c. *Climate-Smart Agriculture Sourcebook, 2nd edition* [online]. Rome. [Cited 15 December 2019]. www.fao.org/climate-smart-agriculture-sourcebook/en

FAO. 2018a. *Transforming food and agriculture to achieve the SDGs.* (also available at www.fao.org/3/I9900EN/i9900en.pdf).

FAO, IFAD, UNICEF, WFP & WHO. 2018. *State of Food Security and Nutrition in the World. Building Climate Resilience for Food Security and Nutrition.* Rome, FAO. 202 pp. (also available at www.fao.org/3/i9553en/i9553en.pdf).

FAO. 2019a. *State of Food Security and Nutrition in the World. Safeguarding Against Economic Slowdowns and Downturns.* Rome. 239 pp. (also available at www.fao.org/3/ca5162en/ca5162en.pdf).

FAO. 2019b. *Climate-smart agriculture and the Sustainable Development Goals: Mapping interlinkages, synergies and trade-offs and guidelines for integrated implementation*. Rome. 144 pp. (also available at www.fao.org/3/ca6043en/CA6043EN.pdf).

Ferrarese, C., Mazzoli, E. & Rinaldi, R. 2016. *Review of economic and livelihood benefits for ASAP-supported investments*. Rome, IFAD.

IFAD. 2017. Social, Environmental and Climate Assessment Procedures (SECAP). Rome. (also available at www.ifad.org/en/document-detail/asset/39563472).

IPCC. 2014a*:* Mach, K.J., Planton, S. & von Stechow, C., eds. Annex II: Glossary. In R.K. Pachauri & L.A. Meyer, eds. *Climate Change 2014: Synthesis Report,* pp. 117–130*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. IPCC, Geneva, Switzerland. (also available at https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_Annexes.pdf).

IPCC. 2014b. *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. R.K. Pachauri & L.A. Meyer, eds. IPCC, Geneva, Switzerland. 151 pp. (also available at www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf).

IPCC. 2014c. *Climate Change 2014: Mitigation of Climate Change*. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, *et al*., eds. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

IPCC. 2018. *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, *et al.* eds. In Press. (also available at https://www.ipcc.ch/sr15/download/).

IPCC. 2019a. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.* P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D. C. Roberts, P. Zhai, *et al.* eds. In press. (also available at www.ipcc.ch/report/srccl/).

MacLeod, M., Eory, V., Gruère, G. & Lankoski, J. 2015. *Cost-Effectiveness of Greenhouse Gas Mitigation Measures for Agriculture: A Literature Review.* OECD Food, Agriculture and Fisheries Papers, No. 89. OECD Publishing, Paris.

Mbow, C., Rosenzweig, C., Barioni, L.G., Benton T.G., Herrero, M., Krishnapillai, M., Liwenga, E. *et al*. 2019: Food Security. In P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.-O. Pörtner, D.C. Roberts, P. Zhai, *et al.,* eds. *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems*, 437–550. In press. (also available at www.ipcc.ch/site/assets/uploads/sites/4/2019/11/08_Chapter-5.pdf).

OECD. 2012. *OECD environmental outlook to 2050: the consequences of inaction*. Paris.

OECD. 2015. *The Economic consequences of climate change*. Paris.

Stern, N. 2014. *Growth, climate and collaboration: towards agreement in Paris 2015*. Policy Paper. Centre for Climate Change Economics and Policy and Grantham Research Institute on Climate Change and the Environment, London.

World Bank. 2016a. *Poverty and Shared Prosperity Report 2016: Taking on Inequality. Background Paper. Who are the poor in the developing world*? Washington, DC. (also available at http://documents.worldbank.org/curated/en/187011475416542282/pdf/WPS7844.pdf).

World Bank. 2016b. *Shock Waves. Managing the Impacts of Climate Change on Poverty*. Washington, DC. (also available at https://openknowledge.worldbank.org/bitstream/handle/10986/22787/9781464806735.pdf).

World Bank. 2016c. *Climate Change Action Plan (CCAP)*. Washington, DC. (also available at http://pubdocs.worldbank.org/en/677331460056382875/WBG-Climate-Change-Action-Plan-public-version.pdf).

World Bank, AAA, CIAT, CCAFS & ICRAF. 2019. *Climate-Smart Agriculture Investment Plan Development Guide: From Concept to Action*. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

ADDITIONAL INFORMATION

Batchelor, C. & Schnetzer, J. 2018. *Compendium on Climate-Smart Irrigation: Concepts, evidence and options for a climate- smart approach to improving the performance of irrigated cropping systems*. Global Alliance for Climate-Smart Agriculture, Rome, Italy. (also available at http://www.fao.org/3/CA1726EN/ca1726en.pdf).

European Bank for Reconstruction and Development (EBRD). 2019. *MDB Climate Action: The EBRD Perspective*. Japan. (also available at www.mofa.go.jp/files/000498434.pdf).

FAO. 2019. Conservation Agriculture. In: *FAO* [online]. Rome. [Cited 15 December 2019]. www.fao.org/conservation-agriculture/en/

MODULE 2

References (in-text citation)

Benestad, R. E., Hanssen-Bauer, I. & Chen, D. 2008. *Empirical-statistical downscaling*. World Scientic.

Braimoh, A., Emenanjo, I., Rawlins, M. A., Heumesser, C. & Zhao, Y. 2016. *Climate-smart agriculture indicators*. World Bank Group, Washington, DC. (also available at http://documents.worldbank.org/curated/en/187151469504088937/Climate-smart-agriculture-indicators).

Dessai, S. & Hulme, M. 2004. Does climate adaptation policy need probabilities? *Climate Policy*, 4(2): 107–128.

FAO. 2012b. *Identifying Opportunities for Climate-Smart Agriculture Investments in Africa*. Rome. (also available at http://www.fao.org/3/an112e/an112e00.pdf).

FAO. 2014. FAO Analysis and Mapping of Impacts under Climate Change for Adaptation and Food Security (AMICAF) project in the Philippines.

Component 3. Bicol report on the Philippines. November 2014 (Also available at action/amicaf/resources/technical-reports/en/)
FAO. 2017b. *Addressing agriculture, forestry and fisheries in National Adaptation Panning*. Rome. 116 pp. (also available at www.fao.org/3/a-i6714e.pdf).
FAO. 2017d. Tracking adaptation in agricultural sectors – Climate change adaptation indicators. Rome. 83 pp. (also available at www.fao.org/3/a-i8145e.pdf).
FAO. 2018a. *Transforming food and agriculture to achieve the SDGs.* Rome. 76 pp. (also available at www.fao.org/3/I9900EN/i9900en.pdf).
FAO. 2019b. *Climate-smart agriculture and the Sustainable Development Goals: Mapping interlinkages, synergies and trade-offs and guidelines for integrated implementation*. Rome. 144 pp. (also available at www.fao.org/3/ca6043en/CA6043EN.pdf).
Giorgi, F., Christensen, J., Hulme, M., Von Storch, H., Whetton, P., Jones, R. & Mearns, L. 2001. Regional climate information — Evaluation and projections. J.T. Houghton, Y. Ding, D.J. Griggs, M. Noguer, P.J. van der Linden, X. Dai, K. Maskell, & C.A. Johnson, eds. In: *Climate Change 2001. The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change,* pp 583–638. Cambridge University Press, UK. (also available at www.ipcc.ch/site/assets/uploads/2018/07/WG1_TAR_FM.pdf).
Hanssen-Bauer, I., Achberger, C., Benestad, R., Chen, D. & Førland, E. 2005. Statistical downscaling of climate scenarios over scandinavia: A review. *Clim Res,* 29:255–268.
IPCC. 2007. *Climate change 2007: impacts, adaptation and vulnerability.* Contribution of Working Group II to the Fourth Assessment Report of the IPCC. Cambridge University Press, Cambridge, UK.
IPCC. 2014b. *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. R.K. Pachauri & L.A. Meyer, eds. IPCC, Geneva, Switzerland. 151 pp. (also available at www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf).
Manzanas, R., Brands, S., San-Martín, D., Lucero, A., Limbo, C. & Gutiérrez, J.M. 2015. Statistical downscaling in the tropics can be sensitive to reanalysis choice: a case study for precipitation in the Philippines. *Journal of Climate,* 28(10): 4171–4184.
Meybeck, A., Azzu, N., Doyle, M. & Gitz, V. 2012. Agriculture in National Adaptation Programmes of Action (NAPA). In A. Meybeck, J. Lankoski, S. Redfern, N. Azzu & V. Gitz, eds. *Building resilience for adaptation to climate change in the agriculture sector*, pp. 163–172. Proceedings of a joint FAO/OECD Workshop. Rome, FAO. (also available at www.fao.org/3/i3084e/i3084e13.pdf).
Peduzzi, P. 2006. The Disaster Risk Index: overview of a quantitative approach. In J. Birkmann, ed. *Measuring Vulnerability to Natural Hazards*. New Delhi, Teri Press, 265–289.
Rippke, U., Ramirez-Villegas, J., Jarvis, A., Vermeulen, S.J., Parker, L., Mer, F., Diekkruger, B., *et al.* 2016. Timescales of transformational climate change adaptation in sub-Saharan African agriculture Nat. Clim. Chang.
Rockel, B. 2015. The regional downscaling approach: A brief history and recent advances. *Current Climate Change Reports,* 1: 22–29.

UNFCCC. 2012. *NATIONAL ADAPTATION PLANS: Technical guidelines for the national adaptation plan process*. Bonn, Germany. 152 pp (also available at https://unfccc.int/files/adaptation/cancun_adaptation_framework/application/pdf/naptechguidelines_eng_high__res.pdf).
UNFCCC. 2016a. Focus: Mitigation – NAMAs, Nationally Appropriate Mitigation Actions. In*: UNFCCC Topics* [online]. Bonn. [Cited 15 December 2019]. https://unfccc.int/topics/mitigation/workstreams/nationally-appropriate-mitigation-actions
USAID. 2019. *Tools for Evaluating Climate Change Adaptation Program Interventions: A Toolkit*. (also available at www.climatelinks.org/sites/default/files/asset/document/2019_USAID_ATLAS_Evaluating%20CCA%20Program%20Interventions_Toolkit.pdf).
World Bank. 2014. *Mainstreaming adaptation and climate change in agriculture and natural resource management projects. Guidance note.* Washington DC.
World Bank. 2019. *Zambia Climate-Smart Agriculture Investment Plan: Analyses to Support the Climate-Smart Development of Zambia's Agriculture Sector.* Washington, DC. (also available at https://openknowledge.worldbank.org/handle/10986/31383).

ADDITIONAL INFORMATION

FAO. 2011. *A Technical Report for the Study on Impacts of Climatic Variability on Agriculture in the Bicol Region of the Philippines: Implications for climate change adaptation.*
FAO. 2016. *The State of the Food and Agriculture: Climate Change, Agriculture and Food Security*. Rome, Italy. 190 pp. (also available at www.fao.org/3/a-i6030e.pdf).
FAO. 2017. *Climate-Smart Agriculture Sourcebook, 2nd edition*. Rome, Italy. http://www.fao.org/climate-smart-agriculture-sourcebook/en
FAO. 2018. Briefing Note: Cost-benefit analysis for climate change adaptation policies and investments in the agriculture sectors. NAP-Ag Programme. Rome. (also available at www.fao.org/3/I8905EN/i8905en.pdf).
FAO & UNDP. 2019. *Strengthening monitoring and evaluation for adaptation planning in the agriculture sectors.* Rome http://www.fao.org/in-action/naps/resources/learning/monitoring-and-evaluation-guide/en/
GCF. 2018. GCF/B.20/Inf.13: *Mapping of elements related to project or programme eligibility and selection criteria.* Meeting of the Board 1 – 4 July 2018 Songdo, Incheon, Republic of Korea Provisional agenda item 14. https://www.greenclimate.fund/documents/20182/1087995/GCF_B.20_Inf.13_-_Mapping_of_elements_related_to_project_or_programme_eligibility_and_selection_criteria.pdf/59f01057-4b0c-cb5f-70e1-e846692af153
Giorgi, F., B. Hewitson, J. Christensen, M. Hay, L.E. & M.P. Clark. 2003. Use of statistically and dynamically downscaled atmospheric model output for hydrologic simulations in three mountainous basins in the western United States. *Journal of Hydrology* 282: 56–75.
IFAD. 2015. *How to do note: Climate change risk assessments in value chain projects*. Rome.
Jacobs, H. and Al-Azar, R. 2019. Dare to Understand and Measure (DaTUM) – A literature review of Monitoring and Evaluation (M&E) frameworks for Climate-Smart Agriculture. Rome, FAO.
(also available at www.fao.org/3/ca5759en/ca5759en.pdf).

Leung, L. R., L. O. Mearns, F. Giorgi & R. Wilby. 2003: Workshop on regional climate research: Needs and opportunities. *Bull. Amer. Meteor. Soc.,* 84: 89–95.

UNFCCC. NAPAs. In*: UNFCCC Topics* [online]. Bonn. [Cited 29 October 2019]. https://unfccc.int/topics/resilience/workstreams/national-adaptation-programmes-of-action/introduction.

UNFCCC. National Communications non-Annex I Parties. In*: UNFCCC Process and meetings* [online]. Bonn. [Cited 29 October 2019]. http://unfccc.int/national_reports/non-annex_i_natcom/submitted_natcom/items/653.php

UNFCCC. NDC Spotlight. In*: UNFCCC Topics* [online]. Bonn. [Cited 29 October 2019]. https://unfccc.int/process/the-paris-agreement/nationally-determined-contributions/ndc-spotlight

USAID. 2013. *Analysing Climate Change Adaptation Options Using Multi-Criteria Analysis.* African and Latin American Resilience to Climate Change (ARCC). https://www.climatelinks.org/sites/default/files/asset/document/Multi-Criteria%2520Analysis_CLEARED_0.pdf

MODULE 3

References (in-text citation)

TECHNICAL NOTE 1

Akter, N. & Islam, M. R. 2017. Heat stress effects and management in wheat. A review. *Agronomy for Sustainable Development*, 37(37). https://doi.org/10.1007/s13593-017-0443-9

Asian Development Bank (ADB). 2017. *Climate Change Profile of Pakistan*. Mandaluyong City, Philippines. (also available at https://www.adb.org/sites/default/files/publication/357876/climate-change-profile-pakistan.pdf).

Burn, D.H. & Hag Elnur, M.A. 2002. Detection of hydrologic trends and variability. *Journal of Hydrology,* 255(1–4): 107–122.

Ikram, F., Afzaal, M., Bukhari, A. & Ahmed, B. 2016. Past and Future trends in Frequency of Heavy Rainfall Events over Pakistan. *Pakistan Journal of Meteorology*, 12 (24): 57–78.

Lutz, A.F., Immerzeel, W.W., Kraaijenbrink, P.D.A., Shrestha, A.B. & Bierkens, M.F.P. 2016. Climate Change Impacts on the Upper Indus Hydrology: Sources, Shifts and Extremes. *PLoS ONE,* 11(11): e0165630. https://doi.org/10.1371/journal.pone.0165630

Manzanas, R., Brands, S., San-Martín, D., Lucero, A., Limbo, C. & Gutiérrez, J.M. 2015. Statistical downscaling in the tropics can be sensitive to reanalysis choice: a case study for precipitation in the Philippines. *Journal of Climate,* **28**(10): 4171–4184. doi: 10.1175/JCLI-D-14-00331.1

Zahid, M. & Rasul, G. 2012. Changing trends of thermal extremes in Pakistan. *Climate Change,* 113: 3–4. DOI: 10.1007/s10584-011-0390-4

Zhang, X., Harvey, K.D., Hogg, W.D. & Yuzyk, T.R. 2001. Trends in Canadian streamflow. *Water Resources Research* 37(4): 987–998.

Zhu, T., Ringler, C., Mohsin Iqbal, M., Sulser, T.B. & Arif Goheer, M. 2013. Climate change impacts and adaptation options for water and food in Pakistan: scenario analysis using an integrated global water and food projection. *Water International,* 38 (5): 651–669.

ADDITIONAL INFORMATION

Ali, S. 2018. *Current and future climatic change and extreme events over Pakistan using observe data (1976-2015) and climate models simulation (2006-2100).* Global Change Impact Studies Centre (GCISC), Ministry of Climate Change, Pakistan.

Asian Development Bank (ADB) & World Bank. 2010. *Pakistan Floods: Preliminary Damage and Needs Assessment.* http://documents.worldbank.org/curated/en/655781468058769881/2011-Pakistan-floods-preliminary-damage-and-needs-assessment

Expert Team for Climate Change Detection and Indices (ETCCDI): ETCCDI/CRD Climate Change Indices *[online].* Rome. [Cited 15 December 2019]. http://etccdi.pacificclimate.org/list_27_indices.shtml

FAO. 2010. Crop calendar - An information tool for seed security *[online].* Rome. [Cited 15 December 2019]. www.fao.org/agriculture/seed/cropcalendar/welcome.do

Fischer, G., van Velthuizen, H., Shah, M. & Nachtergaele, F. 2002. *Global agro-ecological assessment for agriculture in the 21st Century: methodology and results.* IIASA. (also available at http://pure.iiasa.ac.at/id/eprint/6667/1/RR-02-002.pdf).

World Bank. 2006. *Pakistan Strategic Country Environmental Assessment, vol. 2, Technical Annex: The Cost of Environmental Degradation in Pakistan—An Analysis of Physical and Monetary Losses. In* Environmental Health and Natural Resources. Report 36946-PK. World Bank, Washington, DC.

TECHNCIAL NOTE 2

References (in-text citation)

Branca, G. 2018. *Benefit-cost analysis of climate-smart agriculture investments in Zambia*. Background paper No. 3.

IFAD. 2019. *Climate Adaptation in Rural Development (CARD) assessment tool. User guide.* (also available at https://www.ifad.org/documents/38714170/41085512/Card_usermanual_W.pdf/e867a16c-e581-8038-aa6f-1767a10629a3).

UNFCCC. 2012. *National Adaptation Plans: Technical guidelines for the national adaptation plan process*. Bonn, Germany. 152 pp. (also available at https://unfccc.int/files/adaptation/cancun_adaptation_framework/application/pdf/naptechguidelines_eng_high__res.pdf).

World Bank. 2017. *Guidance Note on shadow price of carbon in economic analysis.* Washington, DC.

ADDITIONAL INFORMATION

FAO. 2018. *Valuing forest ecosystem services – training manual for planners and project developers.* Rome.

IPCC. 2014. *Climate Change 2014: Synthesis Report*. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. R.K. Pachauri & L.A. Meyer, eds. IPCC, Geneva, Switzerland. 151 pp. (also available at www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf).

World Bank. 2019. *State and Trends of Carbon Pricing 2019 (English)*. Washington, DC. http://documents.worldbank.org/curated/en/191801559846379845/State-and-Trends-of-Carbon-Pricing-2019

TECHNICAL NOTE 3

References (in-text citation)

Bernoux, M., Branca, G., Carro, A., Lipper, L., Smith, G. & Bockel, L. 2010. Ex-ante greenhouse gas balance of agriculture and forestry development programs. Piracicaba, Brazil. *Scientia Agricola,* 67(1).

IFAD. 2016a. *IFAD Internal Guidelines, Economic and Financial Analysis of rural investment projects: Basic concepts and rationale.* Rome.

IFAD. 2016b. *IFAD Internal Guidelines, Economic and Financial Analysis of rural investment projects: Case studies.* Rome.

IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Hayama, Japan.

IPCC. 2014. *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands.* T. Hiraishi, T. Krug, K. Tanabe, N. Srivastava, J. Baasansuren, M. Fukuda & T.G. Troxler, eds. IPCC, Switzerland.

Lal, R. 2004. Carbon Emission from Farm Operations. *Environment International*, 30: 981–990.

Parker, R.W.R. & Tyedmers, P.H. 2014. Fuel consumption of global fishing fleets: current understanding and knowledge gaps. *Fish and Fisheries,* 16(4): 684–696.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., McCarl, B., *et al.* 2007. Agriculture. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer, eds. In *Climate Change 2007: Mitigation.* Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 497–540. Cambridge University Press, Cambridge, UK and New York, NY, USA.

ADDITIONAL INFORMATION

International Energy Agency (IEA). 2013. *IEA [online]*. France. [Cited 30 September 2017]. www.iea.org

Milne, E., Neufeldt, H., Rosenstock, T., Smalligan, M., Cerri, C.E., Malin, D., Easter, M., et al. 2013. Methods for the quantification of GHG emissions at the landscape level for developing countries in smallholder contexts. *Environmental Research Letters,* No. 8.

TECHNICAL NOTE 4

References (in-text citation)

IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories.* Hayama, Japan.

UNFCCC. 2009. UNFCCC Resource Guide Module 3: National greenhouse gas inventories. Bonn, Germany. 36 pp. (also available at https://unfccc.int/resource/docs/publications/09_resource_guide3.pdf).

ADDITIONAL INFORMATION

FAO. 2017. *GLEAM-i User Guide - A tool for estimating livestock production, greenhouse gas emissions and assessing intervention scenarios* [online]. Rome. [Cited 15 November 2019]. www.fao.org/fileadmin/user_upload/gleam/docs/GLEAM-i_User_guide_2_Revision_3.pdf

FAO. 2017. *CS-FOR Working Paper: Livestock Development.* FAO Investment Centre Division, Rome.

FAO. 2018. *CS-FOR Working Paper: Assessment of Pastures Sector and Recommendations for CS-FOR Project*. FAO Investment Centre Division, Rome.

FAO. 2018. *Global Livestock Environmental Assessment Model - Model Description, Version 2.0* [online]. Rome. [Cited 15 November 2019]. www.fao.org/fileadmin/user_upload/gleam/docs/GLEAM_2.0_Model_description.pdf

FAO. 2019. *Global Livestock Environmental Assessment Model (GLEAM)* [online]. [Cited 12 November 2019]. www.fao.org/gleam/en/

Gerber, P.J., Henderson, B. & Makkar, H.P. 2013. *Mitigation of greenhouse gas emissions in livestock production: a review of technical options for non-CO_2 emissions,* No. 177. FAO, Rome.

Gerber, P.J., Steinfeld, H., Henderson, B., Mottet, A., Opio, C., Dijkman, J., Falcucci, A. & Tempio, G. 2013. *Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities*. FAO, Rome.

Kyrgyz Republic. 2015. *Intended Nationally Determined Contributions* [online]. [Cited 16 December 2019]. https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/Kyrgyzstan/1/Kyrgyzstan%20INDC%20_ENG_%20final.pdf

Mottet, A., de Haan, C., Falcucci, A., Tempio, G., Opio, C. & Gerber, P. 2017. Livestock: On our plates or eating at our table? A new analysis of the feed/food debate. *Global Food Security*, *14*: 1–8.

Sejian, V., Lal, R., Lakritz, J. & Ezeji, T. 2011. Measurement and Prediction of Enteric Methane Emission. *International Journal of Biometeorology*, 55: 1–16. http://dx.doi.org/10.1007/s00484-010-0356-7

TECHNICAL NOTE 5

References (in-text citation)

FAO. 2015b. *MOSAICC: A modelling system for the assessment of the agricultural impacts of climate change.* Rome. (also available at www.fao.org/3/a-i5294e.pdf).

Fujisawa, M., Gordes, A. & Heureux, A. 2020. Assessing the impacts of climate change on the agriculture sectors in Malawi. The MOSAICC methodology for national adaptation planning. Rome, FAO. https://doi.org/10.4060/ca8624en

Government of Malawi (GoM). 2016. *National Climate Change Management Policy* [online]. [Cited 28 October 2019]. https://reliefweb.int/sites/reliefweb.int/files/resources/NCCM-Policy-Final-06-11-2016.pdf

Government of Malawi (GoM). 2018. *Assessing climate change impacts on future crop yields in Malawi*. Department of Climate Change and Meteorological Services (DCCMS). FAO internal document. Rome.

UNFCCC. 2012. *NATIONAL ADAPTATION PLANS: Technical guidelines for the national adaptation plan process*. Bonn, Germany. 152 pp (also available at https://unfccc.int/files/adaptation/cancun_adaptation_framework/application/pdf/naptechguidelines_eng_high__res.pdf).

World Bank. 2018. Malawi Country Overview. In: *Where we work: Malawi* [online]. Washington, DC. [Cited 24 October 2019]. www.worldbank.org/en/country/malawi/overview

ADDITIONAL INFORMATION

FAO. 2015. *Country fact sheet on food and agriculture policy trends: Malawi* [online]. [Cited 24 October 2019]. www.fao.org/3/a-i4491e.pdf

FAO. 2016. *Malawi and FAO: Building capacities and knowledge to achieve resilience and sustainable food security* [online]. [Cited 28 October 2019]. www.fao.org/3/au198e/AU198E.pdf

FAO. 2019. FAOSTAT. Malawi. In: *FAOSTAT* [online]. Rome, Italy. [Cited 24 October 2019]. http://www.fao.org/faostat/en/#country/130

FAO. 2019. *Modelling System for Agricultural Impacts of Climate Change (MOSAICC)* [online]. [Cited 15 November 2019]. http://www.fao.org/in-action/mosaicc/en/

Irish Aid. 2018. *Malawi Country Climate Risk Assessment Report* [online]. [Cited 24 October 2019]. https://www.climatelearningplatform.org/sites/default/files/resources/malawi_climate_risk_assessment_report_-_final_version.pdf

Kuik, O., Reynes, F., Delobel, F. & Bernardi, M. 2011. *FAO-MOSAICC: The FAO modelling system for agricultural impacts of climate change to support decision-making in adaptation*. Rome, FAO. 23 pp. (also available at www.fao.org/3/a-be787e.pdf).

Li, G., Messina, J., Peter, B. & Snapp, S. 2017. Mapping land suitability for agriculture in Malawi: Agricultural Land Suitability Mapping. *Land Degradation & Development*, 28(7): 1887–2320.

Reddy, S.K. & Gondwe, K. J. 2016. *Malawi NAP Stocktaking Report* [online]. UNDP. [Cited 24 October 2019]. https://www.adaptation-undp.org/sites/default/files/uploaded-images/malawi_nap_stocktaking_report_final_2016.pdf

TECHNICAL NOTE 6

References (in-text citation)

FAO. 2016c. *RIMA-II: Resilience Index Measurement and Analysis – II*. Rome. 80 pp. www.fao.org/3/a-i5665e.pdf

FAO. 2019c. *Resilience analysis in the target areas of "Carbon Sequestration through Climate Investment in Forests and Rangelands (CS-FOR)" project in the Kyrgyz Republic.* FAO Resilience Analysis Report, No. 18. Rome, Italy. pp. 45. www.fao.org/documents/card/en/c/CA4323EN/

Food Security Information Network (FSIN). 2014. *Resilience Measurement Principles, toward an agenda for measurement design.* FSIN Resilience Measurement Technical Working Group, Technical Working Series. (also available at http://www.fsincop.net/resource-centre/detail/ en/c/213177/).

GCF. 2014. *Annex VIII: Mitigation and Adaptation Performance Measurement Frameworks.* GCF/B.08/45. Decisions of the Board – Eighth Meeting of the Board, 14–17 October 2014, Songdo, Incheon, Republic of Korea. https://www.greenclimate.fund/document/mitigation-and-adaptation-performance-measurement-frameworks

GCF. 2016. *Further development of some indicators in the performance measurement frameworks.* GCF/B.13/26. Meeting of the Board, 28–30 June 2016, Songdo, Incheon, Republic of Korea. http://www.greenclimate.fund/documents/20182/226888/GCF_B.13_26_-_Further_development_of_some_indicators_in_the_

performance_measurement_frameworks.pdf/0ad22e10-703d-49ae-baad-eb87669d0223
IFAD, FIC & IEH. 2013. *Climate Change Impact on Pastures and Livestock Systems in Kyrgyzstan* [online]. [Cited 06 November 2019]. www.ficlima.org/wp-content/uploads/2013/10/Summary-Report-Kyrgyzstan-Final-2013.pdf.
International Federation for Human Rights (FIDH). 2016. *Women and children from Kyrgyzstan affected by migration: An exacerbated vulnerability.* Paris. 64 pp. www.osce.org/odihr/269066?download=true

ADDITIONAL INFORMATION

FAO. 2019. *Disaster risk reduction at farm level: Multiple benefits, no regrets.* Rome, Italy. (http://www.fao.org/3/ca4429en/ca4429en.pdf)
FAO. 2019. FAOTERM. In: *FAO TERM PORTAL* [online]. Rome, Italy. [Cited 06 November 2019]. www.fao.org/faoterm/en/
GCF. 2019. *Adaptation: Accelerating action towards a climate resilient future.* GCF Working Paper No. 1. Songdo, Incheon, Republic of Korea. www.greenclimate.fund/documents/20182/194568/Accelerating_action_towards_a_climate_resilient_future.pdf/9215ecb7-923a-9cfb-e4ae-d8f0be6e7b29
Hoddinott, J. & Quisumbing A. 2010. Methods for Microeconometric Risk and Vulnerability Assessment. *In* R. Fuentes-Nieva & P.A. Seck, eds. *Risk, Shocks and Human Development: On the brink,* pp. 62–100. London, Palgrave Macmillan, United Nations Development Programme (UNDP).
IPCC. 2018. Annex I: Glossary. Matthews, J.B.R. ed. In V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, *et al.,* eds. *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty,* pp. 541–562. In Press. www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_AnnexI_Glossary.pdf
ODI. 2015. *A comparative overview of resilience measurement frameworks*. Working paper 422. London. www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/9754.pdf).

TECHNICAL NOTE 7

Denis Alder. 2002. *MYRLIN Toolkit* [online]. [Cited 15 November 2019]. http://denisalder.net/menu.php?pg=myrlin
FAO. 2017d. *Tracking adaptation in agricultural sectors – Climate change adaptation indicators.* Rome. (also available at www.fao.org/3/a-i8145e.pdf).
OPEN FORIS. 2019a. *Openforis: Free open-source solutions for environmental monitoring* [online]. [Cited 15 November 2019]. http://www.openforis.org
OPEN FORIS. 2019b**.** *Collect Earth Online* [online]. [Cited 15 November 2019]. http://www.openforis.org/tools/collect-earth-online.html

System for earth observations, data access, processing & analysis for land monitoring (SEPAL). 2019. *SEPAL* [online]. [Cited 15 November 2019]. https://sepal.io

SECTOR NOTE 1

References (in-text citation)

Allison, E.H., Perry, A.L., Badjeck, M.-C., Neil Adger, W., Brown, K., Conway, D., Halls, A.S., et al. 2009. Vulnerability of national economies to the impacts of climate change on fisheries. *Fish and Fisheries,* 10(2): 173–196. https://doi.org/10.1111/j.1467-2979.2008.00310.x

Badjeck, M.-C., Allison, E.H., Halls, A.S. & Dulvy, N.K. 2010. Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, 34(3): 375–383. https://doi.org/10.1016/j.marpol.2009.08.007

Barange, M., Bahri, T., Beveridge, M.C.M., Cochrane, K.L., Funge-Smith, S. & Poulain, F., eds. 2018. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. 654 pp. (also available at www.fao.org/3/i9705en/I9705EN.pdf).

Caribbean Regional Fisheries Mechanism (CRFM). 2015. *Report of Write-shop on FAD Fisheries Management*. CRFM Technical & Advisory Document, No. 2015/04. Kingstown, St. Vincent and the Grenadines. http://www.crfm.net/~uwohxjxf/images/Final_Report_of_Write-Shop_on_FAD_Fisheries_Management__29_July_2015_online_copy.pdf

Chang, Y., Lee, M.-A., Lee, K.-T. & Shao, K.-T. 2013. Adaptation of fisheries and mariculture management to extreme oceanic environmental changes and climate variability in Taiwan. *Marine Policy*, 38: 476–482. http://doi.org/10.1016/j. marpol.2012.08.002

Cheung, W.W.L, Bruggeman, J. & Butenschön. 2018. Projected changes in global and national potential marine fisheries catch under climate change scenarios in the twenty-first century. *In* M. Barange, T. Bahri, M.C.M. Beveridge, K.L. Cochrane, S. Funge-Smith & F. Poulain, eds. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options,* pp. 63–86. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. 628 pp http://www.fao.org/3/I9705EN/i9705en.pdf

FAO. 2016b. *The State of the Food and Agriculture: Climate Change, Agriculture and Food Security*. Rome, Italy. 190 pp. (also available at www.fao.org/3/a-i6030e.pdf).

FAO. 2018b. *The State of World Fisheries and Aquaculture 2018 – Meeting the Sustainable Development Goals*. Rome. 227 pp. (also available at www.fao.org/3/I9540EN/i9540en.pdf).

FAO. 2019d. *Yearbook of fishery and aquaculture statistics 2017*. Rome. 108 pp. (also available at www.fao.org/3/ca5495t/ca5495t.pdf).

GEF. 2014. Climate change adaptation in the eastern Caribbean fisheries sector. In: *The GEF* [online]. Washington, DC. [Cited 20 August 2017]. www.thegef.org/project/climate-change-adaptation-eastern-caribbean-fisheries-sector

Government of Malawi. 2012. *National Fisheries Policy 2012–2017,* Second Edition. 21 pp.

Handisyde, N., Telfer, T.C. & Ross, L.G. 2017. Vulnerability of aquaculture-related livelihoods to changing climate at the global scale. *Fish and Fisheries*, 18(3): 466–488. https://doi.org/10.1111/faf.12186

Harrod, C., Ramírez, A., Valbo-Jørgensen & Funge-Smith, S. 2018a. How climate change impacts inland fisheries. *In* M. Barange, T. Bahri, M.C.M. Beveridge, K.L. Cochrane, S. Funge-Smith & F. Poulain, eds. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*, pp. 375–391. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. (also available at www.fao.org/3/I9705EN/i9705en.pdf).

Harrod, C., Ramírez, A., Valbo-Jørgensen & Funge-Smith, S. 2018b. Current anthropogenic stress and projected effect of climate change on global inland fisheries. *In* M. Barange, T. Bahri, M.C.M. Beveridge, K.L. Cochrane, S. Funge-Smith & F. Poulain, eds. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*, pp. 393–448. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. (also available at www.fao.org/3/I9705EN/i9705en.pdf).

International Resources Group (IRG). 2008. Impacts of climate change on rural livelihoods in Madagascar and the potential for adaptation [online]. Washington, DC. Quarterly Report. [Cited 22 April 2018]. http://pdf.usaid.gov/pdf_docs/Pnadp632.pdf

Office of the Parties to the Nauru Agreement (PNA Office). 2014. Review of the PNA purse seine vessel day scheme. [online]. [Cited 8 August 2017]. www.pnatuna.com/

Poulain, F., Himes-Cornell, A. & Shelton, C. 2018. Methods and tools for climate change adaptation in fisheries and aquaculture. *In* M. Barange, T. Bahri, M.C.M. Beveridge, K.L. Cochrane, S. Funge-Smith & F. Poulain, eds. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options,* pp. 535–566. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. 628 pp. (also available at www.fao.org/3/i9705en/i9705en.pdf).

Soto, D., Ross, L.G., Handisyde, N., Bueno, P., Beveridge, M.C.M., Dabbadie, L., *et al*. 2008. Climate change and aquaculture: vulnerability and adaptation options. *In* M. Barange, T. Bahri, M.C.M. Beveridge, K.L. Cochrane, S. Funge-Smith & F. Poulain, eds. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options,* pp. 465–490. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. (also available at www.fao.org/3/I9705EN/i9705en.pdf).

ADDITIONAL INFORMATION

Brugère, C. & De Young, C. 2015. *Assessing climate change vulnerability in fisheries and aquaculture. Available methodologies and their relevance for the sector*. FAO Fisheries and Aquaculture Technical Paper No. 597. Rome, FAO. www.fao.org/3/a-i5109e.pdf

Bueno, P.B. & Soto, D. 2017. *Adaptation strategies of the aquaculture sector to the impacts of climate change*. FAO Fisheries and Aquaculture Circular No. 1142. Rome, FAO. 28 pp. www.fao.org/3/a-i6943e.pdf

Cinner, J.E., Adger, W.N., Allison, E.H., Barnes, M.L., Brown, K., Cohen, P.J., Gelcich, S. et al. 2018. Building adaptive capacity to climate change in tropical coastal communities. *Nature Climate Change*, 8: 117–123. https://www.nature.com/articles/s41558-017-0065-x?proof=trueMay

FAO. 2015. *Voluntary Guidelines for Securing Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication*. Rome, Italy. www.fao.org/3/i4356en/I4356EN.pdf

Nguyen, K.A.T. & Pongthanapanich T. 2016. *Aquaculture insurance in Viet Nam: experiences from the pilot programme.* FAO Fisheries and Aquaculture Circular No. 1133. Rome, FAO. 20 pp. www.fao.org/3/a-i6559e.pdf

Watkiss, P. 2015. *Design of policy-led analytical framework*. Deliverable 1.2. of the ECONADAPT project. Bath, UK, ECONADAPT. 87 pp. http://econadapt.eu/sites/default/files/docs/ECONADAPT_D1.2.pdf

SECTOR NOTE 2

References (in-text citation)

Aheyaar, M.M.M. 2012. *Climate change adaptation in water management for food security: Recent developments in Sri Lanka – A review of Existing Knowledge and Information.* Report Submitted to Sri Lanka Water Partnership & Global Water Partnership – South Asia, Colombo.

Amarasingha, R.P.R.K., Suriyagoda, L.D.B., Marambe, B., Gaydon, D.S., Galagedara, L.W., Punyawardena, R., Silva, G.L.L.P., Nidumolu, U. & Howden, M. 2015. Simulation of crop and water productivity for rice (Oryza sativa L.) using APSIM under diverse agro-climatic conditions and water management techniques in Sri Lanka. *Agricultural Water Management*, 160: 132–143.

Chikobola, M. & Tembo, G. 2018. Gaps in the implementation of the e-voucher system in Zambia: Implications for strategies to make the model efficient and effective. *African Journal of Agricultural and Resource Economics*, 13(2): 193–197.

Dhanapala, M.G. & Gunasekera, D.M. 1994. *Sustainable upland farming system research through social mobilization. In* Asian Farming Systems Symposium, Manila (Philippines), 7-10 Nov 1994.

Dharmasena, P.B. 2007. *Indigenous Agricultural Knowledge in Sri Lanka: Back to Practice.* Workshop on Grass-root Innovations at Galadari Hotel, Colombo, 18 September 2007.

FAO. 2011. *Save and grow: a policymaker's guide to sustainable intensification of smallholder crop production*. Rome. 116 pp. (also available at www.fao.org/3/a-i2215e.pdf).

FAO. 2018c. *FAO's Work on Agroecology: A pathway to achieving the SDGs.* Rome. 28 pp. (also available at www.fao.org/3/i9021en/i9021en.pdf).

FAO. 2019e. Introduction to Farmer Field Schools. A Reader for Institutions of Higher Learning. Nairobi. 44 pp. Licence: CC BY-NC-SA 3.0 IGO

Sisira Kumara, W.A.G. & Karunathilaka, W.A.K. Best Practices of Conservation Agriculture in Sri Lanka. In P.R. Pandey & T.R. Gurung, eds. *Best Practices of Conservation Agriculture in Sri Lanka*, pp. 129–159.

Somaweera, K.A.T.N., Suriyagoda, L.D.B., Sirisena, D.N. & De Costa, W.A.J.M. 2016. Accumulation and partitioning of biomass, nitrogen, phosphorus and potassium among different tissues during the life cycle of rice grown under different water management regimes. *Plant and soil*, 401(1-2): 169–183.

Vanlauwe, B., Descheemaeker, K., Giller, K., Huising, J., Merckx, R., Nziguheba, G., Wendt, J. & Zingore, S. 2015. Integrated soil fertility management in sub-Saharan Africa: unravelling local adaptation. *SOIL*, 1: 491–508. (also available at https://soil.copernicus.org/articles/1/491/2015/soil-1-491-2015.pdf).

Weerakoon, W. M. W., Priyadarshani, T. N. N., Piyasiri, C. H. & Silva, L. S. 2010. *Impact of water saving irrigation systems on water use, growth and yield of irrigated lowland rice.* Conference Papers h042894, International Water Management Institute.

Werakoon, W.L. & Schall R. 1989. Conservation Farming Activities – 1987 – 1989. Agriculture Research Station, Mahailluppallama, Sri Lanka. pp. 289.

ADDITIONAL INFORMATION

FAO. 2018. *Scaling Up Agroecology Initiative. Transforming Food and Agricultural Systems in Support of the SDGs.* A Proposal Prepared for the International Symposium on Agroecology 3-5 April 2018. Rome, Italy. http://www.fao.org/3/I9049EN/i9049en.pdf

FAO. 2019. *Global Farmer Field School Platform* [online]. www.fao.org/farmer-field-schools/home/en/

FAO. 2019. *Handbook on climate information for farming communities – What farmers need and what is available.* Rome. 184 pp. Licence: CC BY-NC-SA 3.0 IGO. http://www.fao.org/3/ca4059en/ca4059en.pdf?eloutlink=imf2fao

IFAD. 2016. How to do Note: Designing and implementing Conservation Agriculture of IFAD investments in sub-Saharan Africa. Rome

Premarathna, S., Weligamage, P. & Walisinghe, R. 2015. *Adoption of parachute method in rice crop establishment: Evidence from the Kurunegala District of Sri Lanka.* Proceedings of the 71st Annual Sessions of the Sri Lanka Association for the Advancement of Science, Colombo, Sri Lanka.

Sivaneson, S. & Ponnegipprenthiraraja, A. 2018. Effect of Different Crop Establishment Methods on Growth and Yield Response of Lowland Irrigated Rice in the Northern Region of Sri Lanka. *Journal of Dry Zone Agriculture*, 4(1): 30–34.

Sudarshani, R., Pathmarajah, S., Ariyaratne, M. 2016. *Effect of Crop Establishment Techniques on Morphological and Yield Parameters in Aerobically Cultivated Rice.* 2nd World Irrigation Forum (WIF2), 6–8, November 2016, Chiang Mai, Thailand.

Weerakkody, P.R., Kusum Kumara, S. & Wickremasinghe, W.D. 2011. *Adoption of Parachute Technology by the Farmers in Anuradhapura District*. Colombo, Sri Lanka, Hector Kobbekaduwa Agrarian Research and Training Institute (HARTI).

SECTOR NOTE 3

References (in-text citation)

FAO. 2003. *Unlocking the Water Potential of Agriculture* [online]. [Cited 24 October 2019]. www.fao.org/3/y4525e/y4525e06.htm#bm06

FAO. 2012c. The FAO Component of the Consolidated Appeals 2013: Burkina Faso. In *Resilience*: Resources [online]. Rome. [Cited 24

October 2019]. www.fao.org/resilience/resources/resources-detail/en/c/164371/

FAO. 2017e. *Water for Sustainable Food and Agriculture: A report produced for the G20 Presidency of Germany.* Rome. (also available at www.fao.org/3/a-i7959e.pdf).

FAO. 2019f. *Strengthening agricultural water efficiency and productivity on the African and global level* [online]. [Cited 15 December 2019]. www.fao.org/3/CA2371EN/ca2371en.pdf

Salman, M., Pek, E., Fereres, E. & García-Vila, M. 2020. *Field guide to improve crop water productivity in small-scale agriculture.* Rome, FAO. (also available at www.fao.org/3/ca5789en/ca5789en.pdf).

SECTOR NOTE 4

References (in-text citation)

FAO. 2016d. *The agriculture sectors in the Intended Nationally Determined Contributions: Summary.* Rome, Italy. 16 pp. www.fao.org/3/a-i5666e.pdf

FAO. forthcoming. *From reference levels to results reporting: REDD+ under the UNFCCC: 2020 update*. Forestry Working Paper. Rome.

GCF. 2019. Projects + Programmes. In: *Green Climate Fund* [online]. [Cited 31 October 2019]. www.greenclimate.fund/projects/fp019

MAGBOMA. 2019. *Estrategia Nacional de REDD+ de Guinea Ecuatorial.* Ministry of Agriculture, Livestock, Forestry, and Environment, Equatorial Guinea. (also available at www.fao.org/3/CA2911ES/ca2911es.pdf).

NYDF Assessment Partners. 2019. *Protecting and Restoring Forests: A Story of Large Commitments yet Limited Progress.* New York Declaration on Forests Five-Year Assessment Report. Berlin. https://forestdeclaration.org/images/uploads/resource/2019NYDFReport.pdf

Smith, P., Bustamante, M., Ahammad, H., Clark, H., Dong, H., Elsiddig, E.A. & Haberl, H., *et al***.** 2014. Agriculture, Forestry and Other Land Use (AFOLU). *In* O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, *et al.*, eds. *Climate Change 2014: Mitigation of Climate Change,* pp. 811–922. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, Cambridge University Press.

United Nations Framework Convention on Climate Change (UNFCCC). 2016b. *Ecuador: Biennial update report (BUR 1).* Bonn, Germany. https://unfccc.int/documents/180635

United Nations Framework Convention on Climate Change (UNFCCC). 2019. *UNFCCC REDD+ Web Platform* [online]. [Cited 29 October 2019]. https://redd.unfccc.int/

MODULE 4

References (in-text citation)

ACT Alliance. 2018. *A Resource Guide to Climate Finance: An orientation to sources of funds for climate change programmes and action*. Geneva, Switzerland. 63 pp. (also available at https://actalliance.org/wp-

content/uploads/2018/06/ENGLISH-quick-guide-climate-finance.pdf).
Climate Policy Initiative (CPI). 2018. *Global Climate Finance: An Updated View 2018.* (also available at https://climatepolicyinitiative.org/wp-content/uploads/2018/11/Global-Climate-Finance-_-An-Updated-View-2018.pdf).
FAO. 2016d. *The Agriculture Sectors in the Intended Nationally Determined Contributions: Analysis* by Strohmaier, R., Rioux, J., Seggel, A., Meybeck, A., Bernoux, M., Salvatore, M., Miranda, J. & Agostini, A. Environment and Natural Resources Management Working Paper No. 62. Rome, Italy. http://www.fao.org/3/a-i5687e.pdf
FAO. 2017c. *Climate-Smart Agriculture Sourcebook, 2nd edition* [online]. Rome. [Cited 15 December 2019]. www.fao.org/climate-smart-agriculture-sourcebook/en
FAO. 2018d. *A Preliminary Review of Agriculture-related Activities in the Green Climate Fund Portfolio*. Rome.
FAO. 2019g. *AIDmonitor* [online]. [Cited 22 October 2019]. www.fao.org/aid-monitor/analyse/sector/en/
FAO. 2020. *Global Forest Resources Assessments* [online]. [Cited 15 January 2020]. www.fao.org/forest-resources-assessment/en/
GEF. 2018. GEF Programming Strategy on Adaptation to Climate Change for the Least Developed Countries Fund and the Special Climate Change Fund and Operational Improvements July 2018 to June 2022. 24th LDCF/SCCF Council Meeting, 26 June 2018, Da Nang, Viet Nam. (also available at https://www.thegef.org/sites/default/files/documents/EN_GEF.LDCF_.SCCF_.24.03_Programming_Strategy_and_Operational_Policy_2.pdf).
OECD. 2019. *Climate Finance Provided and Mobilised by Developed Countries in 2013-17*. Paris, OECD Publishing. (also available at https://www.oecd.org/environment/climate-finance-provided-and-mobilised-by-developed-countries-in-2013-17-39faf4a7-en.htm).
Sadler, M. P., Millan Arredondo, A., Swann, S.A., Vasileiou, I., Baedeker, T., Parizat, R., Germer, L.A. & Mikulcak, F. 2016. *Making climate finance work in agriculture (English)*. Washington, DC, World Bank Group. (also available at http://documents.worldbank.org/curated/en/986961467721999165/Making-climate-finance-work-in-agriculture).

ADDITIONAL INFORMATION

Aditi, P. 2019. Feature: *Blended finance for climate and food security – The potential of the farm sector. Climate and Development Knowledge Network.* https://cdkn.org/2019/03/feature-blended-finance-for-climate-and-food-security-potential-for-the-farm-sector/?loclang=en_gb
Convergence. *The State of Blended Finance 2018*. OECD/GIZ. http://www.oecd.org/water/OECD-GIZ-Background-document-State-of-Blended-Finance-2018.pdf
GEF. 2019. *GEF* [online]. www.thegef.org/topics/climate-change
Hirsch, T. 2018. *A Resource Guide to Climate Finance: An orientation to sources of funds for climate change programmes and action.* ACT Alliance Secretariat. Geneva, Switzerland. https://actalliance.org/wp-content/uploads/2018/06/ENGLISH-quick-guide-climate-finance.pdf

IEA. 2015. *Energy and Climate Change: World Energy Outlook Special Report.* Paris, France. https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf

IFAD. 2017. *Second Phase of IFAD's Adaptation for Smallholder Agriculture Programme (ASAP2) – Concept Note.* https://webapps.ifad.org/members/eb/122/docs/EB-2017-122-R-44.pdf

Shames, S., Friedman, R. & Havemann, T. 2012. *Coordinating finance for climate-smart agriculture.* EcoAgriculture Discussion Paper No. 9. Washington, DC: EcoAgriculture Partners. https://www.researchgate.net/publication/262996154_Coordinating_Finance_for_Climate-Smart_Agriculture

World Bank. 2019. *Nationally Determined Contributions (NDCs)* [online]. http://spappssecext.worldbank.org/sites/indc/Pages/CostFilterVisualization.aspx

Glossary of terms

Concept/Terms	Definition	Reference
Adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.	IPCC (2014a)
Adaptive capacity	The ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.	IPCC (2014a)
Adaptation options	The array of strategies and measures that are available and appropriate for addressing adaptation. They include a wide range of actions that can be categorised as structural, institutional, ecological or behavioural.	IPCC (2019a)
Carbon balance	The difference between the carbon emitted and stored by a proposed AFOLU option in comparison with a reference scenario (baseline scenario), during a time reference.	FAO (2012)[69]
Carbon market	A trading system through which countries may buy or sell units of greenhouse gas emissions in an effort to meet their national limits on emissions, either under the Kyoto Protocol or under other agreements, such as those among member states of the European Union.	UNFCCC: Glossary of climate change acronyms and terms[70]
Carbon sequestration	The process of storing carbon in a carbon pool.	IPCC (2019a)
Carbon sink	Mitigation involves human interventions to reduce the emissions of greenhouse gases by sources or enhance their removal from the atmosphere by "sinks". A "sink" refers to forests, vegetation or soils that can reabsorb CO_2. Carbon dioxide is the largest contributing gas to the greenhouse effect.	UNFCCC (2009)[71]
Carbon stock	The quantity of carbon in a carbon pool.	IPCC (2019a)
Climate change	A change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.	IPCC (2019a)
Climate extreme (extreme weather or climate event)	The occurrence of a value of a weather or climate variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable. For simplicity, both extreme weather events and extreme climate events are referred to collectively as "climate extremes".	IPCC (2019a)

69 FAO. 2012. *Using Marginal Abatement Cost Curves to realize the Economic Appraisal of Climate Smart Agriculture Policy Options*. See: www.fao.org/3/a-bq866e.pdf

70 See: https://unfccc.int/process-and-meetings/the-convention/glossary-of-climate-change-acronyms-and-terms

71 UNFCCC. 2009. *Fact sheet: The need for mitigation*. See: https://unfccc.int/files/press/backgrounders/application/pdf/press_factsh_mitigation.pdf

Climate finance	Flows of capital from both public and private sources that support and finance climate-smart investments and aim to achieve climate change adaptation and mitigation objectives.	World Bank (2016)[72]
Climate model	A numerical representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes and accounting for some of its known properties. The climate system can be represented by models of varying complexity. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as a research tool to study and simulate the climate and for operational purposes, including monthly, seasonal and interannual climate predictions.	IPCC (2019a)
Climate projection	Simulated response of the climate system to a scenario of future emissions or concentrations of greenhouse gases (GHGs) and aerosols, and changes in land use, generally derived using climate models. Climate projections are distinguished from climate predictions by their dependence on the emission/concentration/radiative forcing scenario used, which is in turn based on assumptions concerning, for example, future socioeconomic and technological developments that may or may not be realised.	IPCC (2019a)
Climate sensitivity	The change in the annual global mean surface temperature in response to a change in the atmospheric carbon dioxide (CO_2) concentration or other radiative forcing.	IPCC (2019a)
Climate Smart Agriculture (CSA)	An approach to agriculture that aims to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate by sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible.	FAO (2017c)
Climate variability	Variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all spatial and temporal scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).	IPCC (2019a)
CO_2 equivalent (CO_2-eq) emission	The amount of carbon dioxide (CO_2) emission that would cause the same integrated radiative forcing or temperature change, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs.	IPCC (2019a)
Conservation Agriculture	A farming system that can prevent land losses while regenerating degraded lands. It promotes maintenance of a permanent soil cover, minimum soil tillage, and diversification of plant species. It enhances biodiversity and natural biological processes above and below the ground surface, which contribute to increased water and nutrient use efficiency and to improved and sustained crop production.	FAO (2017)[73]
Conventional farming	Conventional agriculture is an industrialized form of farming characterized by mechanization, monocultures, and the use of synthetic inputs such as chemical fertilizers, pesticides and genetically modified organisms (GMOs), with an emphasis on maximizing productivity and profitability and treating the farm produce as a commodity.	FAO (2009)[74]

72 Sadler *et al*. 2016. *Making climate finance work in agriculture (English)*. Washington, DC, World Bank Group.

73 FAO. 2017. Conservation Agriculture Fact Sheet. In: *Plant Production and Protection Division*. Rome. [Cited 6 August 2019]. www.fao.org/3/i7480en/I7480EN.pdf

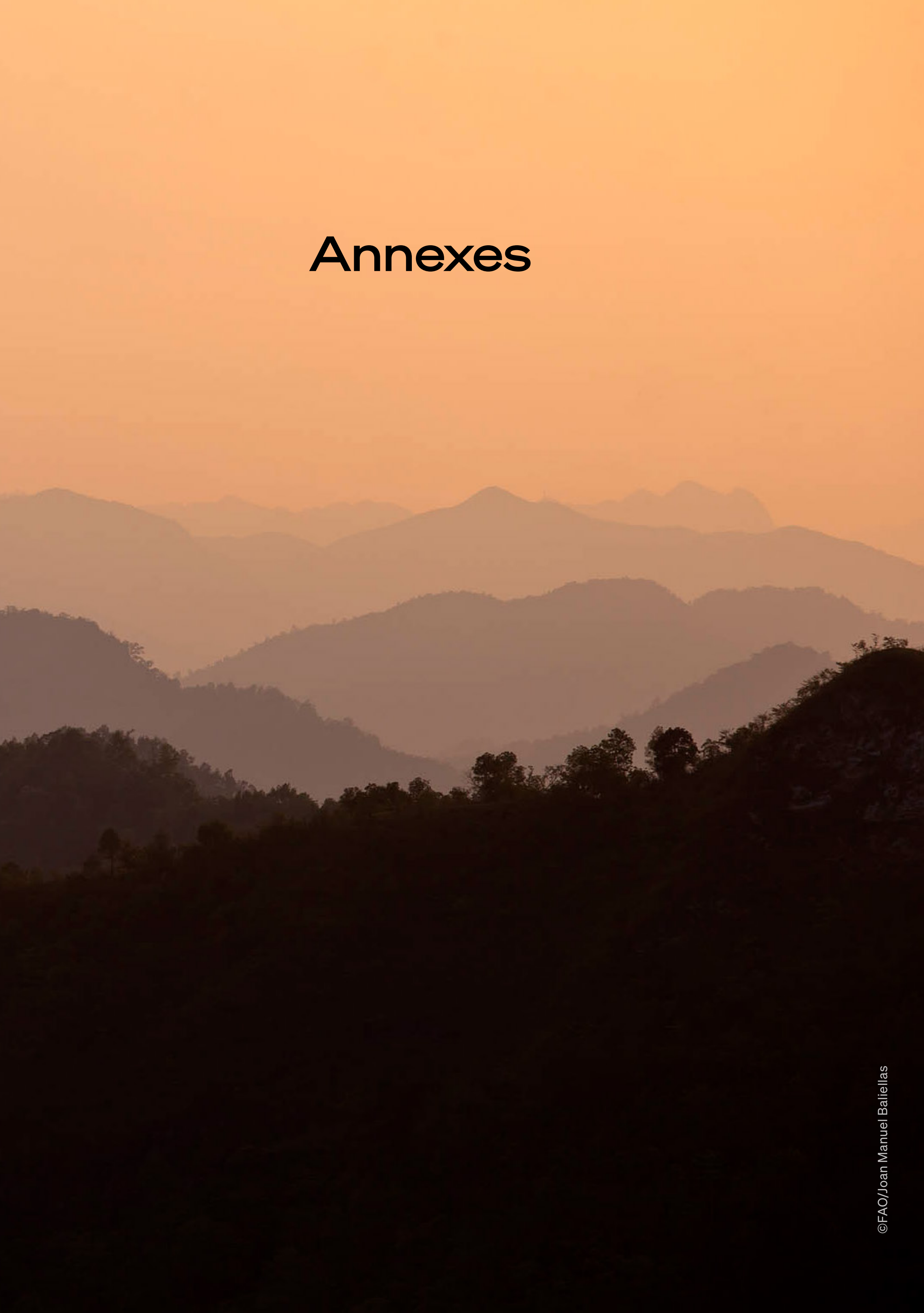
74 Nemes, N. 2009. *Comparative analysis of organic and non-organic farming systems: a critical assessment of farm profitability*. Rome, FAO.

Cost-benefit analysis	Monetary assessment of all negative and positive impacts associated with a given action. Cost-benefit analysis enables comparison of different interventions, investments or strategies and reveal how a given investment or policy effort pays off for a particular person, company or country. Cost-benefit analyses representing society's point of view are important for climate change decision making, but there are difficulties in aggregating costs and benefits across different actors and across timescales.	IPCC (2019a)
Disaster risk management (DRM)	Processes for designing, implementing, and evaluating strategies, policies, and measures to improve the understanding of current and future disaster risk, foster disaster risk reduction and transfer, and promote continuous improvement in disaster preparedness, prevention and protection, response, and recovery practices, with the explicit purpose of increasing human security, well-being, quality of life, and sustainable development.	IPCC (2019)[75]
Ecosystem services	Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food, fibre or fish, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation.	IPCC (2019a)
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, resources and infrastructure, or economic, social or cultural assets in places and settings that could be adversely affected.	IPCC (2019a)
Hazard	The potential occurrence of a natural or human-induced physical event or trend or physical impact that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.	IPCC (2019a)
Impacts	The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather and climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial.	IPCC (2019a)
Livelihood	The resources used and the activities undertaken in order to live. Livelihoods are usually determined by the entitlements and assets to which people have access. Such assets can be categorised as human, social, natural, physical, or financial.	IPCC (2019a)
Maladaptation	Adaptation actions that may lead to an increased risk of adverse climate-related outcomes, increased vulnerability to climate change, or diminished welfare, now or in the future.	IPCC (2014a)
Mitigation	A human intervention to reduce emissions or enhance the sinks of greenhouse gases.	IPCC (2019a)
Monitoring	The systematic tracking of the state of an initiative at any given time in terms of activities, inputs, outputs, targets and outcomes. It can also be used to describe the tracking of trends.	FAO (2017d)

75 IPCC. 2019. Summary for Policymakers. In: *IPCC Special Report on the Ocean and Cryosphere in a Changing Climate*. H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer, eds. In press.

Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.	IPCC (2014a)
Risk	The potential for consequences where something of value is at stake and where the outcome is uncertain, recognizing the diversity of values. Risk is often represented as probability of occurrence of hazardous events or trends multiplied by the impacts if these events or trends occur.	IPCC (2014a)
Transformation	A change in the fundamental attributes of natural and human systems.	IPCC (2014a)
Uncertainty	A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of human behaviour.	IPCC (2019a)
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.	IPCC (2014a)

Annexes



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ANNEX A. SELECTED POTENTIAL IMPACTS OF CLIMATE CHANGE ON AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU) SECTORS, BY REGION

	North America	Latin America and the Caribbean	Europe	
CROP AND LIVESTOCK	Yields of major crops decline modestly by mid-century but more steeply by 2100	In temperate areas, soybean, wheat and pasture productivity increases	Temperate and polar regions benefit from changes	
	Climate favours fruit production in the Great Lakes region, while late season heat stress challenges US soybean yields	Drier soils and heat stress reduce productivity in tropical and subtropical regions	Initial benefits in mid-latitude countries turn negative with higher temperatures	
	Reduced precipitation restricts water availability as irrigation demand increases	Increased salinization and desertification in arid zones of Brazil and Chile	Climate-induced variability in wheat production increases in southern and central Europe	
	Heat stress and lower forage quality reduce milk production and weight gain in cattle	Rainfed agriculture in semi-arid zones faces higher crop losses	High temperatures and humidity increase livestock mortality risk	
FISHERIES AND AQUACULTURE	Many warm- and cool-water species move to higher latitudes	Primary production in the tropical Pacific declines and some species move southwards	Warming displaces some fish populations northwards or to deeper waters	
	Arctic freshwaters experience the greatest warming and most negative impacts	More frequent storms, hurricanes and cyclones harm Caribbean aquaculture and fishing	Invasive tropical species alter coastal ecosystems in southern Europe's semi-enclosed seas	
	Warmer waters and lower water quality increase the incidence of diseases in North Atlantic cetaceans and tropical coral reefs	Changes in freshwater fish species physiology, collapse of coral reef systems	Aquaculture impacted by sea-level rise, acidification, temperature increases	
FORESTRY	Pine forest pest damage increases with higher spring temperatures	Tropical forests are affected more by changes in the water availability and CO_2 fertilization than by temperature change	In Northern and Atlantic Europe, higher temperatures and atmospheric CO_2 levels increase forest growth and wood production	
	Warmer summers boost forest fire risk by up to 30 percent	In Amazonia, increased risk of frequent fires, forest loss and "savannization"	Shrubs increasingly replace trees in Southern Europe	
	Warmer winters favour bark beetles responsible for forest die-off	In Central America, 40 percent of mangrove species are threatened with extinction	An increase in wildfires leads to a significant increase in greenhouse gas emissions	
	Vegetation greening observed in Central America, but browning in other areas largely due to water stress	Vegetation greening observed in parts of South America	Vegetation greening observed in parts of Europe	

SOURCE: FAO. 2016. *The State of Food and Agriculture: Climate Change, Agriculture and Food Security*. Rome. (also available at www.fao.org/3/a-i6030e.pdf).

ANNEX A. (continuation)

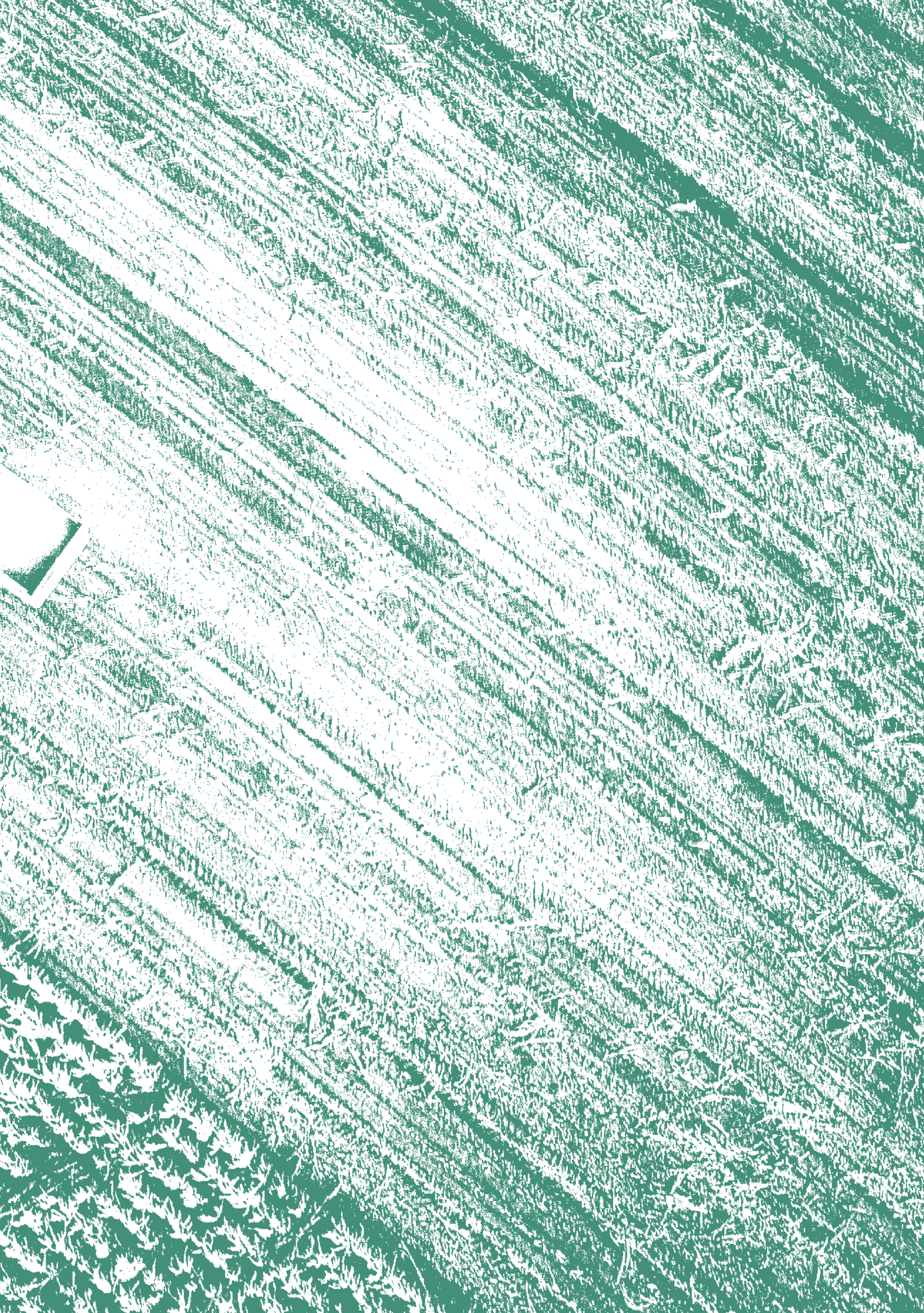
	Sub-Saharan Africa	Near East and North Africa	Asia	Oceania
	Overall impacts on yields of cereals, especially maize, are negative across the region	Rising temperatures threaten wheat production in North Africa and maize yields region-wide	Agricultural zones shift northwards as freshwater availability declines in South, East and Southeast Asia	In New Zealand, wheat yields rise slightly but animal production declines by the 2030s
	The frequency of extremely dry and wet years increases; much of southern Africa is drier, but rainfall increases in East and West Africa	There is a general decline in water availability, but a slight increase in Sudan and southern Egypt	Higher temperatures during critical growth stages cause a decline in rice yields over a large portion of the continent	In Australia, soil degradation, water scarcity and weeds reduce pasture productivity
	Climate change has resulted in lower animal growth rates and productivity in pastoral systems in Africa	In mid-latitudes, higher temperatures lead to richer pastures and increased livestock production	Demand for irrigation water increases substantially in arid and semi-arid areas	In the Pacific islands, farmers face longer droughts and heavier rains
	Rangeland degradation and drought in the Sahel reduce forage productivity	Warmer winters benefit livestock, but summer heat stress has negative impacts	Heat stress limits the expansion of livestock numbers	Higher temperatures increase the water needs of sugarcane
	Sea-level rise threatens coastlands, especially in West Africa	Usable water resources in many Mediterranean and Near East basins decline further	A general decline in coastal fisheries production and greater risk of extreme events in the aquatic systems	Changes in water temperature and currents increase the range of some pelagic species, reduce that of others
	By 2050, declining fisheries production in West Africa reduces employment in the sector by 50 percent	Warming boosts productivity in the Arabian Sea	Redistribution of marine capture fisheries, with numbers declining in the tropics	Changes in water temperature and chemistry strongly affect fisheries and aquaculture
	East African fisheries and aquaculture are hit by warming, oxygen deficit, acidification, pathogens	Catch potential falls by as much as 50 percent in some parts of the Mediterranean and Red Seas	Freshwater aquaculture faces major risks of freshwater scarcity	Nutrient decline reduces krill populations along Australia's east coast
	Changes along coasts and deltas (e.g. death of coral reefs) impact productivity		By 2050, the body weight of marine fish falls by up to 24 percent	Small island states, highly exposed and highly reliant on fisheries, suffer most
	Deforestation, degradation and forest fires affect forests in general	Soil moisture depletion reduces the productivity of major forest species, increases fire risk, and changes pest and disease patterns	Boreal forests and Tibetan plateau alpine vegetation shift northwards	Productivity increases owing to CO_2 fertilization are counterbalanced by the effects of rising temperatures and reduced rainfall
	Forest losses reduce wildlife, bush meat and other non- wood forest production	In the Near East, declining summer rains lead to severe water shortages that affect forest growth	Many forest species face extinction owing to combined effects of climate change and habitat fragmentation	In the Pacific, extreme weather events damage mangrove forests
	Water scarcity affects forest growth more than higher temperatures		A general increase in the frequency and extent of forest fires and the risk of invasive species, pests and diseases	Vegetation greening observed in parts of southeast Australia
	Vegetation browning observed in the Congo Basin		Vegetation greening in parts of Asia, but browning observed in Central Asia and northern Eurasia	

ANNEX B. GENERIC SIMPLIFIED LOGICAL FRAMEWORK STRUCTURE WITH EXAMPLES OF INDICATOR AREAS RELEVANT TO AGRICULTURAL PROJECTS WITH ADAPTATION AND MITIGATION EXPECTED OUTCOMES

	Inclusive Sustainable Agriculture	Adaptation	Mitigation
INPUTS AND ACTIONS	· Capacity building events · Information delivery and exchange systems on agriculture and climate · Inputs and credit · Infrastructure–soil and water conservation	· Capacity building events · Information delivery and exchange systems on agriculture and climate · Inputs and credit · Cash transfers · Climate proofing of infrastructure	· Capacity building events · Information delivery and exchange systems on agriculture and climate · Inputs and credit · Cash transfers · Infrastructure finance
OUTPUTS	· Livelihoods support systems in place: rural credit, insurance, market support · Institutional mechanisms, extension, community groups strengthened · Digital agriculture tools in place and delivering information to farmers · Nutritional support for women and child through agriculture	· Extension systems delivering appropriate CSA advisory · Weather and climate advisory in place, delivering information, including early warnings · Critical inputs for CSA being delivered to farmers · Social protection including weather insurance mechanism established	· Inputs and incentives in place for adoption for emissions reduction · Technologies disseminated through extension · Local institutional mechanisms to manage natural resource management in place (e.g. forest user groups)

OUTCOMES	· Adoption of sustainable agriculture practices (water saving, soil conservation, supporting biodiversity, reducing chemical inputs, etc.)
	· Relevant land-use change
	· Increased production
	· Livelihoods strategy changes
	· Improved diets
		· Adoption of locally appropriate climate-resilient practices (drought, flood, saline tolerance practices and crop and livestock varieties)
		· Diversification of cropping
		· Relevant land-use change
		· Uptake of climate insurance and other social protection
			· Relevant land-use change
			  · Reforestation
			  · Reduced deforestation
			· Adoption of emission-reducing livestock practices
			· Adoption of emission-reducing rice practices (e.g. AWD)

IMPACTS	· Increased agriculture productivity · Reduced negative environmental impacts and improved environ-mental services · Increased food security · Increased incomes and reduced poverty	· Reduced loss and damage to households and agriculture sector · Farming and livelihoods strategies operating viably under new climate conditions	· Reduced GHG emissions · Increased carbon sequestration



ANNEX C. SELECTED EXAMPLES OF ADAPTATION MEASURES TO CLIMATE CHANGE, IN NDCS, BY SECTOR

ADAPTATION MEASURES				
	Data and knowledge	Institutions, policies and financing	Sustainable and climate-smart management	
CROPS AND LIVESTOCK	· Animal health and disease outbreak monitoring and control and long-term feed storage improvement (Lao PDR)	· Reinforcing existing social safety nets (Nigeria) · Microfinance (Uganda)	· Protecting water basins (Ecuador) · Building climate-resilient watersheds in mountainous eco-regions (Nepal) · Increasing protected areas up to 25–30% of the total territory (Mongolia)	
FISHERIES AND AQUACULTURE	· Identifying and conserving endangered fish species (Liberia) · Capacity building in coastal areas (Seychelles)	· Strengthening regulatory framework for protection of beaches, dunes and vegetation (Mauritius) · Developing climate-smart systems to enhance resilience of fisher communities (Liberia) · Blue Economy and Seychelles Strategic Plan 2015 (Seychelles) · Increasing access to financing for mariculture (Maldives)	· Community-based conservation of wetlands and coastal zones (Bangladesh) · Promoting sustainable coastal and maritime tourism; improve quality of fishery products through eco-labelling (Cabo Verde)	
FORESTRY	· Implementing control, monitoring and tracking systems for the appropriate use of forest areas (Bolivia)	· Environmental Services Payments program and the Forest Certification program (Costa Rica) · Systematic land registration and implementation of land tenure regularization reform (Rwanda)	· Community-based forest management following a landscape approach to resource conservation (Nepal) · Reducing slash and burn practices (Lao PDR) · Applying an ecosystem-based approach to reach 0% deforestation rate by the year 2030 (Mexico)	

SOURCE: FAO. 2016. *The agriculture sectors in the Intended Nationally Determined Contributions: Analysis*, by Strohmaier, R., Rioux, J., Seggel, A., Meybeck, A., Bernoux, M., Salvatore, M., Miranda, J. and Agostini, A. Environment and Natural Resources Management Working Paper No. 62. Rome. (also available at http://www.fao.org/3/a-i5687e.pdf).

	Technologies, practices and processes	Disaster risk management
	· Changing cropping patterns and sowing dates (Egypt) · Transition to semi-intensive systems of livestock management (Bolivia) · Promoting indigenous and scientific knowledge use on drought-tolerant crop types and varieties (Zimbabwe) · Improving water management and use (Jordan)	· Permanent monitoring of extreme events and establishing an agro-meteorological unit (Venezuela) · Enhancing national capacity to develop and implement emergency response to agricultural pest and disease outbreaks/epidemics (Bhutan)
	· Developing techniques for agro-ecological fish-farming and the conservation and processing of fish-farming products (Guinea) · Managing coastal and fisheries resources through promotion of non-destructive fishing techniques (Sierra Leone)	· Supporting insurance schemes for farmers and fishers (Seychelles) · Construction of piers and boat storm shelters (Viet Nam) · Early warning systems of sea level rise impacts and extreme weather events (Tanzania) · Coastal Risk Assessment Programme (Barbados)
	· Promoting reforestation and rehabilitation with appropriate tree species (Tonga) · Planting trees for increased resilience, and supporting rural livelihoods and the tourism sector (Lebanon) · Promoting alternative sources of energy to reduce deforestation (South Sudan) · Establishing plantation forests for fuel wood (Republic of Moldova)	· Forest fire risk assessment and management (Bhutan)

INTEGRATING CLIMATE RESILIENCE INTO AGRICULTURAL INVESTMENTS: ILLUSTRATIVE FRAMEWORK

Action categories	Illustrative resilience-enhancing actions through agriculture value chain phases	Non-farming options
	Pre-production	Production
POLICY AND INSTITUTIONS	· Establish favourable enabling environment for formulating and delivering CC policy for agriculture · Climate-proof existing agricultural policies and institutions · Design and deploy new policy instruments aimed at risk reduction for agricultural production through consultative processes · Establish new institutions and approaches to ensure resilience and adaptation options reach, and are adopted by, farming families · Review existing knowledge on CC risks to agriculture and fill knowledge gaps through research	· Develop climate-proofed food security strategies · Strengthen institutions providing services for agricultural adaptation and resilience
FINANCIAL	· Analyse financial implications of CC for agricultural enterprises and national budget – such as rainfall changes leading to failure of tea plantations and consequent loss of tax revenues · Provide/enable financial services to farmers for CCA · Use financial instruments to encourage farmer behaviour resulting in greater resilience	· Provide safety nets to farmers against CC shocks and stressors · Review water pricing policy
INFORMATION, KNOWLEDGE MANAGEMENT AND SOCIAL BEHAVIOUR	· Provide information on CC causes, impacts, risks and options for building resilience · Monitor and learn from CC impacts on resilience of agriculture and natural resources · Encourage long-term continuity and consistency of support for CC resilience projects and programmes in agriculture · Enhance social networks, cohesion and gender equality for resilience	· Provide weather forecasting and information on adaptation options for farmers · Build on local knowledge and climate variability coping strategies
TECHNOLOGY AND ASSET MANAGEMENT	· Identify risks and protect agricultural assets from actual and anticipated climate hazards · Identify and adopt new approaches to agricultural and natural resource management that are resilient to CC · Invest in physical infrastructure or new technologies designed to reduce the impact of current and future climate risks	· Improve ecosystem health and buffering capacity · Develop and apply ways to use natural resources more efficiently · Devise and apply technical means to reduce CC risks to agricultural production through improved extension and other means

SOURCE: Pound, B., Lamboll, R., Croxton S., Gupta N. and Bahadur A.V. 2018. *Climate-Resilient Agriculture in South Asia: An analytical framework and insights from practice.* Action on Climate Today (ACT). Oxford, UK, Oxford Policy Management. http://www.acclimatise.uk.com/wp-content/uploads/2018/02/OPM_Agriculture_Pr2Final_WEB.pdf

Post-harvest	**Market**	
· Develop food storage and distribution capacities · Encourage farmers to move up value chain as part of risk-spreading	· Develop and deploy policy instruments to increase food access, quality and availability · Promote policies that encourage climate-resilient food choices	· Explore policy options for reducing dependence on agriculture and natural resources where these exacerbate CC risks, such as by increasing employment opportunities
· Develop financial instruments to reduce farmer risk at and after harvest	· Develop financial contingencies for emergency situations such as famine caused by harvest failure	· Establish off-farm and non-farm income-generating activities for risk-spreading
· Use media and extension methods to inform farmers of post-harvest value chain diversification opportunities	· Conduct demand monitoring and forecasting for farm products in response to CC · Reduce food wastage	· Advise farmers on how to reduce their exposure to CC risks through non-farm strategies
· Climate-proof agricultural post-harvest infrastructure · Adjust post-harvest technology to new climate realities	· Establish harvest failure contingency systems	· Establish contingency actions against extreme climate risks, such as resettlement or alternative employment

ANNEX E. FAO TOOLS FOR ASSESSMENT OF CLIMATE HAZARDS, IMPACTS AND VULNERABILITY

TOOLS FOR ASSESSING CLIMATE HAZARDS AND IMPACTS		
TOOL NAME	**DESCRIPTION**	**LINK**
Global Agroecological Zoning (GAEZ)	The GAEZ database provides the agronomic backbone for various applications including the quantification of land productivity. Results are commonly aggregated for current major land use/cover patterns and by administrative units, land protection status, or broad classes reflecting infrastructure availability and market access conditions. With this large amount of data, a new system had to be created to make the data accessible to a variety of users. The result is the new GAEZ Data Portal, an interactive data access facility, which not only provides free access to data and information and allows visualization of data, but also provides the user with various analysis outputs and download options.	www.fao.org/nr/gaez/en/#
Modelling System for Agriculture Impacts of Climate Change (MOSAICC)	MOSAICC reflects a methodology and system of models designed to carry out interdisciplinary climate change impact assessment on agriculture through simulations. The main components of the system are a statistical downscaling portal to downscale Global Circulation Models (GCM) data to weather station networks, a hydrological model for estimating water resources for irrigation in major basins, two water balance-based crop models to simulate crop yields under climate change scenarios, and a model to assess the effect of changing yields on national economies. MOSAICC is a country driven process with a focus on capacity development for countries to carry out impact assessments with local information.	www.fao.org/in-action/mosaicc/en/
Agriculture Stress Index Systems (ASIS): global and country level	Using data on vegetation and land surface temperature, ASIS monitors vegetation indices and detects hotspots where crops may be affected by drought. The system contributes greatly to the food security monitoring work of Global Information and Early Warning Systems on Food and Agriculture (GIEWS).	www.fao.org/resilience/news-events/detail/en/c/296089/
Open Foris (Collect Earth and Earth Engine)	Open Foris is a set of open-source software tools to facilitate flexible and efficient data collection, analysis, and reporting. Its modules can be used for forest inventories, land use and land-use change assessment, and climate change reporting.	www.openforis.org
WaPOR	The FAO portal on Water Productivity through Open access of Remotely sensed derived data (WaPOR) monitors and reports on agriculture water productivity over Africa and the Near East. It is a vital new tool to address water scarcity and adapt to changing weather patterns.	www.fao.org/in-action/remote-sensing-for-water-productivity/en/
AquaCrop	AquaCrop is a crop model that simulates the yield response of herbaceous crops to water and is particularly well suited to conditions in which water is a key limiting factor in crop production. AquaCrop balances accuracy, simplicity and robustness. To ensure its wide applicability, it uses only a small number of explicit parameters and mostly intuitive input variables that can be determined using simple methods.	www.fao.org/aquacrop/en/
Assessment tool for the potential impact of climate change on breed distribution	Livestock breeds raised in certain environments have acquired characteristics that enable them to thrive in local conditions and meet the needs of the people that keep them. This means that a changing climate can affect the ability to raise certain breeds in certain areas. This tool models potential future habitats for 8 800 livestock breeds, allowing more informed decision-making on breed management as climate change alters habitats.	www.fao.org/breed-distribution-model

TOOL FOR ASSESSING VULNERABILITY		
TOOL NAME	**DESCRIPTION**	**LINK**
Resilience Index Measurement and Analysis (RIMA)	RIMA is an innovative quantitative approach that analyses why and how some households cope with shocks and stressors better than others do. The first version of RIMA has been technically improved based on its application in ten countries. The direct measure provides descriptive information of household resilience capacity and it is a valuable policy analysis tool to inform funding and policy decisions of governments, international organizations, donors and civil society, so as to target and rank households from most to less resilient. RIMA also measures resilience indirectly to provide evidence on the main determinants of households' resilience capacity. The indirect measure of resilience can be adopted as a predictor tool for interventions that strengthen resilience to food insecurity. It provides new depth and breadth to resilience analysis and supports decision-makers and other stakeholders to better understand the dynamics of positive trends in resilience and thus develop strategies that will yield positive results.	http://www.fao.org/resilience/background/tools/rima/en/

TOOLS FOR ASSESSING MITIGATION POTENTIAL		
TOOL NAME	**DESCRIPTION**	**LINK**
Ex-Ante Carbon-balance Tool (EX-ACT)	This system provides ex ante estimates of the impact of land use and land-use changes, and natural resource management on GHG emissions and carbon balance. EX-ACT is a powerful tool that can ensure agricultural investments are climate-proofed.	www.fao.org/tc/exact
FAOSTAT	FAOSTAT includes a global inventory of GHG emissions from all agricultural activities, including crop production, livestock, and forestry and land-use changes.	http://www.fao.org/faostat/en/#home
BEFS Rapid Appraisal	The BEFS Rapid Appraisal (RA) consists of a set of easily applicable methodologies and user-friendly tools which allow countries to get an initial indication of their sustainable bioenergy potential and of the associated opportunities, risks and trade-offs.	www.fao.org/energy/bioenergy/bioenergy-and-food-security/assessment/befs-ra/en/

ANNEX F. TYPES AND SELECTED EXAMPLES OF ADAPTATION TOOLS IN CAPTURE FISHERIES AND AQUACULTURE

B1. Types and selected examples of adaptation tools in capture fisheries

INSTITUTIONAL RESPONSE
PUBLIC POLICIES
Increase public investments (e.g. research, capacity building, sharing best practices and trials, communication)
Develop climate change adaptation policies and plans addressing fisheries
Provide incentives for fish product value addition and market development
Remove harmful incentives (e.g. for the expansion of fishing capacity)
Address poverty and food insecurity, which systemically limit adaptation effectiveness
LEGAL FRAMEWORKS
Flexible access rights to fisheries resources in a changing climate
Dispute settlement arrangements
Adaptive legal rules
Regulatory tools (e.g. adaptive control of fishing pressure; move away from time-dependent effort control)
INSTITUTIONAL FRAMEWORKS
Effective arrangements for stakeholders' engagement
Awareness raising and capacity building to integrate climate change into research/management/policy/rules
Enhanced cooperation mechanisms including between countries to enhance the capacity of fleets to move between and across national boundaries in response to changes in species distribution
MANAGEMENT AND PLANNING
Inclusion of climate change in management practices, e.g. ecosystem approach to fisheries, including adaptive fisheries management and co-management
Inclusion of climate change in integrated coastal zone management (ICZM)
Improved water management to sustain fishery services (particularly inland)
"Adjustable" territorial use rights
Flexible seasonal rights
Temporal and spatial planning to permit stock recovery during periods when climate is favourable
Transboundary stock management to take into account changes in distribution
Enhanced resilience by reducing other non-climate stressors (e.g. habitat destruction, pollution)
Incorporation of traditional knowledge in management planning and advice for decision-making
LIVELIHOODS RESPONSE
WITHIN SECTOR
Diversification of markets/fish products, access to high-value markets, support to diversification of citizens' demands and preferences
Improvement or change of post-harvest techniques/practices and storage
Improvement of product quality: eco-labelling, reduction of post-harvest losses, value addition
Flexibility to enable seasonal migration (e.g. following stock migration)
Diversify patterns of fishing activities with respect to the species exploited, location of fishing grounds and gear used to enable greater flexibility
Private investment in adapting fishing operations, and private research and development and investments in technologies e.g. to predict migration routes and availability of commercial fish stocks
Adaptation-oriented microfinance

BETWEEN SECTORS
Livelihood diversification (e.g. switching among rice farming, tree crop farming and fishing in response to seasonal and inter-annual variations in fish availability)
Exit strategies for fishers to leave fishing
RISK REDUCTION AND RESILIENCE RESPONSE
RISK POOLING AND TRANSFER
Risk insurance
Personal savings
Social protection and safety nets
Improve financial security
EARLY WARNING
Early warning communication and response systems (e.g. food safety, approaching storms)
Monitoring climate change trends, threats and opportunities (e.g. monitoring of new and more abundant species)
Extreme weather and flow forecasting
RISK PREVENTION
Risk assessment to identify risk points
Safety at sea and vessel stability
Reinforced barriers to provide a natural first line of protection from storm surges and flooding
Climate-resilient structures (e.g. protecting harbours and landing sites)
Address underlying poverty and food insecurity problems
PREPAREDNESS AND RESPONSE
Building back better and post-disaster recovery
Rehabilitate ecosystems
Compensation (e.g. gear replacement schemes)

B2. Types and selected examples of adaptation tools in aquaculture

INSTITUTIONAL RESPONSE	SPATIAL SCALE
PUBLIC POLICIES	
Mainstream aquaculture into national and regional adaptation and development plans	National/regional
More effective sharing of and access to water and coastal space with other users	National/watershed
Investments in research and development of aquaculture adaptation technologies; new species, breeding for species tolerant to specific or a combination of stressors (disease, temperature, salinity, acidification), etc.	National, regional, international
Investments to facilitate the movement and marketing of farm products and supply inputs	National, regional, international
Appropriate incentives for sustainable and resilient aquaculture including taxes and subsidies	National, international
Attention to poverty and food insecurity within aquaculture systems	National, international
LEGAL FRAMEWORKS	
Property rights, land tenure, access to water	National
Standards and certification for production and for resistant facilities	National
INSTITUTIONAL FRAMEWORKS	
Strengthening cross-sectoral and inter-institutional cooperation and coordination	Zone/national/regional
Mainstream adaptation in food safety assurance and control	National
MANAGEMENT AND PLANNING	
Climate change mainstreamed into integrated coastal zone management (ICZM)	National/watershed/regional
Community-based adaptation	Site and community levels
Aquatic protected areas (marine and freshwater) and/or green infrastructure (see ecosystem approach to aquaculture (EAA) guidelines[76]	National/regional
Mainstream climate change in aquaculture area management under the EAA	Zone/watershed/national
Better management practices including adaptation and mitigation, i.e. better feed and feed management, water quality maintenance, use of higher quality seed	Site level/zone/management area
Mainstream climate change into spatial planning and management for risk- based zoning and siting	Site level/zone/management area
Integrate climate change in carrying capacity considerations (production, environmental and social)	Site level/zone/management area
LIVELIHOODS RESPONSE	
WITHIN SECTOR	
Develop and promote new, more resilient farming systems and technologies	Site level/national
Genetic diversification and protection of biodiversity	National
Integrate climate change in microfinance	National
Aquaculture diversification	All
More resistant strains	Site level
More resistant and/or resilient hatcheries and hatchery produced seeds	Zone/national
Value addition	National, regional, international
Better market access; new markets for new species and products	Zone, national regional
Shift to non-carnivorous species	Site level
Fish meal and oil replacement	Site level/national

76 See FAO, "Aquaculture development: 4. Ecosystem approach to aquaculture," *FAO Technical Guidelines for Responsible Fisheries.* No. 5, Suppl. 4. (2010): 53.

Empowering farmers' and womens' organizations	Management area/national
Integrated farming systems and circular economy	Site level/management area
BETWEEN SECTORS	
Diversify livelihoods	Site level/national
RISK REDUCTION AND RESILIENCE RESPONSE	
RISK POOLING AND TRANSFER	
Social safety nets	National
Social protection	National
Aquaculture insurance	National
EARLY WARNING	
Integrated monitoring (relevant aquaculture area), information analysis, communication and early warning of e.g. extreme events, disease outbreaks, etc.	Farm, watershed, zone
Development of national and local vulnerability maps and raising awareness of risks	Subnational/national
Scientific and local knowledge are synthesized and shared; logistics to disseminate information	All
A reliable national risk communication system that supports early warnings	National
Meteorological infrastructure and system that can effectively support crop and farm asset insurance (and particularly weather-indexed or parametric insurance)	National
RISK PREVENTION	
Stronger farming structures (e.g. net pens) and more resilient designs (e.g. deeper ponds)	Site level/national
Enabling adaptive movement between mariculture and inland aquaculture (recirculation aquaculture systems (RAS), aquaponics)	Site level/national
Better water management and biosecurity frameworks	Site level/zone/farm clusters
PREPAREDNESS AND RESPONSE	
Contingency for emergency management, early harvest and/or relocation	National
Rehabilitation and building back better plans	National/international
Relief programmes such as work-for-food and "work in reconstruction and rehabilitation projects" that offer temporary jobs for farmers and farm workers whose livelihoods have been negatively impacted by climate change	International/national
Emergency assistance to avoid additional damage and loss from climate-related disasters – could include fish feed to avoid massive mortality of stock, etc.	National

SOURCE: Poulain, F., Himes-Cornell, A. & Shelton, C. 2018. Methods and tools for climate change adaptation in fisheries and aquaculture. In M. Barange, T. Bahri, M.C.M. Beveridge, K.L. Cochrane,S. Funge-Smith & F. Poulain, eds. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*, pp. 535-566. FAO Fisheries and Aquaculture Technical Paper No. 627. Rome, FAO. 628 pp.

With climate change increasingly threatening agriculture – a vital source of food, income and employment for most of the world's poor – agricultural investments need to become more climate sensitive. This comprehensive knowledge product provides practical reference material on integrating climate risk considerations at all stages of the investment project cycle, from design to implementation, and monitoring and evaluation. It draws on the most recent information and data sources, including the latest Intergovernmental Panel on Climate Change (IPCC) reports. It also showcases FAO-developed tools, tested approaches and selected experiences, and discusses climate financing opportunities for agriculture.

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