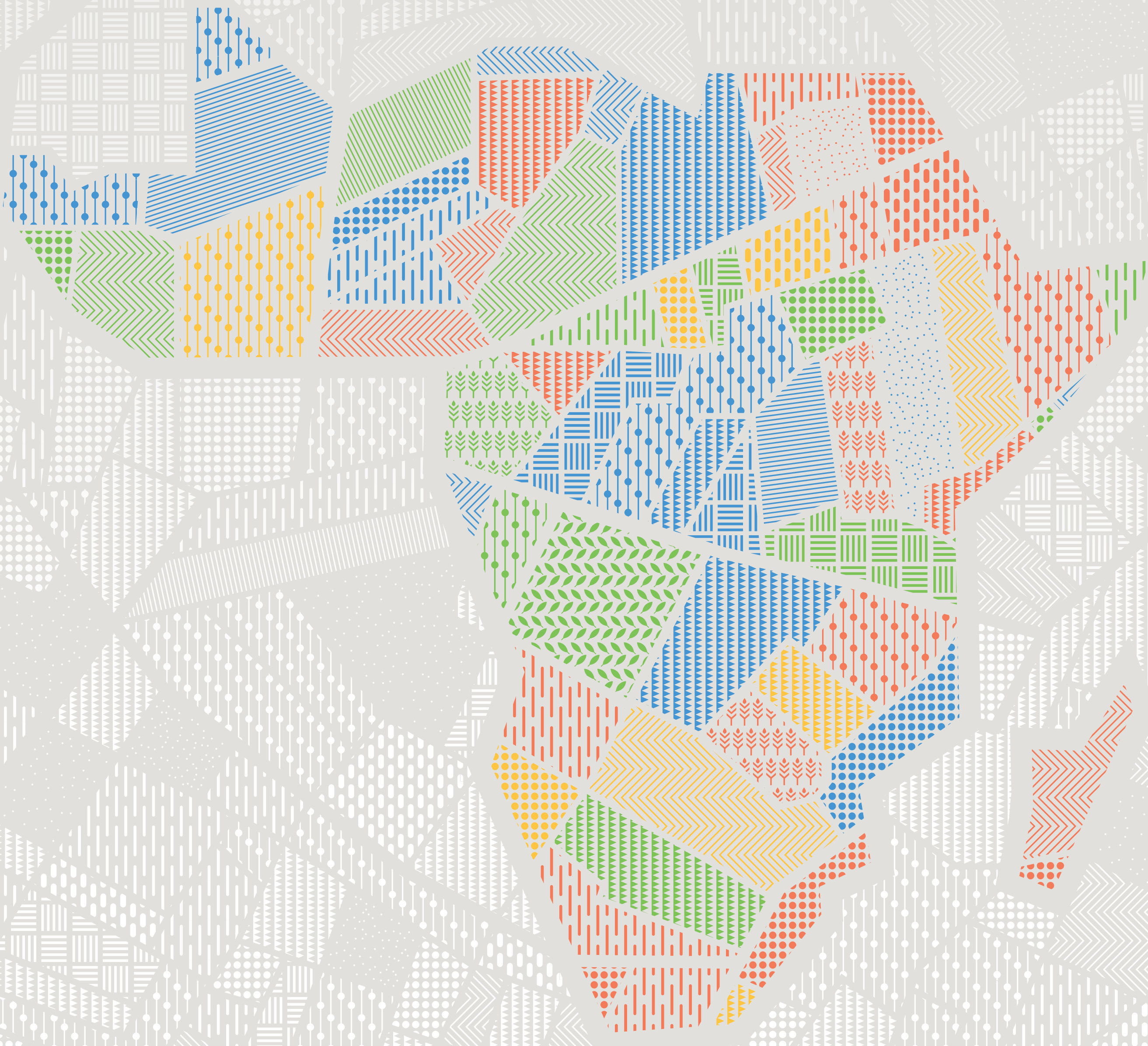
gef GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

UN DP

Empowered lives.
Resilient nations.

Options and Opportunities to Make Food Value Chains More Environmentally Sustainable and Resilient in Sub-Saharan Africa



GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

Empowered lives.
Resilient nations.

Options and Opportunities to Make Food Value Chains More Environmentally Sustainable and Resilient in Sub-Saharan Africa

FOREWORD

Mr. Lamin M. Manneh
Director, UNDP Regional Service Centre for Africa

Mr. Gustavo A. B. da Fonseca, PhD.
Director of Programs, GEF Secretariat

Agricultural food value chains (VCs) are gaining importance as part of broader efforts to achieve food security and improve nutrition, as well as transforming African agriculture and contributing to the Sustainable Development Goals (SDGs). With an increased focus on inputs, markets, financing, agribusiness, and agro-industry, the prospects of commercialization for smallholder farmers will likely expand and involve all major food staples. While much has been done to understand and document good practices that generate global environmental benefits in production landscapes, such knowledge is limited or lacking for food VCs in Sub-Saharan Africa (SSA).

Against this background, the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) have produced the present study to assess options and opportunities to make food VCs more environmentally sustainable and resilient in SSA. A key finding of the study is that while 'sustainability' and 'resilience' are not yet core strategies in food VC development, practical courses of action that can be scaled up do already exist.

Case studies from six VCs in 12 dryland countries in SSA demonstrate that there are multiple approaches and technical practices throughout the region to better harness VCs and reduce environmental impacts and externalities. Nevertheless, in order to make the transition to sustainable and resilient food systems, positive incentives are indispensable. In its widely applicable 'Framework for Action', the study proposes an operational tool that — utilizing an inclusive action-based, multi-stakeholder platform — can facilitate the collective action required to tackle negative externalities and foster a shift towards environmentally sustainable and resilient food VCs.

We hope that the 'Framework for Action', and the findings from the study more broadly, will be taken up by a wide variety of food VC stakeholders at country, regional and continental levels: ranging from technical government staff to expert practitioners, the private sector, bilateral donors, United Nations bodies, researchers, non-governmental organization (NGO) personnel and academics. The findings of this study should help all these actors to make a compelling argument for integrated and innovative policy, management or investment choices that promote and advance environmentally sustainable and resilient food VCs — and thereby contribute to the attainment of the SDGs.

Mr. Lamin M. Manneh

Mr. Gustavo A. B. da Fonseca, Ph.D.

TABLE OF CONTENTS

Boxes

Tables

Figures

AAA	Adaptation of African Agriculture
AGIR	Global Alliance for Resilience Initiative (FR: *Alliance globale pour l'initiative résilience*)
AGRA	Alliance for a Green Revolution in Africa
ARC	African Risk Capacity
AU	African Union
B2B	business-to-business
BAU	Business as usual
BMCT	Bwindi Mgahinga Conservation Trust
CA	Conservation agriculture
CAADP	Comprehensive Africa Agriculture Development Programme
CBA	Cost-benefit analysis
CBD	Convention on Biological Diversity
CFS	Committee on World Food Security
CGIAR	Consortium of International Agricultural Research Centres
CIMMYT	International Maize and Wheat Improvement Center
CSO	Civil Society Organization
CSA	Climate-Smart Agriculture
CSR	Corporate social responsibility
DFI	development finance institution
EAC	East African Community
ECOWAS	Economic Community of West African States
ECOWAP	Economic Community of West African States' Agricultural Policy
EIA	Environmental Impact Assessment
ERIP	Emergency Rice Initiative Project
FAO	Food and Agriculture Organization of the United Nations
FCE	Facilitator for Change Ethiopia
FDI	Foreign direct investment
GAFSP	Global Agriculture and Food Security Program
GAP	Good Agricultural Practice
GCF	Green Climate Fund
GEF	Global Environment Facility
GGWSSI	Great Green Wall for the Sahara and the Sahel Initiative
GHG	Greenhouse gas
GLEAM	Global Livestock Environmental Assessment Model
IAP	Integrated Approach Pilot
IBLI	index-based livestock insurance
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
ILM	Integrated Landscape Management
ILRI	International Livestock Research Institute
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
IUCN	International Union for Conservation of Nature
LIDESA	Livestock Development Strategy for Africa
MBM	Market-based mechanisms
MLN	Maize Lethal Necrosis
MSMES	micro-, small and medium enterprises
NAIP	National Agriculture Investment Plan
NEPAD	New Partnership for Africa's Development
NRDS	National Rice Development Strategies
ODA	official development assistance
OECD	Organisation for Economic Co-operation and Development
PEA	Political economy analysis
PES	Payment for ecosystem services
PGS	Participatory Guarantee Systems

PICS	Purdue Improved Crop Storage
PPP	Public-private partnerships
RAI	Principles for Responsible Investment in Agriculture and Food Systems
RAPTA	Resilience, Adaptation Pathways and Transformation Assessment
REC	Regional Economic Community
RLE	Red List of Ecosystems
SADC	Southern African Development Community
SDGS	Sustainable Development Goals
SEA	Strategic Environmental Assessment
SEM	Sustainable ecosystem management
SFVC	Sustainable food value chain
SIMLESA	Sustainable intensification of maize-legume cropping systems for food security in Eastern and Southern Africa
SLM	Sustainable Land Management
SMES	Small- and medium-sized enterprises
SPA	Sustainability Performance Assessment
SSA	Sub-Saharan Africa
TEEB	The Economics of Ecosystems and Biodiversity
TSA	Targeted Scenario Analysis
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
VC	Value chain
WEF	World Economic Forum

Options and Opportunities to Make Food Value Chains More Environmentally Sustainable and Resilient in Sub-Saharan Africa

THERE ARE SEVERAL PROVEN OPTIONS and opportunities to make food value chains (VCs) more environmentally sustainable and resilient in Sub-Saharan Africa (SSA). Most of the technical and socio-economic solutions for sustainable and resilient practices can be grouped under the broad umbrellas of on-farm diversification, sustainable intensification of agriculture, and off-farm livelihoods and diversification of markets. On the one hand, cost-benefit analyses (CBAs) prove that investments in sustainability can be highly profitable, especially in the long run. Various VC actors — public as well as private — have indeed shown considerable innovation and drive to make the shift towards environmentally sustainable and resilient VCs in SSA. On the other hand, multiple constraints impede the expansion of good practices. A holistic, systemic approach is needed to connect production and consumption, to bridge different policy domains and to create action-oriented partnerships throughout VCs. Four supportive pillars that address the needs for information, resources, enabling policies and implementation support, all brought together through a multi-stakeholder platform, can stimulate the required paradigm shift towards sustainable and resilient food systems.

This study provides an overview of the key continental, regional and national frameworks and policies to promote sustainable and resilient food VCs in SSA, as well as examining their effectiveness. It identifies good practices required for the transition towards sustainable and resilient food VCs in SSA, based on the assessment of negative environmental impacts and externalities, with a focus on six VCs: livestock (meat and dairy), rice, cassava, maize, pulses and mango VCs in several dryland countries, including Burkina Faso, Ethiopia, Ghana, Malawi, Niger, Nigeria, Kenya, Senegal, Swaziland, Tanzania and Uganda. Furthermore, the study identifies incentives and enforcement mechanisms for various stakeholders to make food VCs environmentally sustainable and resilient in SSA, with a special focus on supporting smallholder farmers and small- and medium-sized enterprises (SMEs). Drawing on all these lessons learned, it concludes with a 'Four-Pillar Framework for Action' towards holistic and systemic change.

The challenge is threefold: sustainable ways to feed a growing population amid ecosystem constraints, a changing climate and the lack of incentives

The world population is expected to grow exponentially: from the current 7 billion to 9 billion by 2050, with 3 billion added to the middle class. Urban areas in developing countries will absorb most of the population increase, with nearly 70 percent of people living in cities by 2050. Africa is the second fastest urbanizing continent in the world. These trends will be marked by a sharp increase in the demand for energy, transport, buildings, water and, of course, food.

Meeting the demands, especially for food, of a growing population is challenging, especially in SSA, where adequately but sustainably feeding a growing population is an extremely pressing issue. The region is frequently challenged by chronic food deficits, extremely low crop yields and poor soil quality, compounding the problems of undernourished populations and extreme poverty rates. In addition, households are directly reliant on rain-fed agriculture. Climate change and climate variability, leading to higher temperatures or extreme weather events such as droughts and floods, will further exacerbate the risks along entire food VCs. At the same time, many current agro-food VC practices and economic business models in SSA have negative environmental impacts and externalities, damaging the ecosystems. These pressures lead to problems including biodiversity loss, carbon emissions, soil erosion, water depletion, food waste and diseases.

SSA has great potential for sustainable and resilient VCs — but challenges need to be addressed

About 50 percent of the world's uncultivated arable land (202 million hectares) is in Africa (AfDB, 2016), which also has a growing young population that can be engaged in sustainable agriculture. These advantages that African agriculture brings to food security and the potential for building sustainability and resilience have been recognized by policymakers at the continental, regional and national levels.

However, implementation and enforcement is weak. 'Sustainability' and 'resilience' are not yet core strategies for agro-food VC development, but rather an add-on component. The lack of progress is also due to conflicting interests in policy development and an uncertain policy environment.

Making a transition towards sustainable food value chains (SFVCs) and eventually sustainable food systems is not easy: agriculture in SSA is dominated by small, subsistence farms with few assets and limited capacities to adapt, weak access to inputs, a lack of mechanization, credit and organization, as well as weak market access. In addition, a large part of VC activities is informal, posing problems for data generation, the spread of information and technologies, the enforcement of enabling incentives and the organization of multi-stakeholder partnerships.

Sustainable and resilient food systems require integrated approaches and contextual target solutions

First, before proposing solutions to negative environmental impacts and externalities, it is important to adequately measure them to gain a deeper understanding. There are many tools to measure separate impacts; increasingly popular are systems approaches that can assess impacts and externalities along the entire food VC.

Second, three courses of action can facilitate the shift towards sustainable and resilient food systems:

1. **On-farm diversification:** this refers to maintaining multiple sources of production systems and varying what is produced across farming landscapes and over time, through crop rotation, intercropping or mixed farming.

2. **Sustainable intensification of agriculture**: this brings together the best agronomic practices to optimize production relative to inputs, including land and water, while minimizing negative impacts and externalities, such as pollution or deforestation.

3. **Off-farm livelihoods and diversification of markets**: this course of action goes beyond production to include the broader VCs. It involves adopting new activities in order to differentiate income sources, thereby improving economic resilience and access to markets.

These pathways for action can be implemented through existing good practices, borrowing from Sustainable Land Management (SLM), Integrated Landscape Management (ILM) and Climate-Smart Agriculture (CSA). SLM looks at sustainably managing a land management unit (e.g. farm) through improved water, soil and pest management, while ILM proposes similar practices for an entire landscape rather than a specific unit. CSA jointly addresses food security and climate change challenges through three actions: sustainably increasing yields, adapting to climate change and, where possible, mitigating greenhouse gas (GHG) emissions.

Six VCs in 12 dryland countries reveal risks, challenges and potential for progress

The study looks at six VCs: livestock (including meat and dairy products), rice, cassava, maize, pulses and The study looks at six VCs: livestock (including meat and dairy products), rice, cassava, maize, pulses and mangoes. These were selected on the basis of their socio-economic relevance to dryland countries in SSA, their known environmental impacts and externalities, and the climate change (variability) risks they face or the adaptation opportunities they present.

All activities along the six food VCs generate negative environmental impacts and externalities, most notably GHG emissions, loss of biodiversity, soil degradation, water depletion and post-harvest losses. Impacts, externalities and their level of intensity vary, based on factors such as the type of crop or livestock, the geography, the type of VC (large or small), the level of (in)formality and the level of access to information. In the case of livestock, the release of GHG emissions is particularly harmful, while pulses — which have the unique ability to fix nitrogen in the soil — as well as cassava have a relatively low ecological footprint. Meanwhile, maize and rice are characterized by unsustainable practices related to mono-cropping and generally have a high water footprint. The mango VC also has a number of environmental impacts, such as soil degradation, but as it is an important export product, it is often governed by strict global rules on sustainable production and processing.

Case studies show that there are multiple technical practices throughout SSA to reduce environmental impacts and externalities, based on sustainable intensification and on-farm diversification. However, general adoption of sustainable techniques is slow and needs to be stepped up.

Incentives, combined with control and enforcement mechanisms, are indispensable to achieving sustainable and resilient food systems

The economic logic of shifting to sustainable practices along the VC that shows that there will be a higher return (in the long term) does not take sufficient account of the real balance between higher prices of sustainably produced goods, but also, in many cases, the higher costs of their production. VC actors therefore often stick to unsustainable practices, because the business case for sustainable practices that internalize the costs of negative impacts and externalities is still unclear. There is thus still a compelling opportunity to support enabling market conditions for sustainable practices along the VC. Yet, even if VC actors want to make the shift, they face barriers, such as the lack of access to organic fertilizer or seeds, the lack of bargaining power to negotiate better prices and limited market access. Furthermore, due to trade dynamics or market demand, the system in which VC actors operate favours business models that go against sustainable practices and encourages mono-cropping.

Therefore, positive incentives for the transition to sustainable food systems that also allow for off-farm livelihoods and diversification of markets are needed, as well as much stronger control and enforcement mechanisms to ensure that incentives result in change. Incentives can be grouped into four categories: 1) intrinsic motivation to protect livelihoods and promote public goods; 2) policy and legal incentives; 3) financial incentives; and 4) market demand and market arrangements. The various VC actors can either create incentives or benefit from them, depending on their role within the VC.

The agricultural sector is exposed to various risks, including weather variability, pests and price volatility, which make investments less appealing. The public and private sectors play roles in de-risking by means of loan guarantees, VC financing and insurance schemes. They can also generate market information through targeted actions that foster VC resilience. Furthermore, the public sector can create a proper policy and regulatory environment, and provide the required incentives.

Way forward: a Four-Pillar Framework for Action

In order to further advance the many lessons learned for the required transition towards environmentally sustainable and resilient food VCs, widely applicable, cross-sectoral and systematic actions are required. This study thus puts forward a widely applicable Framework for Action, consisting of four intervention areas, or pillars, that are mutually reinforcing and all provide incentives towards sustainable and resilient food systems:

- '**Information**' provides VC actors, especially smallholder farmers and SMEs, with the awareness, knowledge, technology and expertise required to make the move towards sustainable and resilient food VCs and food systems. This first pillar also refers to communication systems and networks — including education and media — that allow information and

knowledge to be strengthened, harmonized and shared, as well as progress to be monitored.

- '**Resources**' are the public and private financial means needed along the whole VC to make it more environmentally sustainable and resilient, such as greening VCs, innovative financing, donor and banking schemes, and microfinancing.

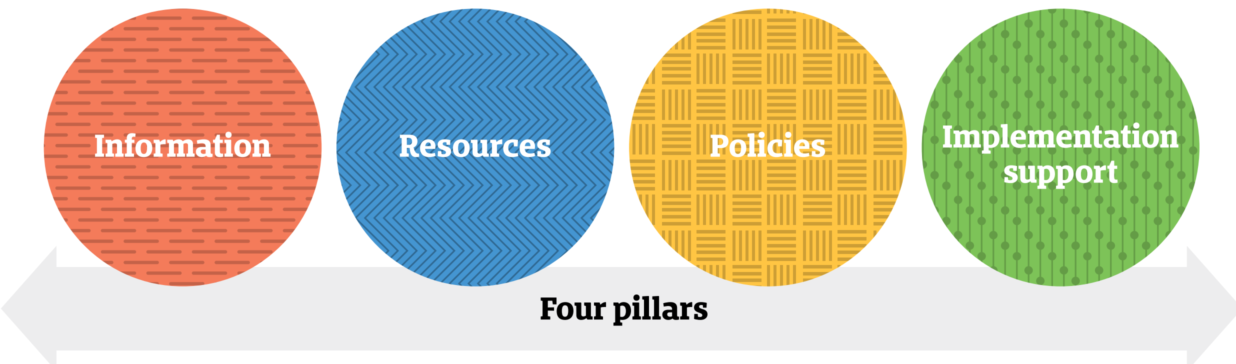
- '**Policies**', and related laws and regulations, play a critical role in overcoming the various challenges to environmentally sustainable and resilient food VCs, such as poor regulatory conditions and onerous administrative procedures. Policies can refer to public policies as well as private regulation.

- '**Implementation support**', through capacity-building and technical assistance, helps translate systemic models into ground-level reality, to achieve environmentally sustainable and resilient food VCs. In other words, it allows new initiatives and intermediaries to be set up and/or the implementation support capacities of existing actors or within existing organizations to be built. Furthermore, infrastructure development (e.g. good roads) and the facilitation of investment infrastructure for sustainability and resilience purposes are also important forms of implementation support.

The implementation of the key actions under the respective four pillars all require an **inclusive and collective action-based multi-stakeholder platform** to facilitate the process towards environmentally sustainable and resilient food VCs and sustainable food systems. This platform will allow all VC actors to engage in a process to share information, promote innovative solutions, plan joint strategies for priority setting, lobby, influence, monitor and evaluate, ensure implementation of policies and guarantee mutual accountability.

A logical approach must be taken to set up and effectively coordinate a multi-stakeholder platform that addresses systemic issues and is mutually reinforcing: 1) map VC actors and relations; 2) list bottlenecks and identify conditions and opportunities for change; and 3) develop collective action plan and actions per group of stakeholders (see Figure 1).

FIGURE 1 **Full implementation of the four pillars for action through a multi-stakeholder platform (compiled by the authors)**



Multi-Stakeholder Platform

1. Map value chain actors and relations
2. List priority bottleneck and identify conditions and opportunities for change
3. Develop collective action plan and actions per group of stakeholders

Global and regional challenges

THE WORLD POPULATION IS EXPECTED to grow exponentially: from the current 7 billion to 9 billion by 2050, with 3 billion added to the middle class. Urban areas in developing countries will absorb most of the population increase, with nearly 70 percent of people living in cities by 2050. Africa is the second fastest urbanizing continent, second only to Asia.[1]

These trends will be marked by a sharp increase in the demand for energy, transport, buildings, water and, of course, food. With humanity's current use of ecological resources and services (its ecological footprint), we are already at 1.6 times the planet's replenishing capacity. Current patterns are therefore unsustainable.[2] Although Africa has a relatively low per capita ecological footprint, this increased by 240 percent between 1961 and 2008 as a result of population growth and increased consumption in a few countries. Consequently, the continent's average per capita footprint is rapidly approaching the available biocapacity within its borders of 1.5 global hectares per person (AfDB & WWF, 2012). On top of this, Africa faces increasing unemployment, particularly among its youth, with a youth unemployment rate in Sub-Saharan Africa (SSA) of 10.9 percent in 2016 (ILO, 2016). Subsequently, with an emigration rate of 1.5 percent, against a global average of 1 percent, Africa has the highest emigration rates in the world. This trend is only expected to increase.[3]

In addition, **market fragmentation and the lack of trade integration in SSA as well as SSA's position in the global trade system are not conducive to sustainable development**. Costly trade logistics, including non-tariff barriers, poor infrastructure (road, rail, port, communications, energy and water), policy and regulatory inconsistencies or failures and geography are the main causes of these trade issues. Another concern for many SSA countries is that large-scale imports of cheap industrialized products (e.g. refined petroleum, vehicles) and food items (e.g. great volumes of rice imports from Asia to West Africa) from other developing countries are increasingly competing with domestic production, with negative consequences for local manufacturing and agro-food production (Chea, 2012; Torres & van Seters, 2016). West Africa, for example, faces a negative food trade balance, which has been deteriorating rapidly over the last decade. Export earnings have given the region the resources to finance a growing share of imported food products, including rice, wheat, meat and vegetables. This has created a paradoxical situation in which a region with exceptional potential for food production is importing more and more food items, a trend that can be explained by the factors discussed previously. In addition, local food production "remains constrained by issues such as poor access to key inputs, lack of secure land rights, water access limitations under erratic weather and poor development of irrigation, weak production technologies […]" (Torres & van Seters, 2016).

The global **challenge ahead is to find sustainable ways to meet the ever-increasing demand for food of a growing population**.[4] This is easier said than done, especially in SSA, where adequately but sustainably feeding a growing population is an extremely pressing issue. The region is frequently challenged by chronic food deficits, extremely low crop yields and poor soil quality, compounding the problems of undernourished populations and extreme poverty rates. In addition, households are directly reliant on rain-fed agriculture as their primary source of income.

At the same time, current agricultural practices leave a harmful footprint on the environment, with many agricultural production practices and economic business models in SSA having negative environmental impacts and externalities.[5] They place pressure on the environment by exceeding its regenerative and absorptive capacity, thereby harming the ecosystems.

1 See: https://www.brookings.edu/blog/africa-in-focus/2015/12/30/foresight-africa-2016-urbanization-in-the-african-context/.

2 In other words: humans use the equivalent of 1.6 Earths to provide the resources, needed to use and to absorb all the waste. See: http://www.footprintnetwork.org/our-work/ecological-footprint/.

3 See: http://www.ilo.org/addisababa/media-centre/pr/WCMS_444474/lang--en/index.htm.

4 Food demand is projected to increase by 70 percent by mid-century.

5 Environmental impacts and externalities are used together in this study. "Environmental impacts" refer to the (direct) impact that unsustainable practices, including reduced yields due to nutrient depletion, reduced productivity and even mortality of livestock due to the lack of grazing opportunities caused by overstocking. An "externality" refers to "the consequence of an economic activity experienced by unrelated third parties. An "environmental externality" is when this externality has an impact on the natural environment, such as pollution. Externalities can also be positive, but these are not the focus of this study. See: www.investopedia.com.

These pressures lead to biodiversity loss, land conversion and deforestation, GHG emissions, soil erosion and degradation, depletion of water resources, contamination from chemicals, food waste, and so forth. However, harm does not occur solely at the production stage: the activities of other VC actors, including the input companies, traders, food processing facilities, retailers as well as consumers generate negative environmental impacts and externalities. For example, the providers of chemical fertilizer, which leads to soil degradation, cause environmental damage. Therefore, **all practices along the VC can have negative effects on agro-food activities**. Moreover, climate change and climate variability will further exacerbate the risks faced by agriculture, which in SSA is dominated by small farms with few assets and limited capacities to adapt, a lack of mechanization and limited access to markets. Climate change and climate variability, leading to higher temperatures or extreme weather events such as droughts and floods, can affect the entire agro-food VC, from production and processing to marketing and consumption of the final product.

Furthermore, in SSA, **food production and all other VC activities, including (cross-border) trade, are dominated by informal systems**. This causes various challenges: data collected may not fully include and represent the informal sector, which poses problems for designing and implementing effective and inclusive policies. Furthermore, official statistics hide many features of real production, processing, consumption and trade patterns that deserve to be taken into account. Overall, policies and programmes seeking to support environmentally sustainable food VC development will often not incentivize the informal sector, in which usually the poorest and most vulnerable people, most notably women, are active (Torres & van Seters, 2016).

Africa has the highest area of uncultivated arable land (202 million hectares) in the world, at about 50 percent of the global total, while its productivity lags behind other developing regions: yields are only 56 percent of the international average (AfDB, 2016). In fact, most of the agricultural growth in SSA can be attributed to expansion of the land area cultivated rather than an increase in agricultural productivity. Although there is potential to continue the cultivation of more land, expansion will unavoidably involve degradation of natural ecosystems. Furthermore, recent studies indicate that the amount of fertile land for cropland expansion may be considerably less than earlier estimates indicate (Chamberlin et al., 2014). Therefore, SSA needs increased and sustainable investments to sustainably increase agricultural productivity. In other words, the alternative is ecological intensification of agriculture. This would require minimizing the constraints to appropriate technology adoption, focusing on sustainable water use through irrigation, as well as implementing best farming practices, while adapting to a changing climate and mitigating the harmful effects of agriculture on the environment (AGRA, 2016). This is **the only way to improve rural livelihoods, but it requires a serious rethink of agricultural development**: one that uses sustainable principles as the entry point for generating productivity enhancements or, in other words, one that places natural and social capital at the heart of investment decisions for long-term sustainability and resilience (Rockström et al., 2016).

Global and regional agendas

This **study is set against the larger background of the global 2030 Agenda for Sustainable Development**, and is especially related to Sustainable Development Goal (SDG) 2 that aims to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture".[6] It is also aligned with the goals of the Paris Declaration, which is the result of the global climate change negotiations under the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Declaration draws special attention to Africa's vulnerability. Moreover, the most recent UNFCCC conference (November 2016) in Marrakech, Morocco, launched the Adaptation of African Agriculture (AAA) Initiative, putting emphasis on agriculture, Africa and adaptation.[7]

The **study is aligned with continental and regional agendas in Africa**. This includes the African Union (AU) Malabo Declaration on Accelerated Agriculture

6 See: https://sustainabledevelopment.un.org/?page=view&nr=164&type=230&menu=2059.

7 See: http://www.aaainitiative.org.

Growth and Transformation for Shared Prosperity and Improved Livelihoods that is committed to enhancing the resilience of livelihoods and production systems and tackling the degradation of ecosystems through adaptation measures and mitigation action to reduce GHG emissions.[8] The study also looks at lessons learned and new opportunities that emerge from other African initiatives, supported by the AU's New Partnership for Africa's Development (NEPAD), such as the Comprehensive Africa Agriculture Development Programme (CAADP), the TerrAfrica Partnership and the African Union Commission's (AUC) Great Green Wall for the Sahara and the Sahel Initiative (GGWSSI). In the same vein, initiatives that specifically promote private sector investments in agriculture, such as the Grow Africa Partnership, are important. This Partnership, jointly created by the AU, NEPAD and the World Economic Forum (WEF) in 2011, consists of a platform, comprising more than 200 companies and governments in 12 countries. Investments should be made within the framework of environmental, social and governance concerns.[9] Furthermore, this study is conducted within the framework of the Global Alliance for Resilience Initiative (AGIR) for the Sahel and West Africa, which fosters synergies, coherence and effectiveness to support resilience, while trying to eliminate hunger. It is placed under the political and technical leadership of the Economic Community of West African States (ECOWAS), the West African Economic and Monetary Union (UEMOA) and the Permanent Interstate Committee for Drought Control in the Sahel (CILSS).[10]

Finally, this study is closely aligned with the objectives of the **Global Environment Facility (GEF)**. In 2015, the GEF launched a programme entitled '**Fostering Sustainability and Resilience for Food Security in Sub-Saharan Africa — An Integrated Approach (IAP-Program)**' that focuses specifically on safeguarding the ecosystem services that underpin food and nutrition security (GEF-6). The GEF applies an integrated approach, with a special focus on the private sector as the driving force for promoting sustainability and resilience in food VCs. The programme also aims to help smallholders to strengthen soil management, gain improved access to drought-tolerant seeds, adjust planting periods and cropping portfolios, and enhance on-farm agro-biodiversity. Furthermore, the **seventh replenishment of resources of the GEF Trust Fund (GEF-7) is under way**.[11] It will transform food systems by continuing to focus on safeguarding ecosystem services and managing negative impacts and externalities. This will involve helping countries tackle biophysical threats to ecosystem services in agro-ecosystems and across food VCs, as well as providing the policy, socio-economic and institutional support that would prevent poor land use. GEF-7 will also aim to align environmental financing to meet the demands for sustainability of food VCs. Such financing will promote innovative approaches that improve crop and livestock productivity without compromising the ecosystem services, as well as renewable energy and energy-efficient technology options in food VCs (e.g. post-harvest storage to reduce losses).[12]

Objectives

The objectives of this study are twofold:

1 It **identifies the good practices required for the transition towards sustainable and resilient food VCs in SSA**, based on the assessment of negative environmental impacts and externalities of the existing food VCs' activities. The VCs selected for this study are **rice, livestock (meat as well as dairy), cassava, maize, pulses and mango**. The selection criteria were based the social, economic and environmental importance of the VCs in SSA. Each VC also faces considerable climate risk.

2 It **identifies incentives and enforcement mechanisms for various stakeholders to make food VCs environmentally sustainable and resilient in SSA**, illustrated by lessons learned on failures and successes. The key focus is on the private sector, and more precisely on smallholder farmers and SMEs, but evidence from multinationals is also presented.

8 See: http://pages.au.int/sites/default/files/Malabo%20Declaration%202014_11%2026-.pdf.
9 See: www.growafrica.com.
10 See: http://www.oecd.org/site/rpca/agir/.
11 The first official GEF-7 meeting was held in Paris on 28–30 March 2017.
12 See: www.thegef.org.

This is a practice-oriented study that aims to formulate concrete action-oriented intervention areas, brought together under four pillars. It is based on evidence-based good practices, and the identification of practical frameworks, specific entry points and incentives to take up these practices. This study thereby contributes to the discussion on how to make the much-needed shift towards more sustainable food systems. The sustainable food system **concept simultaneously takes into account environmental health, social equity and human health, and economic vitality of food systems.**[13]

Approach, methodology and target audience

This study is based on a VC approach, sometimes called the 'from farm-to-fork' approach. It is increasingly being used in development thinking and practice, because it is able to capture an entire system, thus allowing the root problems to be identified and innovative solutions to be found.[14] Recently, thinking in terms of a '**sustainable food value chain' (SFVC) has been gaining popularity**. An SFVC is defined as "the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources" (FAO, 2014: p. 6). Unlike traditional understanding of the commodity chain or the supply chain, the SFVC concept emphasizes that "value added and sustainability are explicit, multidimensional performance measures, assessed at the aggregated level" (FAO, 2014).

The study is based on **the definition of SFVC and follows a similar logic**: the **sustainability of the VC plays out simultaneously along the economic, social and environmental dimensions**, although the environmental dimension receives the most attention (FAO, 2014). For each respective VC, the study will look at its pre-production, production, and post-production stages, thereby taking into account the full range of stakeholders involved in reducing negative impacts and externalities, including CSOs (NGOs, farmers' organizations), farmers, citizens, agribusiness and government entities.[15]

Ultimately, this type of systems approach **allows linkages to be made between different sectors, policy areas, levels of intervention and stakeholders**. This means that for each respective VC, the ever-increasing links can be examined between development cooperation, trade, economic diplomacy and environmental sustainability frameworks as well as different policy areas, most notably agriculture, trade, nutrition and climate change. Second, it allows linkages to be made between the global, regional, national and local levels of intervention. Third, it brings together various stakeholders, including public and private sector, smallholders and multinationals.

Furthermore, **crosscutting considerations**, including working towards gender-sensitive VCs and taking into account indigenous knowledge, are needed in SFVC development. In addition, an important driver of environmental degradation and resource stress is the global dietary transition in which traditional diets are being replaced by diets higher in sugars, fats, oils and meat. Such diets can not only lead to chronic non-communicable diseases but also increase emissions and deforestation. Therefore, developing VCs that target both environmental sustainability and resilience and that ensure **nutrition security** is key for the future.[16] As making VCs more nutrition-sensitive can help improve the quality of the foods that are available, affordable and acceptable, SFVC development will consider the nutritional value of each food commodity.

13 See:http://staging.unep.org/10yfp/Programmes/ProgrammeConsultationandCurrentStatus/Sustainablefoodsystems/tabid/1036781/Default.aspx.

14 The concept 'from farm-to-fork' means that a food product moves from upstream in the chain, where farmers grow and harvest it, towards the market – through intermediaries including producer organizations, processors, transporters, wholesalers and retailers – and on to the downstream level of consumers (FAO, 2014). A value chain is defined as "sequence of related business activities (functions) from the provision of specific inputs for a particular product to primary production, transformation, marketing and up to final consumption. It includes the set of enterprises that performs these functions, i.e. the producers, processors, traders and distributors of a particular product". UNDP Regional Service Centre for Africa, Private Sector AFIM Unit. 2015. Towards Sustainable and Resilient Food Value Chains. IAP Launch 2015 - Addis Ababa. PowerPoint presentation.

15 See: http://img.teebweb.org/wp-content/uploads/2016/01/TEEBAgFood_Interim_Report_2015_web.pdf, p. x-xi.

16 For example, see: http://dapa.ciat.cgiar.org/announcing-a-new-value-chains-for-nutrition-project-for-2016-2018/.

Methodologically, this study draws from four streams of data:

1 **Desk research**, including academic and other research-based work as well as practice-oriented studies from United Nations agencies or the private sector. This study does not conduct formal quantitative analyses.

2 **Case studies**, presenting evidence of good practices to strengthen environmental sustainability and build resilience, mainly drawing on experiences within 12 SSA countries located in the drylands zone, including five countries in West Africa (Senegal, Burkina Faso, Ghana, Nigeria, Niger), five in Eastern Africa (Ethiopia, Uganda, Kenya, Tanzania, Burundi) and two in Southern Africa (Malawi, Swaziland). Drylands comprise the arid and semi-arid lands and dry subhumid areas (see Annexes, Figure 1). Making up 43 percent of the inhabited surface in Africa, they are home to 268 million people (40 percent of the continent's population) (IIED & SOS Sahel, 2010). As smallholder farms in these dryland regions face the greatest threat of environmental degradation, they most urgently need to harness good practices for sustainability and resilience such as soil and water conservation, diversification of farmlands, agroforestry and integrated management of crops and livestock. However, many smallholder farmers still lack property rights and suffer from land tenure insecurity. This negatively impacts land investment choices, which in turn affects agricultural productivity, livelihoods and conservation efforts.

3 **Interviews** with experts, mostly based in the 12 SSA countries, to provide insights into the most up-to-date practices on the ground.

4 **An expert validation workshop**, held in Debre Zeyit, Ethiopia on 9 and 10 May 2017, aiming to present, review, discuss and validate the draft study, with a view to finalizing it based on the feedback received. The two-day workshop encouraged all participants to get involved in optimal dialogue, debates and exchange. Discussions were based on and supported by field experiences, involving interactions from stakeholders from various backgrounds. The workshop was invitation-only, bringing together about 25 experts from various backgrounds, including governments, Regional Economic Communities (RECs), farmers' organizations, the private sector (representatives from big companies as well as SMEs), civil society, specialized agencies, development partners and research institutes.

This study is intended to reach a wide variety of stakeholders — from government technical staff to expert practitioners, national donor agencies, United Nations agencies, private sector actors, researchers, staff from NGOs, universities or government think-tanks — who want to make a compelling argument for integrated and innovative policy, management or investment choices that promote and advance environmentally sustainable and resilient food VCs.

Structure

This study is organized into five chapters:

Chapter 1 discusses the socio-economic relevance and policies with regards to the six selected VCs. It also sets the scene by describing the most important continental, regional and national frameworks and policies to promote sustainable and resilient food VCs in SSA, and by assessing what has and has not worked.

Chapter 2 gives an up-to-date and general overview of approaches and tools to measure environmental impacts and externalities of food VCs as well as practices to overcome them.

Chapter 3 discusses the key negative environmental impacts and externalities of the six selected VCs and presents good practices to overcome them.

Chapter 4 identifies key incentives and enforcement mechanisms for key VC actors to take up environmentally sustainable and resilient practices.

Chapter 5 presents a 'Four-Pillar Framework for Action', based on lessons learned from the previous chapters. The four pillars consist of key actions for each group of VC actors, ultimately implemented through a multi-stakeholder platform. Finally, it suggests three additional recommendations that are required to move further towards sustainable food systems.

Frameworks and policies to promote environmentally sustainable and resilient food VCs in SSA

KEY MESSAGES

This study addresses six VCs — livestock (focusing on meat and dairy), rice, cassava, maize, pulses and mangoes — selected on the basis of their socio-economic relevance in SSA, as well as the increasing policy attention they have received over the years.

All six VCs face challenges, from their input phase until final consumption. With varying degrees of intensity, these include: low production and low quality of production, diseases and pests, a lack of environmental considerations, negative environmental and climate change impacts, climate variability, a lack of market linkages and a lack of integration of the informal sector into formal, cross-border trade.

Policies to overcome these challenges and to promote food security, agricultural growth, sustainable development and environmental protection have emerged in SSA, at multiple political levels. However, implementation and enforcement is weak. 'Sustainability' and 'resilience' are perceived as add-on elements, rather than constituting core strategies for agro-food VC development.

The lack of progress in achieving environmentally sustainable and resilient food VCs is due to: a lack of knowledge, data, skills and access to inputs, a lack of organization, a lack of financing, conflicting interests of policy development and an uncertain policy environment.

To make policies work better, it is important to start with adequate policy design, with an emphasis on policy monitoring and allowing for continuous adaptation and reformulation of policies. The way forward requires a combination of policy coherence, policy consistency and policy synergies.

THIS CHAPTER CONSISTS OF THREE sections: it first discusses the socio-economic relevance of the six selected VCs — livestock (focusing on the meat and dairy VCs), rice, cassava, maize, pulses and mangoes — which are not presented in order of priority. More concretely, special attention is afforded to production output, land use, consumption patterns and challenges for growth. This section also looks at the existing continental, regional and national policies and political choices (e.g. prioritization of the VC in agricultural policies) concerning the six VCs. It ends with a list of various key challenges that the six VCs face throughout the chain. Second, a general overview of continental and regional frameworks and policies that promote environmentally sustainable and resilient agriculture in Africa is given. The level of actual implementation and the impact of these frameworks and policies are also assessed in this section. The final section presents key solutions to policy failures.

Socio-economic importance of the six selected food VCs

Socio-economic importance of the livestock VC

The livestock sector in Africa contributes 30 to 50 percent of the agricultural GDP, and this is expected to increase (AU, 2015). Furthermore, according to the Stockholm Environment Institute (SEI, 2015), global consumption of animal products is projected to double by 2050, driven by continued population growth, rising affluence and urbanization. Most of this increase will take place in less developed countries, including

those in SSA, which also have the highest potential to increase productivity and production. It is estimated that developing countries will generate three quarters of global meat production and two thirds of global milk output by 2050. Consequently, much of the increased crop demand in the period prior to 2050 will be for livestock feed (SEI, 2015). From a nutritional point of view, livestock constitutes a major source of protein (Safriel & Adeel, 2005).

This demand-driven rapid evolution of the sector calls for the intensification of livestock production. This represents opportunities for livelihood improvement and income generation for resource-limited smallholder farmers, in particular those in SSA. Over the years, most of SSA has experienced widespread expansion of domestic livestock grazing into natural rangelands. Livestock rearing is now a key economic activity in rangelands, and especially in the drylands, which are home to 40 percent of Africa's population (IIED & SOS Sahel, 2010) and where agroclimatic conditions tend to limit economic activities in SSA. In the face of environmental and climate risks, dryland populations have developed resilience based on adaptive knowledge. They rely on a wide range of wild species, and their livestock and crops are adapted to local conditions through long periods of selective breeding (United Nations, 2011), with livestock being raised mostly in pastoral or in agropastoral systems. Pastoral systems based on livestock mobility optimize the use of resources, because rainfall is highly variable. Livestock mobility in the drylands is also crucial for trading purposes, since the best markets where pastoralists can get good prices for their animals are often far from the best production areas (United Nations, 2011).

However, the increasing pressure over rangelands and particularly drylands aggravated by climate change and climate variability leads to increasing conflict over natural resources (particularly land and water) and land use. In addition, the replacement of grazed rangelands by cropland has led to increasing pressure and conflict over rangeland use, and decreasing rangeland biodiversity. These constraints will become worse in the future, due to human population increase, growing prosperity and a shift in diets, which will increase demand for meat and milk (Alkemade et al., 2013).

In recent years, African policymakers have recognized the need to enhance livestock production to meet the increasing demand by the growing group of urbanized African consumers. The livestock sector in SSA is believed to have the potential to deliver both the agriculture-led growth and the socio-economic transformation envisioned in the June 2014 AU Malabo Declaration (AU, 2015). More precisely, recognizing the challenges and opportunities of the sector, the African Union Commission (AUC), with the support of the Bill & Melinda Gates Foundation, developed a Livestock Development Strategy for Africa (LiDeSA).[17]

LiDeSA aims to transform the livestock sector by harnessing its under-utilized potential (see Annexes, Box 1 for a detailed overview of LiDeSA strategies). The measures of this 20-year strategy (2015–2035) are aimed at "supporting resilience, avoiding environmental degradation [...]". Specific expected results include enhancing ecosystem services by diversifying livestock livelihoods (Strategy 6.2.6.2), and developing an enabling environment and promoting "innovation, incentives and partnerships to reduce greenhouse gas emissions, degradation and other negative impacts" (Strategy 6.2.7.1) (AU, 2015). Furthermore, LiDeSA is aligned with other regional strategies, policy frameworks and guidelines to support the livestock sector. It is also coherent with the Comprehensive Africa Agriculture Development Programme (CAADP) at the continental, Regional Economic Communities (RECs) and Member States' levels.

In the Economic Community of West African States (ECOWAS), for instance, livestock sector development has been prioritized in the two regional agricultural policies (RAPs): the Economic Community of West African States' Agricultural Policy (ECOWAP) and the West African Common Industrial Policy (WACIP). As pastoralism is the main livestock breeding system in the region, specific declarations and ongoing programmes

17 The AUC was mandated, through the decision of the Twenty Fourth Ordinary Session of the Executive Council (Addis Ababa in January 2014), to lead and coordinate the formulation of a Livestock Development Strategy for Africa (LiDeSA). This decision was based on the recommendation of the AU's Ninth Ministerial Conference on Animal Resources, which was held in Abidjan, Côte d'Ivoire in April 2013. (AU, 2015).

have been put in place to support transhumance. The Nouakchott Declaration on Pastoralism,[18] entitled 'Mobilizing Jointly an Ambitious Effort to Ensure Pastoralism without Borders', was adopted in October 2013 in support of Sahel-Saharan pastoral societies. Currently, large programmes such as the Global Alliance for Resilience Initiative (AGIR) and Regional Sahel Pastoralism Support Project (PRAPS) are being implemented in the region to support pastoralism, while others are being formulated to complement them, such as the Regional Investment Programme on Livestock and Pastoralism in the Coastal Countries (PRIDEC) and the Regional Programme on Dialogue and Investment for Pastoralism and Transhumance in the Sahelian and Coastal Countries of West Africa (PREDIP). Countries also have their own national livestock development strategies or plans.[19]

Socio-economic importance of the rice VC

In the majority of African countries, rice constitutes a major part of the diet and in the past two decades, per capita rice consumption in SSA has increased by more than 50 percent.[20] This increased demand is due to population growth, rising incomes, and a shift in consumer preferences in favour of rice, especially in urban areas.

Rice is grown in various agroecological zones in SSA, from humid forests to the Sahel. The three main rice ecologies are: the rain-fed uplands on plateaus and slopes (44 percent of the total rice-growing land area), the rain-fed lowlands in valley bottoms and floodplains (31 percent) and the irrigated systems with relatively good water control in deltas and floodplains (12 percent). These ecologies can be found across agroecological zones (Defoer et al., n/d). However, all of these systems produce low yields, especially since they are characterized by minimal use of inputs, outdated rice varieties and poor seed quality, insufficient policy support, and so forth (see Annexes, Figure 2: Rice cultivation zones in SSA).[21]

With the exception of a few countries that have attained or are close to attaining self-sufficiency in rice production, such as Mali, Tanzania and Uganda, large quantities of rice are imported as demand exceeds production. Despite being the largest rice producer in West Africa, Nigeria is also the region's largest importer (Haggblade et al., 2012). Nevertheless Africa, and especially West Africa, has the potential to increase rice production to meet demand, but there are many challenges, including increasing water scarcity and booming rice demand met by cheap Asian rice imports (see Annexes, Figure 3: Rice production in SSA).

The growing importance of rice is evident in the strategic food security planning policies of many countries. As 64 percent of SSA rice is produced in West Africa, the rice sector has been prioritized in West African RAPs, including the ECOWAP. The Regional Rice Offensive led by ECOWAS aims to double rice production between 2010 and 2020. It is built around National Rice Development Strategies (NRDS).[22]

18 Background: The CAADP defines strategic options and regional activities for pastoral development. The African Union Policy Framework for Pastoralism in Africa (2001) was the first political initiative on the continent aiming to ensure, protect, and improve life, subsistence, and the rights of African pastoralists. The Global Alliance for Resilience Initiative (AGIR) in Sahel and West Africa places pastoralism among its top priorities, as well as the national and international strategies for regional stabilization and long-term development of the Sahel-Saharan areas. The N'Djamena Declaration adopted in May 2013, is a major reference that summarizes the existing frameworks and defines the priorities for a policy of support for regional pastoralism closely linking development and security issues. (Nouakchott Declaration, online: http://www.rr-africa.oie.int/docspdf/en/2013/NOUAKCHOTT.pdf)

19 See for example: Ministry of Agriculture, Livestock & Fisheries, Republic of Kenya, 2013.

20 See: http://irri.org/rice-today/trends-in-global-rice-consumption. According to ReliefWeb (2006), rice consumption increased annually by 4.4 percent from 1961 to 2003 (http://reliefweb.int/sites/reliefweb.int/files/resources/D3F791683E9E280C852571FB0057A7F7-cgiar-rice-sept2006.pdf).

21 In this section 3.2, the focus is not only on drylands, because it makes more sense to produce rice outside of the drylands.

22 In 12 African pilot countries, NRDS documents were formulated with the support of the Coalition for African Rice Development (CARD) (budget $143.7 million) launched by JICA, in partnership with Alliance for a Green Revolution in Africa (AGRA) in May 2008. CARD is a new comprehensive initiative to support the efforts of African countries aiming at doubling African rice production within ten years. It also forms a consultative group of donors, research institutions and other relevant organizations to work with rice producing African countries.

©Mariola Acosta

Socio-economic importance of the cassava VC

Since the beginning of the 1960s, cassava production in Africa has more than tripled, placing the continent among the largest producers in the world (Oakland Institute and AFSA, 2014).[23] This is a positive development, given that cassava has a number of important characteristics that can help overcome the many barriers to food insecurity in SSA. First, it is an insurance crop, able to be left in the ground until needed (up to 24 months after planting) (Barratt et al., 2006). Cassava also grows well in poor soils with limited labour requirements. Second, it is a subsistence crop, usually grown by small-scale farmers who sell the surplus (Soule et al., 2013). At the same time, however, the industrial use of cassava (e.g. starch, paper, textile, pharmaceuticals, ethanol) (Abass et al., 2013; FAO, 2015) and its use in animal fodder is increasing (FAO, 2015). Third, cassava is relatively inexpensive, compared with other crops: some processed forms of cassava, such as gari, are cheaper and faster to prepare than rice for instance. Fourth, cassava is highly nutritious: it is an indispensable part of the carbohydrate diet in SSA, containing nearly twice as many calories as potatoes and having perhaps one of the highest calorie values of tropical starch-rich tubers and roots. Its leaves are high in protein and can be eaten as a vegetable (Barratt et al., 2006). Overall, processing takes place on two scales: at the micro-industry level to produce food products such as gari and flour, and at the industrial level to produce starch, animal feed, etc. (see Annexes, Figure 4 for an overview of the structure of the Nigerian cassava VC) (FAO, 2015).

In SSA, cassava is usually traded informally within countries and in many border areas. The issue of informality and the fact that smallholders in SSA are so scattered have resulted in outreach problems and have often made it impossible to apply environmental standards to the cassava sector.[24] However, in recent years, cassava has gained a lot of renewed interest from policymakers in SSA aiming to 'formalize' the sector. This new turn was embedded in the Global Cassava Development Strategy and Implementation Plan, spearheaded by the Food and Agriculture Organization of the United Nations (FAO) and the International Fund for Agricultural Development (IFAD) in 2000 in cooperation with the International Institute of Tropical Agriculture (IITA) and other research institutes. This initiative has improved the livelihoods of the rural poor through interventions in the cassava VC (Abass et al., 2013). In 2005, the NEPAD Pan African Cassava Initiative

23 The six countries which currently account for most of the cassava area are the Congo, Côte d'Ivoire, Ghana, Nigeria, Tanzania and Uganda. The cassava planted areas increased almost three-fold in Ghana and Nigeria from 1961 to 1999. See: http://www.fao.org/docrep/009/a0154e/A0154E02.htm.

24 ASARECA has recently developed a system of standards for a number of processed cassava forms in the East African Community (EAC), see: http://www.eac-quality.net/.

(NPACI) was launched, to promote cassava as a means of combating poverty across Africa by 2015, by increasing private investment in cassava.[25]

The RECs have also developed cassava growth strategies. For example, the COMESA Cassava Cluster Programme (2011–2015) supported the formation of national and regional cassava clusters to boost job creation and intraregional trade. The programme led to a rise in production in the countries of implementation, including in Burundi and Kenya, and the promotion of cassava in the National Agriculture Investment Plans (NAIPs).[26] For decades however, governments in Eastern and Southern Africa had heavily subsidized maize production, to the detriment of cassava, as explained in the following section. Then, in response to the 1980s droughts, the Zambian and Malawian governments, with the help of the IITA, started to move away from purely maize cultivation to also produce cassava (Abass et al., 2013).[27] In contrast to Eastern and Southern Africa, cassava is more widely produced and consumed in West and Central Africa, with Nigeria being the largest producer (GIZ, 2013).

Socio-economic importance of the maize VC

Maize is the staple food in large parts of SSA: it accounts for 30 percent of the total area under cereal production in this region, compared with 19 percent in West Africa, 61 percent in Central Africa, 29 percent in Eastern Africa and 65 percent in Southern Africa (see Annexes, Figure 5 for a map of the maize-growing zones in SSA). Maize is particularly important in Southern Africa, where it accounts for over 30 percent of the total calories and protein consumed (FAO, 2010).

For decades, the maize subsector in SSA has benefited from strong policy attention. Although maize features in almost all the Agricultural Investment Plans of the Common Market for Eastern and Southern Africa (COMESA) Member States, including those of Kenya,[28] Malawi[29] and Uganda,[30] the yields in SSA remain the lowest in the world, at about two tonnes per hectare, compared with almost 10 tonnes in Northern America.[31] These challenges are often caused by production issues (e.g. diseases and pests) and market constraints (e.g. low market prices), while in countries such as Malawi and Zambia, strong government support for maize has led to an over-reliance on the crop and maize shortages. Malnutrition rates in these countries are therefore extremely high. Fortunately, the heavy subsidies have gradually been removed in recent years and policies on crop diversification (e.g. maize-cassava or soybean-maize) have created renewed political and social interest in combining maize with other crops, thereby slowly moving away from pure maize cultivation.

According to an Oxfam briefing note on maize in Southern Africa (September 2016), a major reason for the market failures is the mutual distrust and lack of cooperation between governments and private traders. The briefing note cites Paul Dorosh, Simon Dradri and Steven Haggblade: "policymakers fear a loss of government control over maize supplies and the politically sensitive maize price." At the same time, "traders have difficulty anticipating what governments will actually do" (Oxfam, 2016). Therefore, more policy dialogue is needed to establish a more favourable environment for a sustainable and resilient maize VC (IFAD, 2014).

Socio-economic importance of the pulses VC

Pulses are the edible seeds of plants of the legume family. Although they come in many shapes and sizes, they all grow in pods and can be dried and stored for long periods of time without refrigeration. Well-known pulse crops are beans, peas and chickpeas, faba beans,

25 See: http://projects.nri.org/gcpmd/files/3_Anga_paper.pdf. In addition, investments in the African cassava sector are expected to increase, a trend of which the 2nd Cassava World Africa Conference on 1–2 March 2016 in Accra, Ghana, is evidence. See: http://www.fanrpan.org/documents/d01903/.

26 Interviews with various stakeholders, Zambia, Malawi, DRC, February 2016.

27 See also:ftp.fao.org/docrep/fao/008/ae748e/ae748e00.pdf.

28 See: http://caadp.net/pdf/kenya%20investment%20plan%20-%20aug%2014%202010.pdf.

29 See: http://caadp.net/pdf/Investment%20plan%20-%20Malawi.pdf.

30 See: http://caadp.net/pdf/Investment%20Plan-uganda.pdf.

31 See: http://www.economist.com/news/middle-east-and-africa/21665005-small-farmers-africa-need-produce-more-happily-easier-it.

cowpeas (black-eyed peas), lentils and pigeon peas. Soybeans and groundnuts are also grain legumes, but because they are primarily used for oil extraction, FAO defines them as oilseeds rather than pulses (Nedumaran et al., 2015; see Annexes, Box 2 for a detailed overview of key pulses and grain legumes).

Pulses are well known for their nutritional value: they are an important source of protein and other key micronutrients such as vitamins and iron (De Jager, 2013). Other benefits include being adapted to very varied agroclimatic conditions across SSA and being able to grow in both subtropical and temperate climates (see Annexes, Figure 6 – Production systems where pulse crops are grown compared with cereal crops). Many pulse crops are drought resistant and because they have the unique ability to fix nitrogen from the atmosphere in the soil, they usually do not have high soil requirements.

In the developing world, SSA has contributed more than 50 percent to the increased production of pulses over the last 14 years, thanks to an overall growth rate in production of 1.8 percent per year. This means that in terms of production growth, SSA has outperformed Latin America and the Caribbean and South Asia, the two largest pulse-producing regions in the world. A major contributor to this positive story in SSA is the high growth rate in the production of cowpeas (Akibode & Maredia, 2011), with the West African drylands and Nigeria being the largest producers in SSA. While cowpeas are grown primarily for fodder in Niger and Mali, in Nigeria and Eastern Africa the bean is an important staple food. It is often intercropped with millet or other taller plants. According to UNCCD (2009), "The income-generating aspect of bean production is becoming more significant, principally near urban markets, where populations increasingly rely on beans as an inexpensive source of protein". Other typical pulses that grow in the drylands of SSA are pigeon peas and chickpeas.[32]

Due to these unique characteristics, the attention of policymakers to pulses has been steadily increasing, with the sixty-eighth session of the United Nations General Assembly declaring 2016 as the International Year of Pulses to draw attention to their multiple benefits.[33] Furthermore, CAADP underlines the need to focus on high micronutrient foods such as pulses for nutrition (NEPAD, 2009). COMESA has developed a number of standards (COMESA Standards) for agricultural products, including on beans, to facilitate intraregional trade, while ECOWAS mentions the importance of legumes as a climate-change-resilient crop.[34] However, pulses are not indicated as a priority VC in its regional strategy, the ECOWAP.

Despite increasing policy interest, investments in pulses have been low compared to staple cereals such as wheat, rice and maize (Cook, 2016). Although only Uganda selected beans as a strategic agricultural VC in its NAIP, some countries such as Kenya and Ethiopia are directing increasing attention to the pulses sector. For example, in Ethiopia the Agricultural Transformation Agency has helped legume farmers to increase produce and links them to the market. Ethiopia is now quickly becoming a major producer and exporter of pulses, mainly chickpeas and faba beans (Kissinger, 2016). Pulses VCs vary between large-scale commercial farms connected to international commodity markets and smallholder subsistence farmers, who only sell their surplus on the market.

Socio-economic importance of the mango VC

The mango, a high-value commodity in international markets popular for its attractive appearance and good taste, was introduced in Eastern Africa in the fourteenth century. Before 1980 however, African farmers grew inferior mango varieties that had a low market potential and could not be easily intercropped. Since then, farmers have benefited from new research findings and the introduction of varieties of better quality mangoes that have been easier to market (ICRAF, 2007).[35] Nowadays, mango is also very nutritious, especially for children: it is a good source of vitamins A and C and it contains small amounts of calcium and iron, among others (Rice et al., 1991, cited by ICRAF, 2007).

32 See: http://grainlegumes.cgiar.org/the-pulse-of-the-drylands/.

33 See: http://www.fao.org/pulses-2016/en/.

34 See: http://climatechange.ecowas-agriculture.org/node/49.

35 The improved varieties start producing mangoes in the 3rd year of planting and they start producing commercial yields by the 5th year. By the 9th year, a mango tree can yield between 250 and 600 kg per tree, depending on variety and season (ICRAF, 2007: 52–53).

Mangoes grow well in the lowland to upper midland zones, ideally at altitudes below 1,000 m. Once a mango tree is well established, it is drought resistant, especially when the taproot has reached the water table.[36] Mangoes grow best at an average temperature of 15°C–30°C; when the temperature falls below 15°C, growth slows down and fruit quality decreases (ICRAF, 2007). Mango trees are nevertheless cultivated in many drylands in areas with low rainfall, in oasis centres and often under irrigation. Ideal climates, however, for mango trees are humid tropical or semi-arid subtropical agroclimatic zones, with a dry period of at least three months; their deep root system allows them to be grown with little rainfall.

Globally, Nigeria ranks ninth in the world among the major mango-producing countries (see Annexes, Table 1 for an overview of the world's major mango-producing countries). Production has also increased in other SSA countries: in Kenya, the production of mango (together with mangosteen and guava) increased by about 65 percent between 2007 and 2011 (from 384,461 tonnes/year to 636,585 tonnes/year). Furthermore, mangoes are a high-value commodity in international markets. Significant mango exporters in SSA include Côte d'Ivoire, South Africa, Burkina Faso, Mali and Ghana (ITC, 2014). Although large quantities are exported to industrialized countries, including the European market, trade opportunities of fresh mangoes are limited, due to their delicateness and therefore vulnerability when transported. There is, however, considerable trade and market interest in processed mango, mostly in pulp or dried form (FiBL, 2011).

Although mango has a high commercial value, more is still consumed in the local market in SSA than is exported, and the substantial potential for regional trade in SSA has not yet been realized. For example, in Kenya more than 95 percent of total produce is consumed locally, while only 1 percent is exported regionally (Ouko, 1997, cited by ICRAF, 2007). The African Union's (AU) Boosting Intra-Africa Trade agenda aims to promote intraregional trade by strengthening sectoral or product-based institutions and building the competitiveness of enterprises in agro-food VCs. It includes an aid-for-trade component, which aims to prioritize VC connectivity within regions. Some RECs have started to place a strong focus on mangoes and other fruits, based on their export potential. For instance, 'mango' is listed as a priority commodity among the COMESA Member States.[37]

Common challenges in the six selected food VCs

The six VCs all face bottlenecks throughout the chain, from the input phase until final consumption. The key challenges are:

- Lack of high-yielding and pest-resistant/tolerant varieties/breeds
- Low quality of produce
- Lack of inputs
- Lack of environmental considerations
- Negative environmental and climate change impacts, and climate variability
- Inability of smallholder producers to meet the requirements of buyers such as retailers, intermediaries or food processing companies (due to low produce and low quality of produce)
- Lack of integration of small- and medium-sized enterprises (SMEs) from the informal sector into existing, cross-border VCs
- Poor post-harvest management and market linkages

This list is not exhaustive, and the degrees of severity and intensity differ among the VCs, depending on the food product and other circumstances such as geography or infrastructure.

36 Above an altitude of 1200 meters, trees are more susceptible to disease.
37 See: http://caadp.net/pdf/Investment%20plan%20-%20Malawi.pdf.

African frameworks and policies that promote environmentally sustainable and resilient food VCs

Strategies and policies for food security and agricultural growth

The first key initiative to make food security a priority dates back to 2003, when the African Heads of State and Government agreed on CAADP, which recognized the role of smallholder agriculture in reducing poverty. The strategic food commodities include rice, legumes, maize, beef, dairy, poultry, fisheries products, cassava, sorghum and millet,[38] five of which are covered in this study. In 2003, African Heads of State and Government also came together in Maputo to agree on the Maputo Declaration, where they stressed that the implementation of CAADP was "a matter of urgency" (Assembly of the African Union, 2003, cited in Poulton et al., 2014). CAADP is implemented through regional and national partnership compacts and investment plans, whereby Member States have committed to allocating at least 10 percent of the national budget to the agricultural sector, with the aim of achieving at least 6 percent agricultural growth annually. NEPAD, established in 2002, is responsible for coordinating the implementation of CAADP.

Furthermore, in 2014, the AU launched the Malabo Declaration on Accelerated Agricultural Growth and Transformation for Shared Prosperity and Improved Livelihoods, which committed to enhancing the resilience of livelihoods and production systems by the year 2025.[39] In the Malabo Declaration, the African Heads of State and Government renewed their CAADP commitments. However, since 2003, only 13 of the 54 countries have met or surpassed the 10 percent public spending target in one or more years and although overall agricultural production has increased, it has remained well below the annual 6 percent growth target.[40] The Malabo Declaration is aligned with the AU Agenda 2063, which aims to create positive socio-economic transformation and serve as a broad framework for Africa's development in the coming five decades. It envisages inclusive growth and sustainable development for Africa (Aspiration 1 of 7). The Agenda also promotes "sustainable use and management of water resources for socio-economic development […]".[41]

In both the CAADP Results Framework and the Malabo Declaration, the key focus is on increased agricultural production and inclusive development; sustainability and resilience are mentioned, but they are not the entry points to production increase. It is nonetheless important that these types of continental frameworks and policies push for sustainable and resilient agriculture and VCs (AU, 2016). Agricultural growth objectives without a commitment to sustainability will be detrimental to the long-term development of SSA countries: by failing to take into account ecosystems, they will cause various types of environmental degradation, starting at the field level. If, on the other hand, the commitments of the CAADP Results Framework and the Malabo Declaration were to ensure that a certain percentage of agricultural output would be produced in a 'sustainable' manner, this may have a more positive impact.

Environmental and climate-smart strategies and policies

At the continental, regional and national levels in SSA, actions have been taken to avoid the adverse impacts of short-term environmental degradation, including land degradation and long-term climate change. Firstly, at the continental level, the AU has developed an Action

38 See: http://www.commit4africa.org/content/au-resolution-abuja-food-security-summit-2006.

39 See: http://pages.au.int/sites/default/files/Malabo%20Declaration%202014_11%2026-.pdf and http://www.nepad-caadp.net/sites/default/files/Core-Meetings/implementation_strategy_report_english.pdf. The Malabo Declaration is obviously in the right place to try to reach the CAADP objectives, but it looks at agricultural transformation in an even broader sense: CAADP is part of the agricultural transformation, but Malabo declaration includes CAADP, as well as issues of finance, goals to end hunger and poverty, stimulating intra-African trade, issues of resilience, accountability and delivery (Poulton et al., 2014).

40 See: http://www.resakss.org/region/africa-wide/growth-options.

41 See: http://agenda2063.au.int/.

© Phil Behan/UN Photo/WFP

Plan for the Environment Initiative of NEPAD. This Action Plan identifies 11 key regional environmental issues, which are also identified as priority programme areas for regional environmental cooperation: 1) combating land degradation, drought and desertification; 2) conservation and sustainable use of marine, coastal and freshwater resources (including wetlands); 3) prevention, control and management of invasive alien species; 4) climate change adaptation and mitigation; 5) transboundary conservation or management of natural resources; 6) management of cultural heritage; 7) sustainable management of (subsoil) non-renewable resources; 8) sustainable management of cities; 9) integrated waste management and pollution control; 10) sustainable energy production and consumption; and 11) addressing negative impacts of population dynamics (including HIV/AIDS and armed conflicts) on the environment.[42]

Most other key regional actors, such as the African Development Bank (AfDB), the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP) and the World Bank, prioritize environmental issues in their strategy setting. Examples of strategies include the AfDB's Africa Regional Environment Strategy, the World Bank's Africa Environment Strategy and the UNDP/UNEP Poverty–Environment Initiative (Ekbom, 2009).

Other interventions have been set up to support sustainable and resilient natural resources management and economic development in vulnerable regions by, for example, building infrastructure that is resilient to extreme weather events. Generally, the fight against land degradation and desertification and the preservation of ecosystems are the main intervention areas. One key initiative is the TerrAfrica Partnership that leverages funds to scale up sustainable land management (SLM) in SSA.[43] TerrAfrica, launched in 2005 for a 12-year period, aims "to mainstream and up-scale SLM by strengthening enabling environments for mainstreaming and financing effective nationally driven SLM strategies" (www.terrafrica.org). SLM is defined as "a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising food and fibre demands, while sustaining ecosystem services and livelihoods. SLM is necessary to meet the requirements of a growing population. Improper land management can lead to land degradation and a significant reduction in the productive and service (biodiversity niches, hydrology, carbon sequestration)

42 See: http://www.nepad.org/resource/action-plan-environment-initiative-0.

43 See: www.terrafrica.org: The TerrAfrica Partnership, supported by NEPAD, leverages funds to scale up sustainable land management in SSA. It is a regional initiative to support African countries to develop programme-based initiatives to achieve this. TerrAfrica also works to improve coordination between African governments, the international development community and other stakeholders. The programme contributes to realizing the objectives of CAADP and the Action Plan for the NEPAD Environment Initiative. See: http://www.nepad.org/programme/terrafrica.

©Fred Noy/UN Photo

functions of watersheds and landscapes" (World Bank, 2006). In sum, SLM includes management of soil, water, vegetation and animal resources.[44]

Other initiatives include the Africa Regional Strategy for Disaster Risk Reduction (DRR). African countries have also contributed to mitigation efforts, notably through the adoption of low carbon energy technologies and measures to reduce deforestation and forest degradation, in particular through the programme for Reducing Emissions from Deforestation and Forest Degradation (REDD+).

Furthermore, the ambitious Great Green Wall for the Sahara and the Sahel Initiative (GGWSSI) was developed by the AU and is led by 11 countries bordering the Sahara to the south.[45] It aims to fight land degradation and desertification and promote economic and social development. Initially aiming to develop a 15-km-wide strip of vegetation across the continent, from Senegal to Djibouti, its objectives now include poverty reduction and food security. According to Tondel et al. (2015), "Following the start of its implementation in 2011, a regional strategy, country action plans and transnational action plans for Burkina Faso, Mali and Niger were adopted. The GGWSSI has succeeded in raising awareness about sustainable land management challenges and in attracting African and international support (including international climate finance [and GEF finance])", but concrete implementation has been slow (Tondel et al., 2015). This is due to various reasons, one being that the agency responsible for implementation is different in each of the 11 countries. For example, in Djibouti, this agency is placed under the Ministry of Environment, which is plagued by limited resources, while in other countries, an independent agency benefiting from more resources from various sources was set up at government level.[46]

The World Bank Group-Global Environment Facility (GEF) has launched the Integrated Approach Pilot (IAP) entitled 'Fostering Sustainability and Resilience for Food Security in Sub-Saharan Africa', which focuses specifically on safeguarding the natural resources

44 Concrete examples of SLM techniques, including soil conversation, improved water management, diversified agricultural systems and agroforestry, are discussed in chapter 3.

45 Thomas Sankara, the then Head of State of Burkina Faso, first proposed the GGWSSI in the 1980s to stop the spreading of the Sahara. This idea was voiced again about 20 years later by the then President of Nigeria, Olusegun Obasanjo, who brought it forward to the African Union (AU) in 2005 at a summit of the Community of Sahel-Saharan States. AU HSG endorsed the GGWSSI as a pan-African programme in 2007. The UN endorsed it in 2011 (pers. comm. with an AUC officer, June 2014). For more information on the status of the GGWSSI, see: http://global-mechanism.org/news-events/events/forging-innovativepartnerships-for-the-implementation-of-the-great-green-wall.

46 Interview, Under-Director Great Green Wall, Djibouti, 12 October 2016, Nairobi, Kenya.

— land, water, soils, trees and genetic resources — underpinning food and nutrition security. It will bring a holistic perspective to the management of these resources in smallholder agriculture and thereby help smallholders strengthen the management of soil health, gain improved access to drought-tolerant seeds, adjust planting periods and cropping portfolios, and enhance on-farm agrobiodiversity.[47] The seventh replenishment period (GEF-7), which is under way at the time of writing, will create an important entry point for VCs in the 12 IAP countries.[48]

At the regional level, the main RECs, including ECOWAS, COMESA, the Economic Community of Central African States (ECCAS), the Southern African Development Community (SADC) and the East African Community (EAC), have developed environment strategies. Strengthened pan-African leadership (e.g. creation of AU, formulation of NEPAD) and designated regional responsibilities via the RECs have resulted in progress being made on regional cooperation on environmental issues. This progress has been achieved mainly in terms of policy and strategy formulation, as well as financing. However, there has been less advancement in terms of forceful implementation on the ground (Ekbom, 2009).

Progress varies between regions. According to Ekbom (2009), "Arguably most progressive, SADC Member States have committed themselves to sustainable development and to actively participate in negotiation and ratification of major multilateral environmental agreements. Key guiding documents for action include SADC's Environment and Sustainable Development Policy and Strategy Document and the Protocol on the Environment. The objective on environmentally sustainable development as expressed in SADC's Regional Indicative Strategic Development Plan (RISDP) is to mainstream environmental and sustainable development issues into all sector policies, programmes and activities at national and regional level. Although the level and quality of implementation remains to be fully assessed, SADC is becoming very active and ambitious with respect to considering environmental and climate change issues in its development work. SADC's commitments and plans constitute a tall order but points at their ambition in this field" (Ekbom, 2009).

Finally, climate change policies and strategies are progressing in SSA: African policymakers at the continental, regional and national levels are attempting to mainstream climate change into their agricultural policies, generally referring to this as Climate-Smart Agriculture (CSA). In 2009, Heads of State and Government in COMESA held a Summit in Zimbabwe to approve the 'Regional Framework on Climate Change', which promotes the role of agriculture, forestry and land use in climate change adaptation and mitigation. Within this framework, COMESA has organized training programmes on climate change financing, while its 'Regional CAADP Compact', signed in 2014, explicitly promotes CSA. In 2015, COMESA launched the COMESA CSA Partnership to work with governments to launch national CSA programmes in each country, with one of the first being in Madagascar.

ECOWAS is also considered to be a front runner on regional CSA policies. For example, according to Knaepen et al. (2015), its Regional Agriculture Investment Plan (RAIP) "envisages a specific outcome related to climate change adaptation and mitigation. In June 2015, ECOWAS organized a Regional CSA Forum in Bamako, Mali, that brought together various types of stakeholders to fully integrate CSA into implementation of the ECOWAP […]. It developed the first steps towards an intervention, funding and monitoring-evaluation framework. Moreover, the West African CSA Alliance was created to bring together all actors to fully regionalize this framework." This Alliance aims to help mainstream climate change into plans, including NAIPs (Knaepen et al., 2015). At the national level, CSA, once specialist scientific jargon, has entered the mainstream of policy discourse, especially in terms of integrating climate change adaptation into agriculture frameworks and interventions, most notably the CAADP NAIPs. In addition, in its Vision 25x25, the AU has set a goal of having 25 million smallholder households practising CSA by 2025. This Vision is to be implemented by the African Climate-Smart Agriculture Alliance (ACSAA), under the leadership of NEPAD, which aims to align CSA policies across the continent.[49]

47 For more details, refer to: www.thegef.org.

48 See: https://www.thegef.org/topics/integrated-approach-pilots.

49 See: http://csa.octoplus.co.za/.

Key challenges to policy implementation

Despite these efforts, the practices of sustainable, resilient and climate-proofed agriculture face implementation and enforcement challenges that are often caused by the following issues:

1 A lack of knowledge, data, skills and access to inputs: farmers do not always have access to knowledge related to sustainable and resilient practices or access to inputs and equipment such as machinery, seeds or seedlings, improved breeds, and fertilizers. The introduction of sustainable and resilient practices is only possible if markets for inputs and products are secured. In addition, while a lack of skills is often related to a lack of knowledge, it can also be caused by the lack of labour availability, which depends on people's health and competition with other income-generating activities.

2 A lack of organization and bargaining power: farmers and other VC actors (e.g. processors) are in many cases not sufficiently organized, which affects sustainable development in various ways. For example, as individuals they lack the means to make certain investments, such as water storage facilities for their fields. Furthermore, existing associations or cooperatives lack leverage and bargaining power vis-à-vis stronger actors in the chain.

3 A lack of financing: small-scale land users in subsistence agriculture as well as small- and medium-scale service providers (e.g. providers of machinery) have fewer resources to modernize their practices and services and to make the required investments than commercial or large-scale farmers with a high degree of mechanization. Therefore, initial investment constraints need to be overcome and may require external assistance, especially when benefits accrue mainly in the long term. Thus any material and financial support should build on currently available resources, while poor and marginalized land users require special attention.

4 Policy incoherence: there are reports of cases in which interest groups have influenced policies and regulations to their advantage, but to the disadvantage of more vulnerable stakeholders, such as farmers. There are also cases of policies abruptly changing, thereby sending confusing signals to VC actors. In Malawi, for example, a continuous drought in 2015 led to the government heavily promoting cassava, thereby encouraging investment in the sector. However, at the beginning of 2017, policy attention once again focused on maize, creating an uncertain policy environment for farmers who had invested in cassava cultivation and production. Moreover, agricultural growth policies (e.g. AU CAADP policies) are often not in line with the natural resources management objectives of sustainable growth targets.[50] At the same time, the various labels, multiple messages and commitments serving different regional and global unions, agencies, conventions and so forth, can also create confusion. In sum, problems persist and policies fail due to policy incoherence, both at the horizontal (also understood as cross- or inter-pillar incoherence, i.e. the lack of policy coordination between different pillars or sectors) and vertical (the policy coherence between hierarchically higher and lower levels) levels.

Solutions to policy failures

To overcome these challenges, there is a pressing need for benefits and costs (in monetary and non-monetary terms) and short- and long-term gains to be accurately assessed. At the same time, besides the costs and benefits, and access to inputs, markets and knowledge, other elements related to improved livelihoods need to be considered: practices need to be socially and culturally acceptable, flexible enough to allow local adaptation and innovation, and considered to add value to the land and to quality of life (Liniger et al., 2011).

Furthermore, policy implementation specifically can be enhanced by a six-step approach for better policy implementation and enforcement, starting with adequate policy design, placing strong emphasis on policy monitoring, ensuring policy consistency and ending with reformulation of policies, when necessary

50 Based on inputs during UNDP/GEF Expert Validation Workshop, Debre Zeyit, Ethiopia, 9–10 May 2017.

(see Box 1). It is crucial that the political economy is taken into account along each of the six steps.

Finally, there are three conditions for effective policy design and implementation: ideally, there should be a combination of policy coherence, policy consistency and policy synergies, as depicted in Figure 2. The first requirement ('policy coherence') refers to the importance of aligning different policies, such as environmental and agricultural policies. Additionally, vertical and horizontal coherence is crucial (see previous section). The second condition ('policy consistency') is based on the consistency between short-term and long-term policies, and on avoiding an uncertain policy environment. Third, 'policy synergies' refers to joint or coordinated efforts to achieve greater policy impact and effectiveness, for instance, through joint policy design involving various ministerial departments and offices that traditionally do not tend to cooperate.

©Harandane Dicko/UN Photo

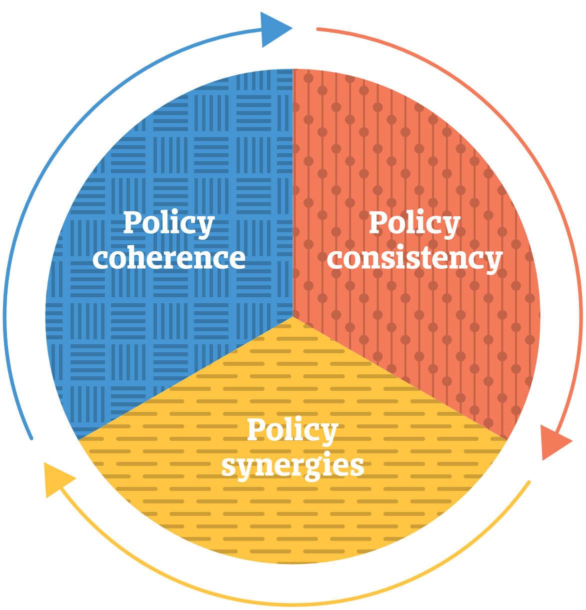
BOX 1

Six steps to make policies work better

1. Policy design, adjusted to the local context
2. Policy implementation
3. Policy enforcement
4. Policy monitoring
5. Policy evaluation
6. Policy reformulation and adjustment

FIGURE 2

Three conditions for effective policy design and implementation



Source: UNDP/GEF Expert Validation Workshop, Debre Zeyit, Ethiopia, 9–10 May 2017

Approaches and tools to measure environmental impacts and externalities of food VCs and good practices to overcome them

KEY MESSAGES

There are multiple technical assessment tools to measure specific, negative environmental impacts and externalities of food VCs, such as greenhouse gas (GHG) emissions or water depletion. Systems approaches are increasingly used, such as the Life Cycle Assessment (LCA) that allows environmental impacts and externalities of the entire food VC, from pre-production to post-production stages, to be measured.

In recent years, cost-effectiveness appraisals have become increasingly important to make food VCs environmentally sustainable and resilient: these appraisals go beyond technical measurements, taking into account the institutional, political and socio-economic context. For example, the UNDP Targeted Scenario Analysis (TSA) captures the value of ecosystem services within decision-making. Although older methods such as the Environmental Impact Assessment (EIA) have been laid down in legislation in many SSA countries, their implementation proves challenging. It is even doubtful whether EIA could ever be a practical tool for smallholder farmers, because they often operate in the informal economy.

Measurement tools, data, statistics and research face various challenges in SSA. For instance, data can be biased, generated in the interest of the research-requesting institution. There is also a lack of ownership and participation of smallholder farmers in research as well as a lack of oversight mechanisms for data.

Environmentally sustainable and resilient food VCs can be achieved on the basis of three courses of action: on-farm diversification, sustainable intensification of agriculture, and off-farm livelihoods and diversification of markets. These pathways argue for a paradigm shift in which sustainability is an entry point to agricultural growth and SFVCs. Through these concrete courses of action, farmers and other VC actors can apply a wide range of techniques to ensure environmentally sustainable and resilient food VCs, borrowing from SLM (e.g. through improved water management), Integrated Landscape Management (ILM) (e.g. landscape management through woodland management) and CSA (e.g. agroforestry practices).

HUMAN ACTIVITIES ALONG THE FOOD VC, including use of chemical pesticides, forest clearing, mono-cropping, not treating agricultural wastewater containing pesticides, and transporting food in polluting trucks, have led to negative environmental impacts and externalities in agriculture: "biodiversity is disappearing at an unprecedented rate, soils are being irreversibly damaged, freshwater is increasingly in short supply and the climate is changing" (Kueffer et al., 2012).[51] Inevitably, this has negative impacts on food systems. Additionally, there are institutional and policy barriers to the promotion of sustainable and resilient agriculture, such as the lack of incentives and the lack of extension services.

Before seeking solutions to overcome these negative environmental impacts and externalities, they need to be measured. However, the sheer volume of literature on measurement approaches and tools, and the many differences in entry points, has made it difficult to see the bigger picture. Given the high complexity of food systems and the wide range of environmental impacts and externalities, there is no standard 'one-size-fits-all' set of approaches or tools to measure them.

To further complicate matters, all stages of the VC have associated, and sometimes different, environmental impacts and externalities. Reynolds et al. (2015) make a useful distinction between three stages of the VC to enable the key types of environmental impacts

51 It should be noted though that environmental factors can also create opportunities (e.g. suitable soil types, water for irrigation or processing, climate change creating conditions that allow new crops) (IFAD, 2014). This study looks in the first place at the environmental factors creating risk (e.g. land degradation, biodiversity loss, pollution).

and externalities, resulting from different agricultural practices, to be discussed at each of these respective stages of the food VC:

1. Pre-production: including site and field selection, land clearance, soil tilling and other land preparation for planting.

2. Production: including natural and synthetic input for crop production (nutrients, water, agro-chemicals) and the consequences of nutrient and water management and pest control strategies.

3. Post-production: including crop residues and other waste disposal, and pollution attributable to crop transport, processing and storage. In this study, trade (including leakages, waste, certifications and standards) is added to this third stage.

At each of these stages, a wide range of negative impacts and externalities is generated, but this study looks specifically at GHG emissions, water depletion and pollution, soil erosion and the loss of biodiversity. These key impacts and externalities are discussed in more detail per respective VC in chapter 3, although reference is also made to others, including energy use, nutrient cycling[52] or pesticide pollution, when relevant.

The objective of this chapter is twofold: firstly, it aims to describe and summarize key approaches and tools that are currently used to measure the environmental impacts and externalities of food VCs. A differentiation is made between systems approaches that look at environmental impacts and externalities along the entire VC, such as the LCA, and technical tools that measure one specific externality. Secondly, it aims to give an overview of recommended actions to address the identified environmental impacts and externalities, starting by putting forward three courses of action towards environmentally sustainable and resilient food VCs, before presenting approaches and techniques with the common denominator of 'sustainable agriculture' or more precisely SLM, ILM or CSA.

Approaches and tools for measurement

Recent decades have seen a steady increase in the number of systems approaches that are able to assess the environmental impacts and the sustainable performance of agricultural production (van der Werf and Petit, 2002, cited by SEI, 2015). More recently, the environmental impact of livestock production specifically has gained attention. SEI (2015) conducted a useful literature review of 50 frameworks for evaluating the environmental sustainability of livestock systems, while reviewing nine frameworks in more depth (for a summary, see Annexes, Box 3 and Table 2). These nine frameworks (all rapid assessment tools) needed to fulfil at least two of the following selection criteria (SEI, 2015):[53] cover multiple environmental impact dimensions that are measured by selected indicators, cover multiple temporal and spatial scales and target a broad audience.

The LCA: technical measurements of the entire VC

The LCA framework, also assessed in the aforementioned SEI study, aims to assess the environmental impacts and externalities of a complete VC. Due to its encompassing approach, it has become increasingly popular in recent years, prompting its selection for more detailed discussion here. It is used to assess the livestock VC (Fraval, 2014, cited by SEI, 2015), as well as crop VCs such as rice (Suenaga et al., 2016). According to SEI (2015), "Since LCAs include the entire value chain, they also give rise to further impact dimensions that cover

52 The chemical process of producing nitrogen fertilizer (usually made of ammonia) is highly energy-intensive. The gases released when nitrogen fertilizer is taken up by the soil produce atmospheric nitrous oxide, which is a major GHG contributing to global climate change. Misuse of nitrogen is one of the main pollutants in farming systems in the developing world. The low uptake efficiency of nitrogen fertilizer has also led to higher aquatic nitrate concentrations and the growing occurrence of hypoxic dead zones in the world's coastal waters (Mulvaney et al. 2009).

53 The nine framework that are reviewed are Vital Signs — African monitoring systems, Response-Inducing Sustainability Evaluation (RISE), AgBalance, Life-Cycle Assessment (LCA), World Agricultural Watch (WAW), Environmental Sustainability Index (ESI), Sustainability Performance Assessment (SPA), MESMIS and GAIA (SEI, 2015).

transportation, processing, consumption, losses and reuse along the product value chain".[54] More concretely, LCA can be used to measure the nine key environmental impact dimensions (Fraval, 2014):[55]

1 greenhouse gas emissions

2 energy use

3 water usage and pollution

4 biodiversity loss

5 nutrient cycling, mainly of nitrogen and phosphorus

6 land use

7 land cover changes

8 waste products and emissions

9 eco-toxicity

There are various units of measurement for these impact dimensions. In the case of GHG emissions, measurements are made in CO_2-equivalents per kilogram of product, and manure management. For energy use, there are different methodological approaches, such as Energy Assessments that consider the use of fossil energy and link energy use to environmental impact. Meanwhile, biodiversity is measured by a large number of indicators, including the share of protected areas or the share of protected species. Furthermore, the LCA methodology was recently used to develop an ISO standard to assess environmental impact (defined in ISO standards 14040 and 14044), allowing crop VCs such as rice to be examined (Fraval, 2014). Ultimately, the LCA has the capacity to evaluate intervention options that could improve negative impacts and externalities. It could thus inform stakeholders and decision-making processes.[56]

The Global Livestock Environmental Assessment Model (GLEAM) is an LCA approach, designed to identify negative environmental impacts and externalities along the livestock VC, with a special focus on measuring GHG emissions.[57] GLEAM can therefore assess the global impact of the livestock sector. Many of those impacts, however, are driven by national or local environmental and social conditions. Thus, global averages and indicators are usually misleading and do not adequately help to understand real problems and how to tackle them. Based on spatially explicit modelling of livestock distribution, GLEAM uses Excel software to estimate GHG emissions from each stage of production. Its assessments help design adaptation and mitigation scenarios: for example, using GLEAM, FAO found that with certain interventions, livestock farmers can increase production and reduce emissions by nearly a third. GLEAM currently supports a range of national and international projects, including CSA initiatives in Niger and Malawi.[58]

Another important tool is the Sustainability Performance Assessment (SPA), a multidimensional framework that aims to be holistic, rapid and simple to use. Its measurements include the output indicator (kg CO_2/unit) and input by the farmer (kg fertilizer).[59] Finally, the multi-regional input-output (MRIO) data, focusing on environmental footprints, also takes a holistic approach. It allows the intensity of environmental pressure per unit economic output and the environmental footprint of final demand, among other factors, to be measured.[60]

54 See: https://sustainabledevelopment.un.org/content/documents/9429GSDR_2016_Brief_LCA_Suenaga.pdf.

55 Fraval (2014) did a review of 70 LCAs for livestock, fisheries and aquaculture of which 10 focused on developing countries. He found some gaps in LCA application: the methodologies for modelling, indicator specification, allocation of impact and incorporating sensitivity analysis are not yet specified enough, especially in the case of developing countries, where progress can be rapid and environmental safeguards weak. On a more general level, this is due to the lack of accurate data for direct or indirect activities, lack of modelling of specific systems, limitation in expertise, time or financial constraints (see: https://ilri-cleaned.wikispaces.com/file/view/1009CLEANEDReviewLCAlstockfish.pdf; see also Annexes, Figure 6)

56 See: http://www.fao.org/gleam/model-description/en/.

57 IFAD's model focuses on three key stages of the value chain: input supplies, agricultural production and post-production (storage, processing, transport and retail). For each of the respective elements that constitute each phase (e.g. seeds, animal feed, financial services, and so on, in the "input supplies" phase), climate risk issues have been identified and secondly, the required climate risk management interventions are listed (IFAD, 2015; see Annexes, Table 3).

58 See: http://www.fao.org/gleam/en/ and see here for the webinar on GLEAM usage: https://www.youtube.com/watch?v=jBaFcCje3nU.

59 For more details, see: http://www.saiplatform.org/activities/alias/sustainabilityindicators/SPA.

60 See: http://www.environmentalfootprints.org/mriohome.

Tools to measure specific environmental impacts and externalities

Research has produced plenty of technical tools that are designed to measure a specific negative environmental externality, such as soil erosion or biodiversity loss. This section discusses a number of tools that are widely used in this study to measure the key environmental impacts and externalities.

The most common negative environmental externality to be measured is 'GHG emissions'.[61] For example, FAO developed the Ex-Ante Carbon-balance Tool - FAO (EX-ACT)[62] to estimate the impact of agriculture and forestry development projects, programmes and policies on the carbon-balance. This includes projects on climate change mitigation, sustainable and resilient land or water management or food security. It helps project designers prioritize activities with high benefits in economic and climate change mitigation terms. The carbon-balance is defined as the net balance from all GHGs that were emitted or sequestered due to project implementation as compared to a business as usual (BAU) scenario. EX-ACT is cost-effective, requires a small amount of data, and uses Microsoft Excel sheets in which the user inserts basic data on agricultural VC activities (e.g. processing, transportation), which can help in finding the required information. EX-ACT is mostly used at the project level, but it can easily be up-scaled to the programme/sector level and can also be used for policy analysis. The FAO's EX-ACT team is currently developing a new EX-ACT version that will provide co-benefits appraisal of VC on GHG emissions, climate resilience and income.[63]

Second, there are various tools to investigate the geomorphological processes related to soil erosion (Boix-Fayos et al., 2006). Hsieh et al. (2009) developed a 'mesh-bag method' that quantifies the redistribution of the eroded soil in a field: the mesh bags are in close contact with the bare soil surface, which allows water and a negligible amount of soil particles to infiltrate the bottom mesh. The spatial and temporal patterns of soil erosion and the associated nutrient movement revealed by the mesh-bag method are promising: the method can provide valuable insights into the soil erosion processes in agricultural and natural lands (Hsieh et al., 2009).

Third, one way to measure water-use efficiency is to measure it as the ratio of total biomass or grain yield to water supply on a daily or seasonal basis. This is a common method among crop scientists (Sinclair et al., 1984, cited by Sharma et al., 2015). There is also the irrigation system perspective of water-use efficiency. This method depends upon water accounting, where losses occur at each stage as water moves from the reservoir to the farm gate, where it is applied to the farm, stored in the soil and finally consumed by the crop for final crop production (Barrett Purcell & Associates, 1999, cited by Sharma et al., 2015). "Depending upon the area of interest, it is possible to measure the water conveyance efficiency, application efficiency, irrigation water use efficiency and crop water use efficiency" (Barrett Purcell & Associates, 1999, cited by Sharma et al., 2015).[64]

Fourth, the most important cause of biodiversity loss in the past five decades has been land conversion, in most cases for agricultural purposes (Loh, 2015).[65] To measure biodiversity loss, it is crucial to look at the five main pressures on biodiversity, as identified by the Convention on Biological Diversity (CBD): habitat loss and degradation, overexploitation and unsustainable use, climate change, excessive nutrient load and other forms of pollution, and invasive alien species.[66] In order to measure the loss of biodiversity, the Aichi Biodiversity Targets, implemented through the Strategic Plan for Biodiversity 2011–2020, set a number

61 Other measurement tools for GHG emissions are the Mitigation Optimization Tool (see: https://ccafs.cgiar.org/mitigation-options-tool-agriculture-0#.WBBfDVcQjBK.), the Small-Holder Agriculture Monitoring and Baseline Assessment Tool, the Cool Farm Tool (see: https://coolfarmtool.org), the Standard Assessment of Agricultural Mitigation Potential and Livelihoods (SAMPLES; See: http://samples.ccafs.cgiar.org/measurement-methods-overview/) or the Ecological Footprint Analysis (EFA; See: http://www.footprintnetwork.org/en/index.php/GFN/page/footprint_basics_overview/.)

62 See: http://www.fao.org/tc/exact/ex-act-home/en/.

63 See: http://www.fao.org/fileadmin/templates/ex_act/pdf/Flyer/Flyer_EXACT_VC_DRAFT3.pdf.

64 See also the study 'Methodological Tools for Assessing Productivity of Water in Agriculture and Interacting Systems with Respect to Tanzania and Ethiopia', developed by SWMRG, Morogoro, Tanzania (2004): http://www.iwmi.cgiar.org/assessment/files_new/research_projects/Sokoine_Literature%20Report.pdf.

65 Worth mentioning are the GEF's activities to promote conservation and enhancement of carbon stocks through sustainable management of land use, land-use change, and forestry (LULUCF). LULUCF's activities include increasing afforestation and deforestation, establishing positive incentives for sustainable forest management, and so on. These activities happen in synergy with biodiversity and land degradation projects. See: https://www.thegef.org/sites/default/files/publications/LULUCF_brochure_web_version_%281%29_0.pdf.

66 The CBD is a multilateral treat that aims to develop national strategies for the conservation and sustainable use of biological diversity (entry into force in 1993). See: https://www.cbd.int/gbo3/?pub=6667&section=6711.

of targets that were agreed upon by the CBD Member States.[67] Furthermore, CBD convened the Initiative for Biodiversity Impact Indicators for Commodity Production in 2014, which seeks to compile "a set of generic biodiversity impact indicators for agriculture" that "cuts across agricultural commodities [(crops)]" and "can be used by public and private sector organizations as well as standards and certification bodies to integrate biodiversity impact monitoring into their work" (Loh, 2015). The framework allows the biodiversity impacts of crop production to be measured, while looking at seven major impacts, including conversion of natural habitat and soil erosion. Each impact area is subdivided into various indicators. For example, the habitat indicators include tree species diversity, canopy height and ground cover (Loh, 2015). Another example of a tool for farmers to measure their on-farm biodiversity is the GAIA Biodiversity Yardstick, which makes biodiversity measurable and comparable. This yardstick consists of 40 questions and six themes, including crop varieties used and the management of non-productive elements in the fields (such as water courses).[68]

Furthermore, a useful planning guide that identifies and ranks ecosystems, based on their conservation status, is the Red List of Ecosystems (RLE). Developed by the International Union for Conservation of Nature (IUCN), the RLE is a set of categories and criteria to assess the risks to ecosystems and to focus on where they are threatened. It is especially useful in gaining a picture of habitat loss and degradation, and overexploitation and unsustainable use. It can be applied at any geographical scale, be it district level or national level, and aims to support conservation, monitor resource use and manage decision-making by identifying the ecosystems that are most at risk. It complements the IUCN Red List of Threatened Species, which is the world's most comprehensive inventory of the global conservation status of plant and animal species[69] and uses a set of criteria to evaluate the extinction risk of thousands of species and subspecies. The RLE approach comprises five rule-based criteria for assigning ecosystems to a risk category, including the 'degradation of abiotic environment' and 'declining distribution' that can lead to a loss of characteristic native biota, reduce niche diversity and so forth. These criteria are applied to categorize ecosystems, ranging from 'collapsed', to 'critically endangered', to 'least concern'. However, RLE is not widely applied in SSA yet (IUCN, 2016).

Approaches that go beyond technical measurements of impacts and externalities

Various approaches, including the EIA, can assess environmental impacts at an initial stage — prior to policy or programme implementation — to help policymakers develop regulations and actions that can prevent environmental impacts and externalities in food VCs in SSA. EIA is defined as "the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made"[70] and has been laid down in legislation. It is most efficient when it is implemented as early as possible, at the policy or project-planning phase.[71] In Africa, almost all countries have enacted environmental laws, most of which include specific requirements for EIA, while regional organizations have developed EIA frameworks. For example, the EAC launched the 'Regional Guidelines on EIA of Shared Ecosystems' in 2005, which include water-management projects for agriculture. Nevertheless, Nugent's (2009) review of EIA and monitoring in African aquaculture concluded that the aforementioned regulations and actions developed by policymakers still need to be refined. EIA has so far only been applied to large-scale intensive aquaculture enterprises in Africa, but small- and medium-scale farmers have been left out (Nugent, 2009). It is in fact doubtful whether EIA could ever be

67 See: https://www.cbd.int/nbsap/.

68 See: https://gaia-biodiversity-yardstick.eu.

69 See: http://www.iucnredlist.org/.

70 See: http://www.iaia.org/uploads/pdf/principlesEA_1.pdf. In the case of environmental assessments for public plans or programmes, they are called 'Strategic Environmental Assessment'.

71 See: https://www.env.go.jp/earth/coop/coop/document/10-eiae/10-eiae-2.pdf. Introduced in the late 1960s in the USA, EIA was based on the critique that traditional economic evaluation techniques assessed the costs and benefits associated with a specific development project, without taking into consideration environmental impacts. In other words, it was difficult to put a 'price tag' on long-term environmental degradation. Thus, there was a need for more flexible, non-monetary means of representing environmental gains and losses, and EIA provided answers. Since its introduction, EIA has been taken up in the environmental laws of a number of countries, including the Netherlands and France, as well as in the operations of development assistance agencies, such as the World Bank and UNEP (see: http://unep.ch/etu/publications/eiaman_2edition_toc.htm).

a reliant, practical tool for smallholder and medium-scale farmers. Many farmers operate in 'unregulated', even 'informal', spaces and the majority own only small plots of land, often less than two hectares. Applying EIAs could therefore be a barrier rather than a solution.

Another approach is the Strategic Environmental Assessment (SEA), which is easily confused with EIA. Both EIA and SEA intervene at the planning stages and both are technically and spatially explicit tools. However, while EIA is first and foremost a technical instrument, SEA is its more political counterpart. A key difference is that EIA is project-specific, whereas SEA looks at the cumulative impact of development projects.[72] For example, the World Bank started to apply SEA to its activities in the mid-2000s. One of the pilot projects was to conduct an SEA of the Kenya Forest Act of 2005, with the objectives being to inform the implementation of this Act and the policy dialogue between the World Bank and the Government of Kenya on sustainable natural resource use. The SEA led to a number of achievements, such as raising awareness of the need for intersectoral/interministerial collaboration. However, the impacts were only temporary and did not lead to long-term change (World Bank, 2011).

While EIA and SEA focus specifically on 'environmental assessment', in an attempt to broaden these assessments IFAD introduced the Social, Environmental and Climate Assessment Procedures (SECAP) for IFAD-financed programmes/projects. The SECAP process identifies, assesses and addresses key risks and safeguards and is fully incorporated into the quality enhancement process.[73] Similarly, the UNDP Social and Environmental Standards that came into effect in 2015 aim to mainstream social and environmental sustainability in UNDP programmes and projects.[74]

However, EIA and SEA can only marginally improve a generally negative development in environmental impacts and externalities, since they do not promote multi-sectoral land-use planning or stronger governmental and policy coherence. For agriculture to become truly sustainable and resilient, a paradigm shift is needed, as discussed in more detail in the following chapter.

Furthermore, in recent years, more assessment methods have been emerging, allowing for rapid cost-effective appraisal, based on an understanding of the institutional, commercial and socio-economic environment. These new support tools can also aid decision makers, policymakers and project or programme developers at multiple levels. The Economics of Ecosystems and Biodiversity (TEEB) and TSA, discussed below, are two such assessment methods.

First, TEEB[75] is a global initiative, launched by UNEP in 2009, that helps decision makers "recognize the wide range of benefits provided by ecosystems and biodiversity, demonstrate their values in economic terms and, where appropriate, capture those values in decision-making" (www.teebweb.org).[76] Simply put, it answers the question "Are we paying the correct price for our food?" The initiative looks at the 'eco-agri-food systems' complex, thereby taking into account the entire ecosystem, including agricultural lands, pastures, labour, infrastructure, technology, policies, culture, institutions and markets that are involved in all stages of the VC. Using science-based indicators, it measures impacts, specific ecosystem service indicators that are needed alongside existing biodiversity tools, national income accounts and other accounting systems and, finally, new approaches to macroeconomic measurement that can cover the value of ecosystem services.

Furthermore, under TEEB, a work stream entitled 'TEEB for Agriculture and Food' (TEEBAgFood) takes into account the hidden costs and benefits of agriculture and food systems. These include the economically invisible impacts on water quality, emissions and food safety that are typically not accounted for. In addition, the analyses also include social, economic and political systems and are inclusive of all stages of the VC, not just the farm stage. For example, TEEBAgFood analyses the health impacts of consumption patterns and has been

72 See: http://www.grida.no/graphicslib/detail/difference-between-eia-and-sea_5148.

73 See: https://www.ifad.org/topic/gef/secap/overview; https://www.ifad.org/documents/10180/a36f992c-5e31-4fac-8771-404bea02796b.

74 See: http://www.undp.org/content/undp/en/home/librarypage/operations1/undp-social-and-environmental-standards.html.

75 See: http://img.teebweb.org/wp-content/uploads/2016/01/TEEBAgFood_Interim_Report_2015_web.pdf.

76 'Ecosystem services' have been classified by the Common International Classification of Ecosystem Services (CICES) into three types: provisioning services, regulating and maintenance services and cultural services (TEEB, 2015: 20). Furthermore, TEEBAgFood is collaborating with the Global Alliance for the Future of Food and the Food Tank; finding will be disseminated via the UN (TEEB, 2015).

©Kate Holt/AusAID

applied to livestock, rice and maize VCs (TEEB, 2015). However, as TEEB focuses primarily on the biodiversity-agriculture link, it has been criticized for failing to take into account the wider context of sustainable and resilient agriculture.

Second, in 2013 UNDP developed the TSA, which is consistent with TEEB, but which provides an updated and more encompassing framework. According to Alpizar & Bovarnick (2013), TSA "captures and presents the value of ecosystem services within decision-making, to help make the business case for sustainable policy and investment choices", with TSA able to be applied to crop VCs as well as livestock VCs. "Through TSA, practitioners working with governments and private enterprises can generate and present data related to the management of ecosystems in a way that is more relevant to the choices facing a decision maker" (Alpizar & Bovarnick, 2013). More concretely, a TSA analyst presents the results of BAU and sustainable ecosystem management (SEM) interventions, which are assessed using four types of criteria (financial, economic, employment and equity and fairness) and their associated indicators. For example, the financial criterion can be measured through a change in productivity, annual revenues, investment costs and debt-to-capital ratio. The best indicators are capable of showing changes in the chosen criteria that result from the BAU scenario and SEM interventions. The final product of a TSA is a balanced presentation of evidence, for a decision maker, weighing up the pros and cons of following a sustainable and resilient development path (Alpizar & Bovarnick, 2013).

Bottlenecks in measurements tools, data and research in SSA

Measurement tools, data collection, statistics and research face many bottlenecks in SSA. This is partly due to the fact that many farmers and other VC actors are part of the informal economy, and to other elements linked to general research challenges in SSA. First of all, there are many cases in which different tools or approaches that are designed to measure the same environmental impacts and externalities result in different research results or outputs. In fact, the data and the research results are often in the interest of the research institute or the research-requesting agency, thereby providing biased results. There is therefore a pressing need for tools to be harmonized in many SSA countries, at multiple levels.

Second, scientific research in SSA is characterized by the recurrent issue of the lack of ownership by and participation of smallholder farmers. There are reports of cases in which farmers have been the 'subject of social experimentation'. At the same time, the tools to promote sustainability should be developed in accordance with end users, with capacity-building to ensure that they understand how to use them.

Third, 'data' in SSA poses a challenge not only in terms of its generation and use, but also in terms of access to data and connecting data. There is also a lack of oversight mechanisms for data, especially at the local level, where implementation of tools or approaches based on specific data inputs should happen. In many cases, a lack of farmers' capacity and institutional capacity are to blame for this data access issue, while ministerial fragmentation, creating an unwillingness to share data, further aggravates this issue. Moreover, the lack of baseline studies hampers the generation of data.[77]

Courses of actions and techniques to achieve environmentally sustainable and resilient food VCs

Three courses of action to achieve environmentally sustainable and resilient food VCs

For smallholder farmers to move away from poverty and build resilience, while not harming the environment, the important combination of technical measures and interventions on a socio-economic or institutional level is required (Harris & Orr, 2014). This study identifies three courses of action to achieve environmentally sustainable and resilient food VCs:[78]

1 **On-farm diversification:** this refers to maintaining multiple sources of production and varying what is produced across the farming landscape and over time. These types of diversification (on-farm temporal diversification (e.g. crop rotation) and on-farm spatial diversification (e.g. intercropping, mixed farming)) are employed at the plot or farm levels (in contrast with off-farm diversification, discussed in point three).[79] They allow farmers to adapt to changing climate and weather variability, while enhancing the productivity of their individual livelihood components. Diversified agricultural systems contribute to resilience in a multitude of ways, ranging from pest and disease suppression to increased production and climate change buffering. Closely related to 'diversification' is the concept of 'diversified agroecological systems',

77 This section is based in various inputs during the UNDP/GEF Expert Validation Workshop, Debre Zeyit, Ethiopia, 9–10 May 2017.

78 The (2015) HTDN on 'climate change risk assessments in value chain projects' makes a similar division. According to the HTDN, effective climate interventions will include: 1) Diversification, or the inclusion of a wider set of options to increase farmers' livelihood, farming and environmental management portfolios as a risk management strategy; 2) Climate-proofing, meaning specific interventions to make key stages of the value chain more climate-resilient in ways that bring livelihood and resilience benefits to farmers; 3) Supply chain efficiencies, referring to the measures such as waste reduction that increase efficiency, deliver higher profitability to farmers and SMEs in the value chain, and generate mitigation co-benefits (IFAD, 2015). These climate-risk measures can obviously be tailored to the broader environmental sustainability and resilience context (see Annexes, Table 2).

79 The on-farm and off-farm classification is often made, although some call for a unified diversification classification along sectoral and spatial lines (Barret, 2001, cited by FAO, 2016a).

coined by the International Panel of Experts on Sustainable Food Systems (IPES-Food). Gliessman (2007) defined 'agroecology' as "the science of applying ecological concepts and principles to the design and management of sustainable food systems". 'Diversified agroecological systems' therefore require a transition away from industrial agriculture that is characterized by crop monocultures and a reliance on chemical inputs. In SSA, where most farming systems include various forms of smallholder and subsistence farming, diversified agroecological systems can work for smallholders as well as industrial farms. More concretely, this means the use of locally adapted varieties and species, more labour-efficient systems and technologies, a maximization of multiple outputs, and low external inputs. The basic idea is that agricultural systems should be redesigned to maximize biodiversity, stimulate healthy ecosystems and secure livelihoods. There is evidence that, in terms of outputs, these systems can in fact compete with industrial agriculture (IPES-Food, 2016).

2 **Sustainable intensification of agriculture:** sustainable intensification brings together the practices to optimize production relative to inputs, including land, water, fertilizer, and improving the livelihoods of farmers, while minimizing negative impacts and externalities, such as pollution or deforestation. In other words, it means making more efficient use of the land available, which often requires access to new seeds, varieties and new technologies. In some cases, 'extensification' — whereby farmers acquire land to increase their farm size — is also a viable way out of poverty, but "there is very limited scope for further expansion in SSA without highly detrimental impacts on natural resources (e.g. deforestation)" (Liniger et al., 2011). Although sustainable intensification is a promising pathway to food security, environmental sustainability and resilience, "it should go beyond top-down technologies for production and embrace holistic approaches[,] including indigenous knowledge, practices and solutions" (AGRA, 2016). Requirements include a better use of improved seeds and fertilizers. Furthermore, recent work by Rockström et al. (2016) argues that there is a need to "use sustainable principles as the entry point for generating productivity enhancements", instead of the older paradigm that aimed to enhance agricultural productivity while reducing its environmental impacts. In a nutshell, the authors suggest "adding a new dimension to sustainable agricultural development, namely managing natural capital for long-term productivity and social-ecological resilience at field, watershed, and regional scales, in agricultural systems that operate within planetary boundaries to safeguard Earth system." Based on this approach, intensifying sustainably will require "an understanding of the political economy in which food is traded and prices are determined and the business economy along the value chain from field to consumer" (Rockström et al., 2016).

3 **Off-farm livelihoods and diversification of markets:** the transition towards environmentally sustainable and resilient food VCs will require more than the production-oriented solutions discussed above in the first two points. A third, important course of action is therefore off-farm livelihoods and diversification of markets (e.g. differentiating income sources through wage employment on other farms), at the landscape level. Riisgaard et al. (2010) refer to this as 'functional upgrading', defined as "a situation in which producers take on a new function in the value chain, either by performing downstream activities (for example, grading, processing, bulking up, transporting or advertising), or by engaging in upstream activities such as the provision of services, inputs or finance. Functional upgrading normally leads to vertical integration (when a stakeholder performs more than one value-chain function), except when the producer decides to abandon primary production in order to focus on the new function" (Riisgaard et al., 2010, p. 198). In doing so, households can create a buffer for economic as well as environmental or climate shocks. In addition, the surplus of food produced (gained from moving away from subsistence farming by diversifying activities) should be sold. Therefore, linkages should be set up between input providers, small-scale producers, processors and remunerative markets. Market diversification through commercialization offers improved access to markets and VCs for smallholder farmers' food products. This is, indirectly, a sustainable or even climate-proofed strategy as it would improve incomes and make smallholder farmers more resilient to weather shocks (Harris & Orr, 2014). To achieve this, incentives and the means to enforce them are needed. Incentives can, for example, come from the public sector, if it pays close attention to issues of pricing policies, public procurement, food safety and

©James Kwame/UNDP Somalia

standards, and appropriate credit and infrastructure (CSM, 2016). In sum, smallholder farmers should be empowered to step off the treadmill of unsustainable agricultural practices, build resilience and secure livelihoods. Empowerment should happen in line with a move away from poverty.

These three courses of action inform the following two chapters, in which they will become more concrete on the basis of experiences and case studies in SSA. The first two courses of action (on-farm diversification and sustainable intensification of agriculture) are strongly production-oriented and most relevant to chapter 3, in which good practices are discussed. Both of these courses of action consist of technical options and concrete practices, but they also go one step further: they argue for a paradigm shift in which sustainability is an entry point to agricultural development. Meanwhile, the third option (off-farm livelihoods and diversification of markets) is about creating linkages between farmers, other VC actors and the market. Although also referred to in chapter 3, this is mainly addressed in chapter 4, in which incentives and enforcement mechanisms to alter behaviour are investigated.

Multiple techniques to make food VCs more environmentally sustainable and resilient

In order to implement these broader courses of action, concrete practices are needed that avoid negative impacts and externalities and that lead to environmentally sustainable and resilient agro-food VCs. These techniques and interventions range from specific "climate-proofing" actions (e.g. more heat-resistant storage facilities) to major diversification and transformative change (e.g. a major shift in farming systems or diets).

There are many labelled approaches and practices towards 'sustainable and resilient agriculture', that can be gathered under the 'sustainable agriculture' umbrella. Sustainable agriculture, like 'sustainable development', encompasses benefits from social, environmental and economic angles. It claims that farming systems must be "resource conserving, socially supportive, commercially competitive and environmentally sound" (Ikerd, 1990, cited by Knaepen et al., 2015). Under the sustainable agriculture umbrella, some practices are at the farm level (e.g. sustainable intensification), whereas others relate to comprehensive, holistic approaches (e.g. ILM). Some support a more nature-driven agriculture, such as agroecology, while others support a more technology-driven agriculture, such as precision agriculture.[80] Most of these practices are context-specific and evolve over time, in line with emerging issues and advances in scientific knowledge.[81]

In the quest to find the best possible approaches, techniques and practices within African divergent contexts and scenarios, it is crucial to build complementarities among the many available methods "while seeking new knowledge and avoiding getting stuck in debates about definitions and 'boundaries' of different approaches" (Neely and Dixon, 2006, cited by Knaepen et al., 2015). The following section provides an overview of three broad approaches, consisting of various techniques towards environmentally sustainable and resilient food VCs:

1 **Sustainable land management (SLM), according to GCP et al. (2015), refers to "the process of managing a land management unit — farms, production forests, protected areas — in a sustainable [and resilient] way**. SLM across a range of different land management units is necessary in order to achieve sustainable landscapes". It consists of various practices that can help preserve and enhance ecosystem services in all land-use systems and there is an important United Nations Convention to Combat Desertification (UNCCD) framework that applies SLM practices to cropland, irrigated land and rangeland in dryland areas. These practices allow the same area of land to produce an increased output, while using resources more efficiently and reducing negative environmental impacts and externalities. There is a long list of key interventions that can be broadly grouped into three management techniques:

- **Improved water management**, including proper soil preparation, crop selection and timing of planting to reduce run-off and utilize available water resources even in the absence of irrigation. Efforts to overcome water constraints on crop production in smallholder systems include irrigation and other water-management practices and the use of diverse and drought-resistant varieties, depending on local contexts.

- **Improved soil management**,[82] including ensuring farmers do not over-use fertilizers, and promoting the use of crop rotation, intercropping with leguminous species, reduced tillage and the incorporation of agricultural residues. Minimal tillage and the retention of crop residues in particular can often reduce soil erosion and GHGs and support soil fertility, and may increase yields. For many SSA smallholders, cropping systems, implementing rotations and intercropping, along with organic manures and targeted small amounts of synthetic fertilizer, all frequently increase crop yields and financial returns from investments in inputs, while simultaneously improving food system stability.

80 See glossary for the definitions of these approaches.

81 See: http://www.pablotittonell.net/2016/06/green-sustainable-smart-or-ecological/. Tittonell criticizes the many neologisms to express the need for a new global agricultural model.

82 The 68th UN General Assembly declared the year 2015 as the UN International Year of Soils to raise global attention to the importance of sustainable soil management. The role of soil as a methane sink is huge: they can store more than 4000 billion tonnes of carbon whereas, by contrast, forests and the atmosphere store only 360 and 800 billion tonnes, respectively. In addition, the loss of carbon and nitrogen also reduces soil organic matter, particularly humus, which greatly increases the water retention properties of soil, natural disease resistance in crops and total yield potential. There are several farming techniques and management practices that can regenerate soil structure and attract beneficial organisms within the soil food web (see: http://www.fao.org/soils-2015/en/).

©Marco Dormino/UN Photo

- **Improved integrated pest (including disease and weed) management** "relying primarily on interventions supporting crop health and discouraging pest outbreaks […] have seen growing effectiveness and acceptance among farmers" (Reynolds et al., 2015). Obviously, these techniques are used within several of the approaches. Improved soil management is an integral part of agroecology techniques, but it is also a practice of ecosystem-based agriculture.

SLM techniques also make it possible to address issues of resilience, including climate change impacts, while safeguarding an ecosystem's integrity so that it can continue to provide the ecosystem goods and services upon which agriculture is dependent (CDE, 2009). SLM across a range of different land management units is necessary in order to achieve sustainable landscapes. However, SLM commonly focuses on the site level and on particular stakeholder groups, rather than on the broader landscape level.

2 **Integrated landscape management (ILM) goes one step further: it views the entire landscape as a way of achieving the principles outlined in the United Nations Sustainable Development Goals or SDGs** (GCP et al., 2015). Although the notion of a 'landscape approach' is not new, it has gained in importance in recent years, becoming a major topic of national and international policy discourse. This is because ILM uses the entire landscape or place-based ecosystem planning to shape development projects, thereby contrasting with sector-based approaches (e.g. water, health, agriculture).[83] The landscape approach offers tools for allocating and managing land to achieve economic, social and environmental objectives in areas where agriculture and other productive land uses compete with environmental and biodiversity goals. Evidence shows that farmer-managed natural regeneration contributes to food security by improving the fodder available to animals, reducing loss of fertile topsoil and raising incomes, while adaptation to climatic variability is enabled by diversifying local livelihoods. Originating from biodiversity protection and conservation NGO circles, the landscape approach is increasingly popular among governments and the scientific community, with the simplicity of ILM practices contributing to their success. In Africa, for instance, development partners are supporting Niger's farmers in their long-established practices of woodland management that promotes regrowth from living tree rootstock (an example of farmer-managed natural regeneration).

83 See: http://www.unep.org/stories/story/landscape-approach-development.

©Marco Dormino/UN Photo

Proposed as an action-oriented means of achieving overlapping SDGs, ILM should encourage development partners, investors and national governments to prioritize support for integrated place-based or context-based, rather than sector-based, development (Thaxton, 2015).

3 **Climate-smart agriculture (CSA) is a newer concept, with a strong focus on tackling negative climate impacts**, whereas SLM and ILM take into account the broader environmental constraints (e.g. pollution impacts). It was developed by FAO in 2010 as a holistic approach that "integrates the three dimensions of sustainable development by jointly addressing food security and climate change challenges. It is composed [of] three main pillars: 1) sustainably increasing agricultural productivity and incomes, 2) adapting and building resilience to climate change and 3) reducing and/or removing greenhouse gas emissions, where possible" (FAO, 2013, cited by Knaepen et al., 2015). There is a wide variety of 'climate-smart' techniques and practices, some of which support these food security, climate adaptation or climate change mitigation needs on the farm, landscape or institutional/policy levels, as shown in the Annexes, Table 4. For example, agroforestry is a comprehensive, climate-smart system that combines shorter-term production from agricultural activities, including crops and pasture, with the longer-term production from trees on the same plot of land. CSA practices are knowledge intensive and require strong and high-quality extension services. Social capital, public goods, and private assets are also critical preconditions.[84] Moreover, the CGIAR (Consortium of International Agricultural Research Centres) Climate Change, Agriculture and Food Security (CCAFS) programme developed a CSA guide that stresses that a systems approach, including the entire landscape and ecosystem, as well as a VC approach is the way forward: "[...] it is important to pursue synergies between the different elements of the system, analyse and address trade-offs, and perform cost and benefits analysis."[85]

In chapter 3, these techniques will be illustrated by concrete case studies from SSA.

84 See: http://simlesa.cimmyt.org/.

85 See: https://csa.guide/csa/systems-approaches#article-19.

CHAPTER 3

Key environmental impacts and externalities of the selected VCs and good practices to tackle them

KEY MESSAGES

All activities along the six food VCs (livestock (focusing on meat and dairy), rice, cassava, maize, pulses and mangoes) generate negative environmental impacts and externalities with varying degrees of intensity. The most persistent impacts and externalities are GHG emissions, loss of biodiversity, soil degradation, water depletion and post-harvest losses. Most impacts are generated during the production phase, in many cases due to mono-cropping and limited access to organic inputs. The varying degrees of intensity of impacts and externalities can be explained by a number of factors, including the type of crop or livestock, the geographies, the type of VC (large or small), the formal or informal organization of the VC, the farmer's level of access to information, and so forth. Overall, livestock is particularly harmful in terms of releasing GHG emissions, while pulses as well as cassava have a relatively low ecological footprint.

Despite a multitude of challenges, case studies show that there is a patchwork of good practices throughout SSA to reduce environmental impacts and externalities, based on sustainable intensification and on-farm diversification (e.g. through intercropping or crop rotation). However, the adoption of new techniques is slow and limited, since resource-poor farmers cannot always provide the additional labour input required for these practices (as in the case of Sustainable Intensification of Rice). Also, measuring environmental impacts, climate impacts and climate variability along all VCs is a persistent challenge, leading to knowledge gaps. Furthermore, farmers face a persistent lack of access to organic inputs, new technologies, information and markets.

Stronger efforts are needed to place sustainability at the centre of agricultural development. This requires good practices to be up-scaled, which in turn requires social capital, lacking in many SSA countries, to be strengthened. More investment in not only stronger and better varieties of research but also in cross-country learning is also important.

THE SIX SELECTED FOOD VCS, including livestock (focusing on the meat and dairy VC), rice, cassava, maize, pulses and mangoes, have been selected on the basis of their socio-economic and political importance (see chapter 1), as well as on the basis of the negative environmental impacts and externalities that they generate throughout the entire VC. These include GHG emissions, biodiversity impact, or ecosystem endowments (land, soil quality, water (rainfall or irrigation)). Environmental impacts and externalities are discussed at the three stages of the VC: pre-production, production, post-production. However, depending on available information and relevance, this chapter may focus on a particular stage.[86] In addition, climate change risks and climate variability are also discussed for each respective VC, as they may play a role in deciding which VC investments offer opportunities to future livelihoods. Each part discusses the effects that climate change and climate variability can have on the respective VC activities, as well as the other way around: how the activities within the chain can contribute to climatic change or climate variability.[87]

For each VC, this chapter presents their most important negative environmental impacts and externalities and suggests recommended actions to tackle them, which can be brought together under the broader categories of 'sustainable intensification of agriculture' and 'on-

86 Note that in the discussion of the best practices in this chapter, mainly the production stage is discussed. For instance, in the livestock section, the post-production phase is not discussed. An overview of options to overcome some post-production challenges, such as transportation issues (characteristic to meat and dairy transport) is given in chapter 4.

87 The VCs discussed cover short (e.g. cassava) and long (e.g. mango) chains, but this strict differentiation is not always made specifically in the chapter, due to scope limitations. Negative environmental impacts and externalities account for all types of VCs, with varying degrees of intensity. Further research can focus more closely on the differing impacts of short or long VCs.

farm diversification', introduced in chapter 2. The study looks at specific case studies, all presented in boxes, in the 12 countries selected for the GEF IAP: five countries in West Africa (Senegal, Burkina Faso, Ghana, Niger, Nigeria), five in Eastern Africa (Ethiopia, Uganda, Kenya, Burundi, Tanzania) and two in Southern Africa (Malawi, Swaziland), with a focus on the drylands areas in these countries.

The chapter concludes with a table that summarizes the key findings for each VC.

The livestock VC, with a focus on ruminants for meat and dairy production

Key environmental impacts and externalities of the livestock VC

In SSA, livestock production takes place in a wide range of farming systems: extensive (e.g. grazing in the case of ruminant livestock or foraging in the case of poultry and pigs), intensive (in which thousands of animals are fed concentrated feed rations in confined facilities) and the many intermediate systems that exist between the two. These diverse livestock production systems have different positive and negative impacts and externalities.

Smallholder mixed farming (crop-livestock) and pastoral farming (pure livestock) are the predominant livestock systems in SSA (see Table 1; Thornton & Herrero, 2015). The latter, pastoralism, occurs mostly in the drylands.

As the smallholder dairy industry in SSA is still in its early development stages, its direct environmental impact is not yet a cause for concern locally, although it ought to be. Therefore, there is an urgent need for education on improving production efficiency in these small-scale systems.

GHG emissions

Globally, the livestock sector is a major contributor to the ecological footprint, but its negative impacts and externalities differ within the various agronomic zones. Within the agricultural sector globally, most emissions are caused by the livestock sector (roughly 14.5 percent of total global GHG emissions), mostly in the form of methane and nitrous oxide (N_2O) (TEEB, 2015).[88] Although livestock manure, and to a lesser extent feedstock production, are direct sources of agricultural N_2O emissions, these are mainly caused by intensive agricultural fertilizer oxidation rather than by the livestock sector itself.[89]

Cattle, raised for both beef and milk, are generally the animal species responsible for most emissions, representing about 65 percent of the livestock sector's emissions. There are two main sources of emissions, generated at both the pre-production and the production stage: first, feed production, including processing, transport and land-use change, is a major cause. Second, livestock production, including enteric fermentation (digestion and belching from ruminants), manure storage and processing, and energy consumption for processing, releases GHG emissions (Gerber et al., 2013) (see Annexes, Box 4 for more detailed data on livestock-sector GHG emissions). In SSA, the latter accounts for the largest share of GHG emissions, as grain feed usage and industrial processing of livestock products are limited.

Globally, regional emissions and livestock production profiles vary widely. Differences depend on the respective shares of ruminants in total livestock production and emissions intensities for each product. Latin America and the Caribbean have the highest level of emissions (about 1.3 gigatonnes CO_2–eq), followed by East Asia (more than 1 gigatonnes CO_2–eq). North America and Western Europe have similar GHG emission quantities (more than 0.6 gigatonnes CO_2-eq),

88 The highest total of livestock-related greenhouse-gas emissions comes from the developing world, which accounts for 75 percent of the global emissions from cattle and other ruminants and 56 percent of the global emissions from poultry and pigs (Herrero et al., 2013.)

89 According to a 2008 study by the Nobel Laureate Paul J. Crutzen, the amount of N2O release attributable to agricultural nitrate fertilizers has been seriously underestimated, most of which would presumably come under soil and oceanic release in the Environmental Protection Agency data. Atmospheric levels have risen by more than 15 percent since 1750 (Crutzen et al., 2008).

TABLE 1

Major agricultural systems in SSA (ILRI,[1] n/d)

ZONE	CROP/LIVESTOCK INTEGRATION	MAJOR AGRICULTURAL SYSTEMS	MAJOR LIVESTOCK OUTPUTS
Humid	Pure crop	Forest/permanent trees: roots/cereals (trypanotolerant livestock)	Peri-urban milk
Sub	Crop-livestock	Cereals (maize/sorghum) - livestock	Meat, milk, draught power
Highland	Well integrated crop-livestock	Cereals (wheat/teff) - livestock	Power, meat, milk
Semi-arid	Livestock-crop	Cereals (sorghum/millet) - livestock	Milk, draught power
Arid dryland	Pure livestock	Pastoral	Milk, meat

1 See: http://www.fao.org/wairdocs/ilri/x5462e/x5462e0e.htm.
Note: Most potential for fodder production is in the humid zone, which currently has few livestock. Major concentrations of livestock are in the semi-arid zone, despite its low potential for supplying fodder year-round.

while SSA represents about half of the emissions of these two regions (more than 0.3 gigatonnes CO_2–eq) (Gerber et al., 2013).[90] Despite the lower emissions of SSA, as compared to other regions, livestock production systems in SSA are characterized by low productivity and higher GHG emissions intensities. This is due to low-quality feeds, feed scarcity, animals with low productive potential that are often used for draught power and to manage household risk, as well as for production, low feed digestibility, less efficient herd management practices and low reproduction performance: a cow may consume 10 times more feed (mostly grasses) to produce a kilogram of protein than a cow raised in richer regions, as a result of poor feed quality in impoverished regions (Gerber et al., 2013). Therefore, cattle in countries such as Ethiopia and Somalia account for "as much as 1,000 kg of carbon for every kg of protein they produce — in the form of methane from manure as well as from the reduced carbon absorption that results when forests are converted to pastureland" (Walsh, 2013). Another cause of air pollution and GHG emissions is the common use of dry cow dung pellets, or dry manure fuel, in energy generation. Consequently, SSA is the global hotspot of livestock-emission intensities (see Annexes, W for a global overview of GHG efficiency of bovine meat production in the year 2000). Nevertheless, most ruminants in SSA are raised for meat, and meat production is associated with lower feed efficiency and higher emission intensities than a product such as milk (Herrero et al., 2013).[91]

According to the International Livestock Research Institute (ILRI, 2016), however, GHG emissions from livestock waste in Eastern Africa are significantly lower than global estimates. Scientists found that some emission factors established by the United Nations Intergovernmental Panel on Climate Change (IPCC) overestimated both methane and nitrous oxide emissions from cattle excreta, given smallholder practices in Eastern Africa (Odongo, 2016). Indeed,

90 See Annexes, Figure 8 for an overview of global livestock production and GHG emissions from livestock, by commodity and regions (Gerber et al., 2013).
91 Although the emission intensities of ruminant milk and meat differ considerably (12–140 compared with 58 ≥ 1,000 kg CO2 eq per kg edible animal protein, respectively), these decline as the quality of the diet improves (Fig. 5 C and D), to the point at which the emission intensities of the two products are comparable (Herrero et al., 2013).

animals used to low-quality feed tend to develop highly efficient digestive systems to make optimal use of it (Waruru, 2016). As there are very limited GHG measurements from cropping and livestock systems in most of SSA (e.g. almost no information summarizing feeding practices), African countries have relied on default emission factors provided by the IPCC to develop strategies to reduce their GHG emissions. However, these IPCC factors and the recommended mitigation interventions may not be tailored to these agricultural systems in SSA (ILRI, 2016).[92] Therefore, due to a lack of measurement and information, the magnitude and spatial distribution of livestock GHG emissions are highly uncertain. This lack of information, also due to the informal character of the livestock sector, "hampers developing countries in including livestock systems in emission-trading schemes or in improving their national GHG inventories by using country-specific emission factors" (Dickhöfer et al., 2014). More local studies are therefore needed to generate data that can stand up to international scrutiny.

Loss of biodiversity

The effects of livestock grazing on rangelands include the removal of biomass,[93] the trampling of root systems, the replacement of wild grazers by livestock, the spread of diseases from livestock to wildlife and the introduction of invasive species for grazing purposes. These effects can, directly or indirectly, have an impact on rangelands' biodiversity and ecosystems.[94] The ultimate impacts depend on a combination of factors, including "the extent of rangelands grazed by livestock, the grazing intensity [e.g. overgrazing], the original type of vegetation (e.g. impacts are greater when forests are cleared for the purpose of grazing), and land management" (Alkemade et al., 2013).[95] On the other hand, in some cases pastoralist corridors or routes can have positive effects on dryland ecosystems and on biodiversity: the continued use of corridors by livestock increases "the long-distance dispersal capacity of plants, which is especially relevant in hyper-arid areas" (Davies et al., 2012).

Soil degradation

Impacts of livestock on soil are, firstly, the physical impact of the animal on soil as it moves around and reduces vegetation cover, and secondly, the chemical and biological impact of the faeces and urine that the animal deposits into soil. Physically damaged soil can be even more susceptible to the chemical and biological impact of faeces and urine. Heavy grazing livestock such as cattle compact soil structure and destroy vegetation. This is particularly critical in pastoral systems, which are based on the seasonal movement of herds in search of feeding pastures. The impact on the environment is usually visible around drinking water troughs, entrances to fields and other parts of the land where the animals congregate. Destruction of soil structure is harmful because vegetation does not always recover spontaneously, once the grazing animals have left. Compacted soil becomes strong, making it difficult to cultivate. Furthermore, "structureless soil is unlikely to drain well and will pond after moderate rainfall", while "Anaerobic zones in waterlogged soils will encourage denitrification, which implies a loss of nitrogen" (Warren et al., 1986, cited in Whitmore, n/d).[96]

Water pollution

Water contamination is another very visible environmental impact of livestock production in SSA. In mixed systems, water contamination is caused by leakages of nitrogen and phosphorus from manure application into nearby water bodies and resources. Nitrogen and phosphorus present major nutrient concerns for water quality, with increased nitrate concentrations rendering groundwater unsuitable for drinking and capable of causing serious health

92 At ILRI Mazingira Centre, research aims to provide accurate context-specific information on the environmental impacts, particularly on nutrient cycles and GHG emissions of current livestock production systems, to enable predictions of intensification in these systems, and opportunities to mitigate GHG emissions.

93 Livestock often impair the service of forage provision when prime forage species are replaced by non-palatable, often invasive species, leading to replacement of the grassland vegetation by encroaching bush or the reduction of the litter decomposing termite populations, which impairs nutrient cycling, primary production, and carbon sequestration (Zeidler et al. 2002; Whitford and Parker 1989, cited by Safriel & Adeel, 2005).

94 Semi-arid areas, particularly grasslands, have been hugely affected by invasive species that have accompanied farming, including the widespread introduction of non-native grass species for livestock grazing, such as buffelgrass (Pennisetum ciliare). Invasive plants are for instance estimated to affect 10 million hectares (8.28 percent) of South Africa with significant ecological and economic costs (Davies et al., 2012).

95 It should be noted that overgrazing can be due to farmers' or pastoralists' choices as well as government restrictions on movement. Moreover, in some cases, unnecessarily large populations of livestock, detrimental to the environment, are caused by their positive effect on the farmer's or pastoralist's social states (UNDP/GEF Expert Validation Workshop, Debre Zeyit, Ethiopia, 9–10 May 2017).

96 See: http://www.agriculture.de/acms1/conf6/ws4lives.htm.

issues for humans. Moreover, they may contribute to eutrophication of streams and lakes. Furthermore, pollution from pesticides and other chemical uses also contaminates water (UNEP, 2008).[97]

Post-harvest losses

The post-production stage of the livestock VC has negative impacts and externalities in the areas of transportation, processing, consumption, losses and reuse along the product VC, generating waste products, emissions and eco-toxicity.

Climate change risks

Climate change is likely to have considerable impacts on livestock production in the coming decades. These will include a substantial reduction in the quantity and quality of forage available, especially in the dryland regions, and heat stress in animals. Furthermore, the CSA guide states that "Higher temperatures, changing rainfall patterns and more frequent extreme weather events may also impact the spread and severity of vector-borne diseases, accompanied by the emergence of new diseases".[98]

The impact of climate change is even more severe in African drylands, where pastoralism plays a major environmental and socio-economic role. Moreover, "In Africa, 59 percent of the carbon stored in terrestrial ecosystems is stored in drylands. Globally, 36 percent of the carbon stored in terrestrial ecosystems is stored in drylands, mostly in dryland soils. A significant amount of carbon is lost continuously from dryland soils due to poor management. The largely degraded soils of dryland are, for this reason, currently far from saturated with carbon and their potential to sequester carbon may be very high. At the global scale, estimates show that dryland ecosystems contribute 0.23–0.29 Gt of carbon a year to the atmosphere, which is about 4 percent of global emissions from all sources combined. This will be exacerbated by climate change impacts. However, significant gaps in knowledge remain on drylands carbon sequestration potential, acceptable methodologies and cost-benefit ratio of carbon sequestering practices for small scale rural farmers" (UNEP, 2008).

In the case of mixed crop-livestock systems, while much is known about the impacts of climate change on the crop side, less is known about the livestock side. There is also little information on how crop-livestock interactions may be affected by climate change. More research is needed, since these interactions are key to environmentally sustainable intensification, diversification and risk management (Thornton & Herrero, 2015).

Good practices for the livestock VC

Sustainable intensification of mixed as well as pastoral livestock systems

The livestock sector has huge potential for reducing its environmental impacts and externalities and increasing its global environmental benefits, if the best existing practices in a certain region are shared more widely.[99] Sustainable intensification of livestock production systems in SSA will not only provide a much-needed increase to productivity and production output, but it will also reduce the environmental impacts of the sector through a more efficient use of resources.[100] "In regions with low feed efficiencies and high emission intensities, such as SSA […], there is significant scope for improving the efficiency of livestock production through improved feeding and management [and improved breeds for better productivity], given the right production incentives, investment, and institutional support" (Herrero et al., 2013). Hence, complementary feeding, and herd and manure management schemes that enhance animal productivity while minimizing environmental impacts need to be investigated.

In sedentary communities with livestock, resource use efficiency with increased productivity should be optimized: there is an urgent need for improved feed and feeding techniques. Examples for cattle include

97 See: http://www.agriculture.de/acms1/conf6/ws4lives.htm.
98 See: https://csa.guide/csa/practices#article-31.
99 The key focus of this section is on cattle and not on sheep, goats or camels, although these are also raised in some arid lands.
100 ILRI, personal communication, Programme Leader, Livestock Systems and Environment, 27 October 2016.

BOX 2

Livestock systems intensification through improving feed resources: feeding ligneous plants leaves to cattle

The leaves and fruits of ligneous plants (including trees, small trees and shrubs) are important, high-value fodder for livestock. In arid and semi-arid zones, they provide the largest part of the protein supply during the driest months. For example, it is estimated that during the three driest months of the year, up to 80 percent of the protein ration in the Sahel is provided by plants from the Capparaceae family.[1] There is considerable evidence to show that appropriate tree species, when planted on smallholder farms, can be climate-smart across a wide range of situations.

One such tree is Leucaena leucocephala, which has highly nutritious leaves that, when fed as a supplement to livestock, can substantially increase meat and milk yield compared with a low-quality baseline diet. As the CSA guide notes, planting species such as Leucaena on a mixed farm and using them as a feed supplement can thus increase productivity per animal while also increasing resilience, as it can have a substantial impact on household income. For example, feeding 1 kg of Leucaena leaves per animal per day can nearly treble milk yields and live-weight gains (Thornton & Herrero, 2010). The aggregated effects of widespread adoption of this option in the mixed systems of the tropics also has substantial mitigation potential because the intensified diet could substantially reduce the number of ruminants needed to satisfy the future demand for milk and meat (by 42 million and 52 million animals, respectively, by 2030). At the same time, the leaves improve the diet of ruminant livestock, resulting in a substantial reduction in the amount of methane produced per animal per kilogram of meat and milk produced. Local-level challenges include household labour resources, the availability of appropriate planting material and marketing know-how, although these are not insuperable barriers to the widespread uptake of this option. More general challenges include the fact that since the Leucaena is not native to Africa, its overuse risks going against agroforestry or sustainable agriculture goals, such as using indigenous species to promote ecosystem resilience and protect biodiversity. The broad distribution of this tree also makes it particularly sensitive to diseases and parasites. On the other hand, the native Erythrina burana used by Central Ethiopian farmers to shade their coffee plantations is very common in this part of the world, but scientists only recently became aware of its nutritional properties: buranas provide nutritious fodder for the dry season and the leaves, pods and even bark are palatable to animals. The tree is easy to multiply from seeds or cuttings (large cuttings of 2 m in length and 10 cm in diameter are usually used). It is therefore an important multi-purpose tree in agroforestry (CSA guide).[2]

1 See: http://www.fao.org/docrep/003/T0632E/T0632E01.htm.
2 See: http://www.fao.org/docrep/003/T0632E/T0632E01.htm.

improved grazing management, the use of nutritious diet supplements (see Box 2 — example of improving feed resources) and the use of improved pasture and agroforestry species. As for the latter option, the productivity of pastures can be increased through adding nitrogen and phosphorus fertilizers, adjusting the frequency and severity of grazing and, in terms of water availability, utilizing irrigation. Improving pasture quality and productivity offers a readily available means of increasing livestock production, particularly in the humid/subhumid tropics, resulting in faster animal growth rates, higher milk production, earlier age at first calving, and increased incomes. However, while such practices will generally improve pasture quality, they will not necessarily reduce GHG emissions. For example, the addition of nitrogen fertilizer to a grazing system may reduce methane emissions but increase nitrous oxide emissions.

Furthermore, animal health should also be improved through appropriate vaccination programmes, while animal breeds should be improved through genetic improvement or the introduction of crossbred cattle (see Box 3 for an example of improving cattle breeds). Appropriate manure management also ensures that nutrients and energy are recovered and recycled, as well as increasing the productivity of both food and fodder crops.

Pastoralism is often considered to be an effective and suitable farming system in the arid areas of Africa. It should therefore be supported and shared resources should be managed, particularly in the drylands. Although in many cases pastoralism will be to the detriment of biodiversity and ecosystems, there are options for proper management that can reduce impacts and externalities as far as possible, often based on indigenous knowledge and systems:

Under the extremely variable drylands environmental conditions, mobility and varying herd sizes are appropriate management tools.[101] These form part of the traditional pastoral management strategy, which could benefit greatly from appropriate investments and technologies in, for example, pasture and rainfall tracking or in improving markets for livestock offtake. While pastoral herding strategies and communal management practices have been shown to be economically and environmentally justifiable, problems

BOX 3

Improving cattle breeds: changing from local breeds to crossbred cattle

The local breeds of cattle that are farmed in the developing world are well adapted to their environments in terms of disease resistance, heat tolerance and low nutrition needs. However, their productivity is low and the amount of GHG emissions produced per kilogram of milk and meat can be very high. Selecting more productive animals is therefore one strategy that can enhance productivity and reduce emissions intensity. To this end, researchers have attempted to utilize natural genetic variations in cattle populations to breed reduced-emissions cattle, but results have so far been inconclusive.

Cross-breeding programmes can deliver simultaneous adaptation, food security and mitigation benefits. These strategies that make use of locally adapted breeds that are tolerant to heat, poor nutrition, parasites and diseases will become increasingly useful as the climate changes. Cross-breeding coupled with diet intensification can lead to substantial efficiency gains in livestock production and methane output. With widespread uptake, this would result in fewer but larger, more productive animals being kept, which would have positive consequences for methane production and land use. As crossbred animals produce more milk and meat, fewer animals are required to meet demand. Thornton and Herrero (2010) estimated the impacts of widespread adoption of crossbred animals (29 percent by 2030) on meat production in the rangeland systems and on dairy production in the mixed systems of the tropics, finding that the larger animals produce more than double the amount of milk and meat, compared with local breeds.

101 "In recent times, many efforts have been made to replace mobile herding with sedentary livestock production, to replace common property with private tenure, to substitute indigenous livestock with European breeds, and to switch pastoralism from a multi-species and often dairy or fibre-based economy towards single species meat production. The outcome of these changes has been both economically and environmentally harmful and the policy of livestock intensification and sedentarization has been a major contributor to land degradation. In fact, the suggestion that these policies constitute intensification has been challenged since pastoralism traditionally is highly labour intensive. By shifting from a mobile, labour intensive to a sedentary, capital intensive development model, governments have undermined the application of indigenous knowledge that has traditionally enabled sustainable management of rangelands. In some countries, notably in West Asia and North Africa, livestock development policies have additionally contributed to land degradation by supporting capital intensification with policies to subsidise feed and other inputs. [...] The result is that rangeland biodiversity has become heavily degraded, in some cases irreversibly so (Davies et al., 2012).

such as exceeding the variable carrying capacity of rangelands "tend to arise where local governance breaks down, where mobility is impeded, and where investments promote unplanned livestock population growth" (Davies et al., 2012). Traditional pastoral management strategies and indigenous governance and dialogue structures should therefore be supported to address conflicts arising from shared use of natural resources and to avoid their overuse and the resulting biodiversity loss and land/ecosystems degradation (see Box 4 for solutions to pastoralism conflicts between Ethiopia and Kenya).

Drylands and grasslands management is also key to reducing the amount of carbon that is lost continuously due to poor management and to restoring the largely degraded soils.

Improved decision-making tools should be developed to evaluate environmental impacts and externalities and reach better evidence-based trade-offs in land-use decisions and agreements. For instance, in some cases, livestock must be forbidden from certain areas in order to reduce human and wildlife conflict.

On-farm diversification

According to ILRI (n/d), mixed farming systems are a favoured option for intensified land use in many areas of SSA (see Annexes, Figure 9 on livestock diversity and its benefits in terms of tackling climate change). Therefore, there is a need to better understand crop-livestock relations, identify knowledge gaps and popularize mixed farming (see Box 5 for three case studies on mixed systems). According to Thornton and Herrero (2015), "mixed systems can reduce resource depletion and environmental fluxes to the atmosphere and hydrosphere, offer more diversified landscapes that favour biodiversity, and increase system flexibility to cope with socio-economic and climate variability". In addition, ILRI (n/d, citing Brumby, 1986) notes that "the case for integrating animal and crop systems is based on the premise that by-products from the two systems are used on the same farm. Draught power, closed nutrient cycling, improved environmental quality and use of roughages and low-quality feeds contribute to overall higher output per animal and per hectare. Soil fertility improvements result from the volume of organic components that circulate through the soil and plants

BOX 4

Case study: improved grazing management via improved dialogue and shared resources use agreements: the case of pastoralism between Ethiopia and Kenya

The Borana and Gabra pastoral tribes have historically come into conflict over pasture land, water and natural resources due to extreme weather conditions and droughts. The Oromia Pastoralist Association (OPA), created in 2006 to facilitate the cross-border mobility of pastoralist tribes between southern Ethiopia and northern Kenya, is helping address land disputes, resource conflicts and the barriers facing these vulnerable groups in terms of climate change adaptation. The association pursues peaceful coexistence through cross-border community dialogue and the co-creation of conflict resolution strategies, including 'reciprocal resource use agreements', which are helping reduce overgrazing and soil erosion, improve market access for pastoralist products, and build resilience to climate-related stresses. Thanks to OPA's activities, recent years have seen no community conflicts. The model, which has the potential to be transferred to neighbouring regions where resource and water scarcity are growing challenges, has already been replicated in Somalia.[1]

1 See: http://oromiapastoralist.org/.

BOX 5

Three case studies on mixed crop-livestock production systems

1 - Manure management along with other agroecology practices in West Africa: In central and southern Senegal, in agropastoral zones (groundnut basin), research has shown that it is possible to halve net GHG emissions from livestock by improving animals' feed regimes, covering stored manure with sheeting and digging it into the field. Furthermore, a pastoral zone in the north of the country has demonstrated that by fostering agroecological practices, the soil, trees and animals can capture enough carbon to offset emissions from the animals in a borehole catchment area. Furthermore, in northern Côte d'Ivoire and in Burkina Faso, in polyculture-livestock farming systems, the main innovations to boost soil carbon capture also involve applying agroecological principles (plant cover, intercropping, etc.), using organic fertilizers, and suggesting ecosystem governance systems (local land tenure charters, etc.).

2 - Use of kraal manure in Swaziland: The CSA practices and technologies that are being promoted, adopted and implemented in Swaziland include conservation agriculture, use of kraal manure, agroforestry and planting of drought-tolerant varieties. Kraal manure is essentially livestock waste consisting of organic material from the residues of plants that were digested by animals housed in a night enclosure, also known as a 'kraal'. It is collected from the night enclosure and transported to the field using different methods, such as manually using wheelbarrows or head pans, or in tractor trailers. About 23 percent of farmers in Swaziland used kraal manure, while 27.4 percent do not use any form of animal manure. More male than female farmers used animal manure or kraal manure, perhaps because cattle are generally owned by men (FAO, 2005, cited by Manyatsi & Mhazo, 2014). Other farmers use goat manure on high-value crops such as vegetables. A key advantage of using organic manure is its addition of nutrients to the soil. Kraal manure is less expensive than inorganic fertilizers and stimulates microorganisms that release nutrients (Manyatsi & Mhazo, 2014).

3 - Sustainable small-scale dairy development in Tanzania using the CLEANED–LVC[1] framework (SEI, ILRI, 2014): The CLEANED–LVC assessment framework provides an ex-ante rapid assessment tool that can indicate the likely impacts along the VC of planned interventions in livestock and fish production systems. This assessment framework was used in Tanzania to explore the various scenarios of dairy development. Tanzania has the third largest livestock population in Africa, mostly in extensive grazing systems, but increasingly in more intensive production. Demand for milk in Tanzania already outstrips supply and is increasing rapidly, with consumption expected to rise from 45 litres per capita to 100 litres per capita by 2020. The growth in production needed to meet this demand could have considerable negative environmental consequences, if not done sustainably. Furthermore, following the CLEANED–LVC methodology, the dairy production systems, infrastructure and environmental baseline in Lushoto and Handeni districts were mapped using a participatory approach. Secondly, workshops assessed the following scenarios of smallholder dairy development: increased milk yield from 1–2 litres a day to 5–8 litres a day in extensive systems, and from 4–8 litres per day to 10–15 litres per day in more intensive systems. Scenario discussions revolved around: 1) improving feed quantity and variety — to provide more or better feed for improved milk yields, and/or to provide more feed in the dry season to sustain milk yields through the year; 2) improving animal breeds for higher productivity; and 3) improving supporting services and infrastructure. The first action to improve feed resources was highlighted as a primary action, in terms of quality, quantity and fodder preservation, along with supporting interventions including herd management and breeding and strengthening the extension support and dairy marketing chain.

1 Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along Livestock and aquaculture Value Chains. See Annexes, Figure 7 for an overview of CLEANED–LVC project.

and the animal manures that enrich the soil through long-lasting carry-over effects. Livestock also provide a ready means of acquiring cash and support the use of inputs in crop production which in turn generates higher levels of output from both crop and livestock". Furthermore, alternatives for energy generation such as biogas should be introduced to move away from the use of dry animal dung fuel for energy.

The rice VC

Key environmental impacts and externalities of the rice VC

Soil degradation and water depletion

As previously explained, the three main rice ecologies in SSA are the rain-fed uplands, the rain-fed lowlands and the irrigated systems. These ecologies can be found across agroecological zones. Overall, rice production in SSA is dependent on rain-fed systems. However, these traditional and predominant production systems produce low yields as well as environmental impacts and externalities, especially since they are characterized by minimal use of inputs, outdated varieties and poor seed quality at the pre-production stage in which the land is prepared for planting. This leads to land degradation, due to a decline in soil fertility, as well as water shortages and related water stresses, especially in the fragile rain-fed or upland environments.

GHG emissions

Rice production has been linked to a range of different yet interlinked environmental impacts and externalities, such as high GHG emissions, air and water pollution (high weed and pest pressure in rice production) as well as a steady increase in water consumption (rice requires about twice as much water as other grain crops.). High GHG emissions are an especially important externality in wetland rice soils, which constitute a limited share of rice production in SSA. The most dominant emission is methane,[102] due primarily to the anaerobic breakdown of organic matter in wetland, waterlogged rice paddies by methane-generating bacteria (Meinzen-Dick & Rosegrant, 2001). According to Keerthisinghe (n/d), most rice lands can be considered degraded in one way or another. Downstream silting, nutrient mining, pesticide pollution, soil acidification, alkalization, toxicity and salinization and other phenomena continue unabated in irrigated as well as rain-fed rice ecosystems. For instance, rain-fed lowland rice production has placed major constraints on ecosystems: it has led to the planting of river floodplains, mangrove cutting, riverbank modification and erosion, wetland losses, soil salinization, methane emissions, disease/malaria problems around paddies, and so forth. Furthermore, there are cases in which the New Rice for Africa (NERICA) varieties, developed by the Africa Rice Center and often hailed as a solution, have extended rice cultivation to new areas, where they have had a severe impact on dry ecosystem conversion, deforestation, fire frequency and so forth.[103]

Post-harvest losses

Finally, the key externality during the post-production phase is classical post-harvest losses that occur due to post-harvest operations such as drying, milling and storage.

Climate change risks

The overall impact of climate change on rice production in SSA is likely to be negative and linked mainly to water scarcity. The incidence and severity of drought is expected to worsen with climate change. Although rain-fed rice systems, most common in SSA, are especially vulnerable, irrigated lowlands also face increased water competition. In Africa, recurring drought already affects nearly 80 percent of the potential 20 million hectares of rain-fed lowland rice. According to the International Rice Research Institute (IRRI), rainless days for a week in upland rice-growing areas and for about two weeks in shallow lowland rice-growing areas can significantly

102 For example, methane accounts for 70–90 percent of total emissions in Australia and Japan and more than 90 percent in Laos (Suenaga, H. et al., 2014).

103 In 1992, the Africa Rice Center (WARDA) and its partners started the Interspecific Hybridization Project (IHP) in an attempt to combine the useful traits of both cultivated rice species (O. sativa and O. glaberrima). With the support of donors from Japan and the United States and in collaboration with numerous partners in the IHP, WARDA developed interspecific lines with desirable traits tailored to African conditions. In 1999, the interspecific lines were named New Rice for Africa: NERICA (WARDA, 1999) and one year later, WARDA received the prestigious CGIAR (Consultative Group on International Agricultural Research) King Baudouin Award for its achievements with NERICAs (WARDA, 2000). (Norman, J.C. and Kebe, B., n/d).

©Staton Winter/UN Photo

reduce rice yields, leading to production losses of up to 40 percent.[104]

In addition, surveys in hundreds of farmers' fields over the last 10 years show that rice diseases and pests are strongly affected by climate change. Water shortages, irregular rainfall patterns, and related water stresses increase the intensity of some diseases, including brown spot and blast. In addition, weed infestation and rice-weed competition are expected to increase, representing a major challenge for sustainable rice production. Other constraints caused by climate change will include sea-level rise and flooding, which will in turn affect river estuaries and salt levels in tidal rivers. Consequently, there will be considerable rice paddy loss due to salinization, degradation and upriver movements of rice paddies. In such a situation, land and habitat conversion will be the only option, again leading to negative environmental impacts.[105]

Finally, increases in both temperature and carbon dioxide levels will also affect rice production. Higher carbon dioxide levels typically increase biomass production, but not necessarily yield. Higher temperatures can decrease rice yields as they can make rice flowers sterile, meaning no grain is produced. Higher respiration losses linked to higher temperatures also make rice less productive. IRRI research indicates that a rise in night-time temperature by 1°C may reduce rice yields by about 10 percent.

Good practices for the rice VC

Sustainable intensification

In the pre-production phase, using better seeds and rice varieties is key to achieving higher yields, improving stress tolerance (including to drought and salt), reducing susceptibility to rice pests, and also improving nutrition, among other possible benefits. As mentioned previously, access to quality rice seed is a challenge in many SSA countries. Projects to use donor funding to strengthen seed systems are under way. For instance, AfricaRice and its partners, as part of the CGIAR Partnership for Scaling of Improved Seed Varieties Programme, set up a 'Seed scaling technical assistance project' in Ghana, Nigeria, Senegal and Liberia. In Senegal, for instance, the project aims to improve the country's seed certification system, by integrating the private sector into it (Africa Rice Center, 2015). Moreover, NERICA rice varieties have many positive features, such as no grain shattering, superior weed competitiveness, drought tolerance, pest or disease resistance, and the potential for higher yields. In addition, the grain quality of most NERICA varieties is often better than that of their parents. However, as mentioned previously, there is evidence that NERICA varieties have negative environmental impacts, such as dry ecosystem conversion and deforestation.

104 See: http://irri.org/.
105 Ibid.

Moving away from anaerobic to aerobic rice will have an impact on other processes, such as soil organic matter turnover, nutrient dynamics, carbon sequestration, soil productivity, weed ecology and GHG emissions. It is therefore essential to consider all these parameters when identifying integrated management practices to save water (Cantrell & Hettle, 2004). IRRI uses the International Rice Genebank, which offers the most comprehensive collection of rice genetic diversity in the world. Containing around 110,000 different types of rice, it includes rice genes associated with traits that help rice cope with climate change.[106] For instance, IRRI has developed a new, more salt-tolerant rice variety that may become available to farmers in 2017–2018, following extensive trials.[107] It is important to keep up to date with the latest scientific findings on new variety and cultivation technique developments and on correct land-use planning and management regimes, such as avoiding the conversion of valuable natural ecosystems, fires and deforestation.

The potential for rice development is largely determined by the agroecological conditions in which rice can be produced. Different production systems present different yield potentials. To sustain and increase rice production, it is important to identify cost-effective production systems with minimum impact on the environment. According to Defoer et al. (n/d), rain-fed lowlands present a very significant potential to increase yields and therefore increase rice production, without bringing about increased environmental externalities (as it is a rain-based system). However, interlinkages between ecologies (e.g. water or nutrient flow from upland to lowland areas) influence the ecological sustainability of farmland. Various sustainable intensification practices have proven useful for rice. More precisely, the System of Rice Intensification (SRI) offers a set of practices that increase yields while saving water (see Box 6 — SRI in Senegal and Kenya). It has been proven that water management is one of the key entry points for addressing environmental sustainability of the rice VC, i.e. improved water control, water conservation (bunded paddies, contour bunds) and water harvesting (reservoirs, micro-catchments). It is important to increase water productivity, develop low water-use systems/water-saving irrigation techniques, optimize water productivity of shared water bodies, recycle water for aquaculture or irrigation, and also develop rice varieties suited to dry soils (aerobic rice). Efficient water-use technologies are being implemented in rice production, such as intermittent flooding and growing rice under aerobic conditions.

Concerning GHGs, certain methods can reduce the methane emissions of rice paddies. These include mid-season drainage (alternative wetting and drying cycles), introducing a no-till system, and adding soil amendments such as nitrification inhibitors (Suenaga et al., 2016). Furthermore, to control weeds and pests, interventions should encourage farm management practices that decrease environmental impacts and/or increase ecosystem services. For instance, instead of herbicide use, hand weeding or biological control could be practised in rice production in certain areas.

Post-harvest losses in the rice VC could also be reduced through innovative uses of rice waste. Although rice straw and husks are still largely considered a waste product, they can be used for animal feed and bedding (e.g. high-value rice pellets can be produced from low-value broken rice to feed fish).[108] Apart from using rice waste, rice-husk can also be used to purify water and, as such, reduce the environmental impact of the process by eliminating the need for boiling, thus conserving electricity and/or liquefied petroleum gas and the use of harmful chemicals (TEEB, 2015).

Finally, it is important to increase rice production in lowlands, as they have the greatest potential for increasing rice productivity in Africa, but not all lowlands are suitable. Besides agricultural production (mainly rice-based systems, but also vegetable, fruit

106 See: http://irri.org/our-work/research/genetic-diversity/international-rice-genebank. IRRI is developing “C4” rice - rice with a supercharged photosynthesis mechanism that is much better at using sunlight to convert carbon dioxide and water into grain. C4 rice could yield up to 50 percent more grain than existing rice varieties, and would be more water- and nutrient-efficient. See: http://c4rice.irri.org/.

107 See: http://irri.org/news/119-wild-parent-spawns-super-salt-tolerant-rice.

108 Other innovative uses are increasingly being promoted. For instance, Tata Chemicals, a company of India’s Tata Group, co-designs and sells a rice husk-based water filter. Its active element is a bulb of rice-husk ash impregnated with nano silver particles, for purifying water and destroying germs and bacteria. Tata SWACH is a low-priced product (under US$20) and is widely used (over 400,000 units and bulbs sold in 2014–15).

BOX 6

SRI in Senegal and Kenya

SRI is a set of farming practices for increasing the productivity of (irrigated) rice (see Annexes, Box 5 'Practices for SRI' for more detailed information). SRI is a Low External Input (LEI), agroecological and climate-smart methodology that originated in Madagascar in the 1980s to increase rice productivity by improving the management of plants, soil, water and nutrients. SRI includes intermittent flooding as part of the production package. The system advises transplanting young (eight to 10 days old) single rice seedlings and applying intermittent irrigation and drainage to maintain soil aeration. In addition, the use of a mechanical rotary hoe or weeder to aerate the soil and control weeds is encouraged.[1]

According to Cornell University's SRI International Network and Resources Center,[2] the benefits of SRI have been demonstrated in over 50 countries. They include: 20–100 percent or more increased yields, up to a 90 percent reduction in required seed, and up to 50 percent water savings. SRI uses less fertilizer and makes use of what the farmer has available (seed, manures). It may not be necessary to purchase extra external inputs, and it works with nearly all rice varieties (although some varieties respond better than others). SRI principles and practices have been adapted to rain-fed rice as well as to other crops, resulting in yield increases and the associated economic benefits.

A TEEB rice study (2015) compared SRI with conventional production methods. It found that in Senegal, the impact of water consumption under conventional systems was valued at US$801/ha as compared with $626/ha under SRI. Furthermore, revenues per hectare are estimated to be higher under SRI ($ 2,422/ha) versus conventional systems ($2,302/ha). Switching to SRI, society could therefore save around $11 million/annum in water-consumption-related health and environmental costs in Senegal, while the rice-producing community would simultaneously gain around $17 million through yield increases.

In Kenya, Bancy M. Mati (n/d) states that farmers in Mwea have proved that SRI increases rice yields and saves water, as SRI rice obtained yields ranging from 6.0 to 8.5 t/ha compared with the 5.0–6.0 t/ha normally recorded in Mwea. Farmers also noted that a bag of SRI paddy weighed 100-110 kg compared with 80–90 kg for conventional rice. Furthermore, when SRI rice was milled, it had higher quality grains and a stronger aroma, and thus sold faster. In addition, farmers were able to weed SRI paddies three times rather than the usual twice for conventional paddies, while SRI used fewer seeds, thereby reducing production costs. Furthermore, SRI led to water savings of 25 percent.

As climate change will result in increasing variability of rainfall and growing competition for water and land, SRI provides a new opportunity to increase the production value per drop of water and reduce rice water demand.[3] However, some resource-poor farmers have found SRI difficult to practice, since the method requires significant additional labour input. In their study on SRI adoption in Madagascar, Moser and Barrett (2003) found that this extra labour was needed at a time of the year when liquidity is low and labour effort is already high. Therefore, in the case studied, SRI practices were not appropriate for smallholder farmers due to their highly seasonal, labour-intensive nature.

1 See: https://sriwestafrica.org/sri/; The World Bank Institute has developed a multimedia toolkit for farmers with the key elements of SRI, methods of application, benefits and constraints. See: http://siteresources.worldbank.org/WBIWATER/Resources/SRIbrochure.pdf

2 See: http://sri.cals.cornell.edu/

3 For more examples of SRI, see: http://www.slideshare.net/SRI.CORNELL/1602-scaling-up-climate-smart-rice-production-in-west-africa.

©Marco Dormino/UN Photo

and livestock production), inland valleys provide local communities with forest, forage, hunting and fishing resources and constitute important water buffers and biodiversity hotspots. Degradation of vulnerable ecosystems, caused by indiscriminate development for the sole purpose of agricultural production, should therefore be avoided (Rodenburg et al., 2013): for example, due to their environmental services, fragile wetlands should be spared being developed for agricultural purposes.

On-farm diversification

For rice production, diversification through multi-cropping systems is one of the key ways forward. For instance, in rice-wheat cropping systems, sowing wheat after rice harvest under zero-tillage practices offers promising water-saving opportunities (Cantrell & Hettle, 2004). Moreover, diversification of rice-based cropping systems to incorporate legume crops, modify crop rotations and link the system to livestock or fisheries may help enhance household food security, both through improving producer income and adding essential fatty acids, vitamins and minerals to diets.[109]

109 Although this study does not discuss whether more rice cultivation is important to reach SA, CSA or SLM goals, in some regions, crops such as millet and sorghum may be better adapted to arid lands. Instead of planting rice, some lands can actually be revived by making hard grain preparation easier? This is the comparative LCA that should be taken into account in some cases.

The cassava VC

Key environmental impacts and externalities of the cassava VC

Pre-production losses

According to Reynolds et al. (2015), there are relatively few publications available on the entire production process of cassava and its impact on the environment. Cassava has long been regarded as an environmentally sustainable or benign crop for a variety of reasons, including its drought resistance. Traditionally, smallholder cassava food systems (as in most parts of SSA) have fewer environmental impacts than cereal systems and the other food VCs discussed in this study. For instance, their environmental impacts are not substantial during the pre-production stage, because cassava is a low-input crop that does not require much fertilizer. In many cases, cassava is also grown in remote and poor areas, where fertilizer is simply not available or is too costly. Therefore, the environmental impacts from chemical contamination are minimized. In addition, cassava production depends on a supply of quality stem cuttings. Compared to grain crops, which are propagated by true seeds, the multiplication rate of planting materials is very low. Furthermore, cassava stem cuttings are bulky and highly perishable as they dry up within a few days, which may lead to pre-production losses in some cases.[110]

Soil degradation

Most negative environmental impacts and externalities from cassava production are land-use related. In SSA, cassava usually occupies hillside and otherwise exhausted fields, such as drought-prone areas and acidic soils where other crops can grow only with high inputs, if at all (Hershey & Howeler, 2000, cited by Reynolds et al., 2015).[111] Despite the adaptability of cassava to poor soil conditions, depleted soil fertility and soil degradation pose increasing challenges to cassava in many parts of SSA, including on these exhausted fields. At the same time, there is evidence that planting cassava in fertile soils can lead to soil and nutrient depletion (Howeler, 2001).

Loss of biodiversity

The rapid increase in cassava production, especially in Nigeria, led to unavoidable deforestation via slash-and-burn agriculture. Hence, the production of cassava can lead indirectly to a loss of biodiversity: according to an older, but still very relevant study by McNeely (1992, cited by FAO, 2003), Africa had already lost 65 percent of its wildlife habitats by 1986 through conversion into farming land; this process accelerated even further during the 1990s. Cassava production for human consumption clearly contributed to this process. However, compared to the large-scale cultivation of export crops, including groundnut and coffee, the impact of the small-scale production of cassava has been smaller (FAO & IFAD, 2001).

GHG emissions

Traditional cassava processing, in which women play an important role, is highly labour-intensive and largely non-mechanized. However, as it becomes increasingly mechanized and commercialized, male involvement and unsustainable practices are increasing. These new processing technologies for local-level value addition are associated with fuel use and its associated environmental impacts, including both water and air pollution and forest degradation (e.g. through the use of fuelwood) (FAO & IFAD, 2001). More precisely, processing the cassava roots into food requires firewood and fossil fuel (petroleum) to power the tractor and small internal combustion engine, which produces GHG emissions. Firewood consumption also leads to severe deforestation and desertification, two of the key known causes of climate change (Kolawole, 2014).

Post-harvest losses

Food losses are also present in the post-production phase: cassava is highly perishable and thus very susceptible to post-harvest physiological deterioration. Inadequate harvest — mainly due to ineffective manual harvesting, storage and processing methods — is a major problem leading to high rates of post-harvest losses among cassava crops. This lost production equates to not only wasted effort by farmers, but also wasted land

110 See: http://www.iita.org/cassava.

111 From a food security as well as an environmental perspective, this can be seen in a positive light: cassava can grow in otherwise exhausted and abandoned farmlands and there is no need to convert new land for cassava production. This is however not the focus of this study.

clearance. Unlike cassava production itself, the post-harvest process requires considerable labour efforts, because the highly perishable roots must be processed into a storable form soon after harvest. Also, many varieties contain cyanide, which can make the crop toxic if inadequately processed using methods, such as grating, sun drying, and fermenting to reduce the cyanide content.[112] In addition, wastewater from cassava processing, if released directly into the environment before proper treatment, could also be a source of pollution (Kolawole, 2014).

Climate change risks

As a drought-resistant tuber, cassava is expected to be far more resilient in the face of climate change than other staple crops, with particular potential in light of climate change and climate disasters such as El Niño (Barratt et al., 2006; Jarvis et al., 2012).

Good practices for the cassava VC

Sustainable intensification

According to AfD et al. (2010), the cassava supply chains urgently require sustainable intensification, since increased demographic density and shorter fallow periods have led to deteriorating systems. Many technologies exist, but due to the economic conditions needed to disseminate them, they are not often implemented (for instance, due to fertilizer costs). The main challenge for the future is to develop cassava cultivation systems, while relying on ecological intensification in order to maintain soil fertility and control invasive species. A number of good practices are required at all stages of the VC to achieve this:

First, techniques from conservation agriculture and agroforestry can be adapted to cassava. They generally require minimal use of chemical fertilizers and herbicides to control biomass. According to AfD et al. (2010), although research on these techniques for roots and tubers is encouraging, further research and wider acceptance of the results is required. Investment in research is important because cassava is expected to be more resilient to climate change than maize and rice, and it may even be used as a replacement for cereals.[113]

Second, the use of clean planting material is key to managing viral diseases affecting cassava, but it requires coordinated work in several areas such as surveillance, integrated whitefly pest management, crop breeding and seed systems (Legg et al., 2014). Continued research, such as the IITA study that is currently under way, should be strongly promoted.

Third, better storage of roots in the soil, improved harvest and storage practices and improved processing methods are especially useful to reduce post-harvest losses.[114] As for the latter, there are numerous traditional processing techniques for cassava, making it a cheap and easy-to-use product for the final consumer. However, progress will rely on the dissemination of small mechanic processing equipment to increase labour productivity and quality. For example, in Nigeria, the introduction of mechanic graters to prepare gari has enabled women to dedicate less time to cassava fermentation and to focus more on production, thus generating higher yields (Nweke, 2004, cited by AfD et al., 2010).

On-farm diversification

Diversification through 'intercropping' cassava with other species is key to managing environmental impacts and externalities in the cassava VC: cassava can be intercropped with trees and bushes, as well as with vegetables, plantation crops (such as coconut, oil palm and coffee), yam, sweet potato and melon.[115] Among the many existing practices, it seems that intercropping cassava and maize is increasingly common, while intercropping cassava and pulses is becoming increasing popular (see Box 7 for more details on intercropping cassava and grain legumes

112 See: http://www.iita.org/cassava.

113 Ajayi (2015) conducted research on the effects of climate change on the production and profitability of cassava in the Niger Delta Region in Nigeria and listed a number of detailed coping strategies to the effects of climate change on cassava production, including the draining of wetland for cassava cultivation, reforestation, use of early maturing cassava varieties, the preservation of cassava cuttings for planting (Ajayi, 2015: p: 7–8).

114 The Rockefeller Foundation Cassava Innovation Challenge, launched in 2016 together with Dalberg and IITA will provide up to $1 million as well as technical assistance to find solutions that can increase the shelf life of cassava in Nigeria. It is too early to get insights about the outcome of this Challenge, but it is worth keeping an eye on the results. For more details, see: https://www.rockefellerfoundation.org/cassavachallenge/.

115 See: http://www.iita.org/cassava.

BOX 7

Intercropping cassava with other crops in Nigeria

According to FAO (2013), intercropping cassava with grain legumes (such as beans, groundnuts or cowpeas) can make nitrogen available to the cassava crop or — in the case of rotations with grain legumes in marginal areas where cassava is the main crop — available to the successive cassava crop (FAO, 2013). Meanwhile, research in Nigeria has shown that two years of cassava-soybean intercropping led to the incorporation of soybean residues, which in turn led to a yield increase of 10 to 23 percent.[1]

In addition, intercropping reduces the risk of total crop failure. In south-western Nigeria, for instance, maize and cassava are often planted in the first of two annual rainy seasons. The maize is harvested during a short break in the rains, after which the cassava continues alone. Since the two crops have different pest and disease complexes and growth requirements, one may survive even if the other fails. Some farmers even plant a second maize crop: cassava is less risky and any surviving maize is a bonus (FAO, 2013).

1 For other practices, such as green manuring or alley cropping, in other parts of the world, see here: http://www.fao.org/ag/save-and-grow/cassava/en/5/index.html.

in Nigeria), also because pulses are known to make nitrogen available to the cassava crop (see *The pulses VC* on page 54). Intercropping with trees and bushes, also called 'agroforestry', allows farmers to benefit from one crop while the other crops or trees are still growing to maturity (Ferment et al., 2008; Fermont, 2009, cited by Reynolds et al., 2015; Jarvis et al., 2012).[116]

The maize VC

Key environmental impacts and externalities of the maize VC

GHG emissions

In the pre-production phase, the relatively widespread and rising use of synthetic fertilizers in maize systems releases GHGs, both during manufacture of the fertilizer and in its use. However, in SSA, these impacts are only localized, because in most areas fertilizers and pesticides are underused (Reay et al. 2012, cited by Reynolds et al., 2015). Nevertheless, continued maize-related clearing in several large African countries including Nigeria, Ethiopia and Sudan also produces GHG emissions (Fargione et al. 2008; Phalan et al. 2013, cited by Reynolds et al., 2015).

Soil degradation and loss of biodiversity

During the production phase, mono-cropping of maize and unsustainable management practices lead to soil infertility and nutrient shortages. Other environmental impacts and externalities of maize mono-cropping relate to land clearance and degradation and subsequent loss of wildlife habitat and of biodiversity. At the same time, soil infertility and nutrient shortages represent the most severe constraints to maize yields in SSA (Mueller et al. 2012, cited by Reynolds et al., 2015).

Diseases, insect pests and weeds

Diseases and pests are among the major constraints limiting maize productivity in smallholder farming systems in SSA. They include downy mildew, grey leaf spots, common rust and the maize streak virus. The latter caused major losses during a huge outbreak in the 1970s in a number of SSA countries.[117] In more recent

116 See: http://www.worldagroforestry.org/news/agroforestry-potential-nigeria. For more details on intercropping trees and cassava in West Java, see here: http://blog.cifor.org/41242/switching-swidden-to-agroforestry-a-small-intervention-with-big-potential-in-west-java?fnl=en.

117 See: www.iita.org.

years the Maize Lethal Necrosis (MLN) disease has been causing great harm, while armyworms and stem borers, as well as noxious weeds such as striga, can also cause large-scale damage (Pingali & Pandey, 2000).

Post-harvest losses

In the post-production phase, when stored traditionally cereal crops such as maize also suffer significant losses from the many pests and diseases. However, post-harvest losses can also occur during other stages of the VC, e.g. transportation, threshing, drying or milling (Tefera 2012, cited by Reynolds et al., 2015).

Climate change risks

Maize productivity in SSA has traditionally been low, mainly due to the fact that maize is predominantly grown in smallholder farming systems under rain-fed conditions, making maize systems highly vulnerable to climate variability and change. Even small changes in rainfall patterns or amounts can lead to huge losses of yields (Reynolds et al., 2015). In addition, generally low yields in this region are largely associated with drought stress, low soil fertility, weeds, pests, diseases, low input availability, low input use and inappropriate seeds (Adger et al., 2007, cited by Cairns et al., 2013). Future climate change is likely to exacerbate these conditions and therefore be especially damaging to maize yields in SSA (more than to cassava yields, for instance), leading to several severe biotic and abiotic constraints, including high temperatures, drought and pests, and reducing the areas where maize can be grown (Reynolds et al., 2015). In sum, current and future climate change therefore represents a particularly significant challenge because the probable impacts are beyond the range of farmers' previous experiences (Adger et al., 2007, cited by Cairns et al., 2013).

Good practices for the maize VC

Sustainable intensification

There is a substantial body of research on the sustainable intensification of maize-based cropping systems in SSA. Many good practices and technologies are available to manage the environmental impacts of maize systems (Pretty et al., 2011). These include:

The need for soil and water conservation methods: farmers in Burkina Faso have doubled grain yields by using rainwater harvesting techniques such as stone bunds and planting pits. Practised at the community level, rainwater harvesting can recharge underground aquifers and restore stream flow (GCP et al., 2015).

Integrated nutrient management (see the example of South Asia in Timsina et al., 2010) and the improved management of farm fields with different nutrient status, as tested in Kenya and Zimbabwe (Tittonell et al., 2008). Past experience has demonstrated that the use of new maize varieties alongside improved management options can offset yield losses by up to 40 percent. Generally, there is strong evidence that efforts to improve soil management (through minimal tillage, residue retention and intercropping) can reduce soil erosion and nutrient losses, but the adoption of conservation agriculture techniques in SSA remains slow and limited (Bossio et al., 2010; Erenstein et al., 2012, cited by Reynolds et al., 2015). Furthermore, experiences in Zambia show that maize yields in conservation agriculture systems with crop rotations have been 50 percent higher than yields under conventionally tilled maize, as well as reducing soil erosion, chemical inputs, and energy use (GCP et al., 2015).

Improved varieties and management techniques: according to Cairns et al., (2013), climate change adaptation strategies in maize systems in SSA are likely to include improved germplasm with tolerance to drought and heat stress and improved management practices. As Cairns et al. (2013) note, "adapting maize systems to future climates requires the ability to accurately predict future climate scenarios in order to determine agricultural responses to climate change and set priorities for adaptation strategies". Despite the progress that has been made in breeding maize with better tolerance to drought and high temperatures, larger improvements are needed as maize production is likely to be substantially constrained by abiotic stresses in SSA (Reynolds et al., 2015).

More broadly, agroecology and agroforestry practices offer solutions: agroecological farming, as a set of key ILM practices, relies on biologically based, integrated soil-plant-animal cropping systems to supply clean water, reduce pollution and protect biodiversity, in addition to sustainably producing crops, trees and

livestock. Agroforestry in Malawi, for example, increased maize yields by about 50 percent when nitrogen-fixing Faidherbia albida trees were planted on farms (GCP et al., 2015). Some examples of ecological pest management practices include the push-pull strategy used to manage maize stalk borers and striga, biological control of stalk borers, hermetic storage structures to reduce post-harvest losses and the development of host-plant resistance to storage pests and major diseases, such as MLN disease.[118]

On-farm diversification

As seen with the other crops, as well as the livestock subsector, diversification of maize with other crops is recommended. In concrete terms, this can be done by intercropping or rotating leguminous trees and shrubs and annual legumes with maize (Pretty et al., 2011) or by incorporating legume weed residues into maize croplands (Mapfumo et al., 2005). Box 8 presents a case study of maize-legume intercropping systems that

BOX 8

Sustainable intensification of maize-legume cropping systems for food security in Eastern and Southern Africa (SIMLESA): focus on Ethiopia, Kenya, Tanzania, Mozambique and Malawi

The SIMLESA initiative was launched in 2008 by the International Maize and Wheat Improvement Center (CIMMYT), together with the Australian Government and other partners such as FAO and CGIAR. It aims to increase farm-household food security and productivity in the context of climate change by developing more resilient, profitable and sustainable intercropping systems, looking specifically at maize-legume farming systems in Ethiopia, Kenya, Tanzania, Mozambique and Malawi.

For many rural households, food security depends upon enhancing productivity through improved maize varieties and appropriately targeted sustainable intensification practices. SIMLESA ensures that the interventions maximize farm-level productivity, income, resilience and sustainability in these farm systems, based on farmers' own resources and VCs that are realistically able to be used in the long term. The initiative focuses on creating strong partnerships with relevant actors. It then introduces drought-tolerant maize, more productive legume varieties, post-harvest technologies, and cell-phone-managed insurance approaches.

CIMMYT has made substantial progress in developing drought-tolerant maize through conventional plant breeding, and the centre has widely tested and disseminated improved materials in drought-prone areas of Africa. CIMMYT scientists believe they can make further gains by using tools from molecular biology. With the aid of a genomic map that combines data for different types of tropical maize in diverse environments, they are identifying genetic 'hotspots' in maize, i.e. areas of the crop's chromosomes that confer drought tolerance.

This work is critical in light of a recent study that examined the likely impact of climate change on maize yields in Africa and Latin America during the coming decades. The study was conducted jointly by the International Centre for Tropical Agriculture (CIAT) and the ILRI. In parts of Southern Africa, the study predicted drastic yield declines, requiring major adjustments to maize-based systems.[1]

1 See: http://www.cimmyt.org/strategic-plan-2017-2022/

118 See: www.cimmyt.org.

have led to sustainable increases in various countries in Eastern and Southern Africa.

The pulses VC

Key environmental impacts and externalities of the pulses VC

The multitude of pulses generally share certain characteristics that make them "a super crop for sustainability", due to their relatively low negative environmental impacts and externalities.[119] However, the level of intensity of these impacts and externalities depends largely on the type of pulses, the farming system and the agroecological environment.[120]

Fertilizer use

Pulses have the unique characteristic of being able to fix nitrogen in the soil, but the lack of nitrogen in nutrient-poor soils in SSA is in fact one of the main factors limiting their productivity in SSA. In order to overcome this, blanket fertilizer is used that can in turn have negative effects on soil fertility and yields. Adequate analysis of soil characteristics is thus crucial to maximizing the advantages of fertilizer use and the integration of legume crops into farming systems. Nitrogen fixation by legume crops is of particular importance in developing regions in Africa, where smallholder farmers often have limited access to nitrogen fertilizer and prices are much higher than in Asia, due to the high cost of transport and 'small-quantity' distribution and retailing.

Land degradation and water depletion

Land- and water use for pulses cultivation can cause negative environmental impacts and externalities, although these are limited in comparison with many other crops. Mono-cropping of soybean, for instance, can cause water stress and land degradation, while increased soybean production in SSA poses both environmental and socio-economic issues.

Loss of biodiversity

Increasing the production of pulses such as soybean in fragile ecosystems in SSA can lead to increased deforestation and biodiversity loss due to land-use change (Gasparri et al., 2015). Areas that are suited to soybean production include the Southern African savannas and dry forests, which are rich in biodiversity (Beale et al. 2013).

Post-harvest losses

Post-harvest losses in pulse crops are relatively low since the process of drying pulses is a well-known part of traditional knowledge. Lack of adequate storage, both in packaging as in warehouses, can however cause high post-harvest losses, especially in groundnut and common beans. Aflatoxin and weevils are major threats for these crops, if not stored well.

Climate change risks

Estimates of the impact of climate change on pulse crop yields and acreage in climate models has been limited, but given the wide variety of pulse crops used in farming systems, the impact of climate change on pulses VCs will vary greatly. Climate change can nonetheless affect the production and yields of all pulse crops because they are usually grown in rain-fed systems, making them more vulnerable to abrupt drought and erratic rain patterns (Bahl, 2015), while drought, heat and poor soil fertility (e.g. low levels of phosphorus) limit pulses' ability to fix nitrogen. However, smart use of different varieties of pulse crops can make farming systems more climate-resilient.

Climate change impacts differ among the various pulses: high temperatures and lack of moisture can lead to plant drought at crucial flowering and reproductive growth stages, while intermittent rains have been shown to cause Phytophthora blight in pigeon peas (Vadez et al., 2012). Lentil, groundnut and pigeon pea yields are, however, less affected by drought compared to legumes such as cowpea and green gram or mung bean (Daryanto, 2015).[121] Climate modelling by Ramirez-Villegas and Thornton (2015) projects a 30–50 percent

119 See http://peoplefoodandnature.org/blog/pulses-celebrated-internationally-as-a-super-crop-for-sustainability/

120 Due to space limitations, a differentiation among various pulses cannot be made in this study.

121 Daryanto S, Wang L, Jacinthe P-A (2015) Global Synthesis of Drought Effects on Food Legume Production. PLoS ONE 10(6): e0127401.

©Oumou Sow/UNDP Mauritania

reduction in areas suitable for common bean in many regions. On the other hand, the same study shows that some climate change scenarios present opportunities for groundnut in Eastern Africa, while existing groundnut yields and suitable areas in West Africa will most likely be positively affected. Adhikari et al. (2015) show that for soybean, up to 45 percent yield reductions are expected.

Mixed cereal-legume-livestock systems or agricultural systems with rotational cropping are highly interrelated systems; problems such as drought, soil nutrition and pests interact with each other. The impact of climate change on these complex interrelated systems therefore requires more research.

Good practices for the pulses VC

Sustainable intensification

Pulses are often called 'climate-smart crops', because they can help smallholder farmers in drylands or semi-arid regions to withstand weather variability. Therefore, sustainable intensification of pulses in SSA is crucial. The practices of conservation agriculture promote pulses cultivation: these practices are based on the principles of minimum soil disturbance, taking care of permanent soil cover and using crop rotations that give a key role to nitrogen-fixing legume crops. Conservation agriculture can save labour, reduce erosion and thus soil degradation, and mitigate against erratic rainfall and periods of drought. The downside of these practices is that switching to conservation agriculture can cause initial high weed infestations, and the huge labour investments associated with manual weeding pose serious challenges for farmers. Nevertheless, better access to and good information on herbicides can increase the attractiveness of switching to conservation agriculture practices, including the integration of pulses into crop rotation (SIMLESA, 2015).

Sustainable intensification practices have shown benefits for smallholder pulses farmers. Therefore, more investments should focus not only on sustainable access to inputs such as improved seeds, rhizobia and P-based fertilizer, but also on helping farmers make well-informed decisions, on policies that promote pulse production and on strengthening markets for pulses. Farmers need solid information on the good practices, technologies and nutritional benefits of pulse production on which to base their decisions, but other types of information are also crucial. For example,

information from meteorological agencies needs to reach farmers, especially in times of changing weather patterns. Information is needed on the longer-term profitability of integrating pulses in farming systems, taking into account the positive effects on yields of other crops, but also the (perceived) higher labour costs or risks of pests. Sustainable access to inputs, technology and information needs to be achieved through the public and private sector working together, as illustrated by the N2Africa project in Box 9.

Lastly, increased linkages between smallholder farmers and markets and increasing the availability and affordability of improved varieties can help farmers to choose to plant pulses and increase yields and profitability. There are plenty of opportunities to strengthen markets for pulses by raising consumers' awareness of the nutritional benefits of pulses. Promoting and disseminating technologies that make pulses easier to cook can increase the integration of pulses in local diets. Pulses can gain added value through processing activities that tap into growing urban markets of ready-to-eat and healthy foods (see Box 10 — Lessons learned from the Tropical Legumes project).

Pulses are also important as a cash crop for local, regional and international markets, and are often produced by women. In fact, in both East and West Africa, pulses are considered a 'women's crop'. As such, they are not the main cash-generating crop. They do, however,

BOX 9

The N2Africa project: public-private partnerships for sustainable pulse technologies

The N2Africa project is led by Wageningen University in the Netherlands in partnership with IITA and ILRI and national partners in 11 SSA countries. The programme targets the delivery and dissemination of better 'N-fixing' inoculant technologies and improved legume production techniques, for example by using phosphorus-based fertilizer. The project works together with partners from the public and private sectors to strengthen the sustainable supply of these inputs. The symbiotic process between the bacteria and the pulse crops' roots systems can be improved by inoculating the plant with specific bacteria called rhizobium. Both phosphorus-based fertilizer as well as inoculation increase the biological nitrogen-fixing abilities (and thus grain yields) of legume and cereals. The optimization of crop and field management techniques (e.g. soil and water management, weeding) are also very important, while the project is increasingly emphasizing "gender-sensitive approaches for pre- and post-harvest labour-saving tools, [and] value addition at household to SME levels" (http://www.n2africa.org/content/n2africa-partnerships).

In Ethiopia, the N2Africa team works together with Bale Green, a large commercial farm producing chickpeas in rotation with wheat and teff (a local cereal crop) on a large and semi-mechanized scale. They work together with 90,000 smallholder farmer households, organized through various producer organizations, to supply improved chickpea seed, fertilizer and inoculant. Other partners in the partnership are companies producing rhizobium inoculants, public research and extension organizations and development partners. Farmers are trained in improved production practices and farming as a business, while ACOS (a large pulse exporter) and Guts Agro (a food processing company) are offering a guaranteed output market.[1] In the first phase of the N2Africa project, over 230,000 farmers evaluated and employed improved grain legume varieties, the inoculants and pulse-specific fertilizer. The second phase runs until 2019 and aims to reach over half a million smallholder farmers (Sopov et al., 2015).

1 See: http://www.n2africa.org/content/n2africa-partnerships

©Albert Gonzalez Farran

play a significant role in improved nutrition, education and basic household needs, both as ingredients for protein-rich soups and sauces accompanying the main staple food, as well as through the income women derive from selling surplus production. As investments to modernize pulses VCs can lead to women losing autonomy over production, processing and marketing of pulse crops, they can have potential negative effects on household income and nutrition. Programmes aiming to strengthen pulses VCs therefore need to be paired with close monitoring of its effects on the roles of women.[122]

To be able to increase yields of pulses, different approaches are needed for different types of farmers. Empowering smallholder farmers by strengthening organizations can help them reach economies of scale for marketing and processing purposes. Meanwhile, strengthening their knowledge of agricultural practices and technologies can help intensify production on existing acreage. Farmers with resources to invest and clear market output can choose to adopt improved pulse crop varieties that not only yield more, but also

122 See http://grainlegumes.cgiar.org/women-and-youth-in-pulse-value-chains-opportunities-for-inclusion-of-smallholders/

BOX 10

Lessons learned from the Tropical Legumes project in Ethiopia, Nigeria, Burkina Faso and Tanzania

The Tropical Legumes project is a partnership between international agricultural research centres (three CGIAR centres, including the International Crops Research Institute for the Semi-Arid Tropics, ICRISAT, in a leadership role) and national research institutes from Ethiopia, Nigeria, Burkina Faso and Tanzania, funded by the Bill & Melinda Gates Foundation. It aims to develop and deliver improved pulse varieties. The project looks at semi-arid regions in the world with a focus on dryland pulse crops such as chickpea and pigeon pea and dryland grain legumes such as groundnut. It invests in conserving, analysing and breeding pulse varieties and understanding on-farm management practices, processing and agribusiness opportunities to ultimately improve the performance of breeding programmes so that they can efficiently generate new varieties. These improved varieties are developed to meet future challenges that will emerge as climate change advances. In Tanzania, for example, a drought-tolerant, high-yielding sugar bean variety was introduced that has endured the severe drought of recent seasons much better than the local varieties.[1] According to Ehler (2016), "As new varieties quickly replace old varieties in the project areas, significant increases in productivity and production can be detected at national level. Other outcomes include workable and efficient models for production of different seed categories and empowerment of women to produce and market legume seed. The project estimates that it has catalysed the production and delivery of more than 200,000 metric tonnes of improved pulse seed across its target geographies. A key challenge will be sustaining the progress made after the project ends".

1 See: http://tropicallegumes.icrisat.org/bean-power-finger-on-the-pulse-of-a-drought-resilient-future/

mature faster and earlier and need less water than local varieties. In addition, smallholder farmers need better facilities and means for post-production purposes, such as better storage facilities and packaging material to tackle attacks by weevils or pests (see Box 11 — PICS project).

On-farm diversification

Rotational cropping or integrating pulses into crop rotation are well-known ways of reducing environmental impacts and externalities, and sustainably increasing the productivity and profitability of farming systems.[123] The integration of pulse crops into agricultural systems has the potential to increase farmers' overall income, improve soil fertility and soil composition, increase efficient water use (including by reducing evaporation) and increase yields of subsequently planted crops. In particular, chickpea and pigeon pea are known for their efficient use of water. Often, they grow on residual soil moisture, optimizing water resources (Gasparri et al., 2015).

As explained previously, pulses have the unique ability to fix atmospheric nitrogen in the ground. By working together with nitrogen-fixing bacteria in root nodules called rhizobia, they are able to make their own nitrogen fertilizer. This symbiotic process leads to the grains of pulse crops containing two or three times more protein nitrogen than cereal grains. When the plant dies, it leaves nitrogen in the soil that other plants can take up. As pulses contribute to the intensification of agriculture, by increasing total yields of produce grown on the same field, the practice of intercropping cereals and pulses is as old as agriculture itself (Titonell & Giller, 2013). In Ghana, field studies in forest and forest/savanna agroecological zones have shown that intercropping pigeon pea and maize can increase maize yields by 75–200 percent (Adjei-Nsiah, 2012). The cereal crops grown in the same field, either at the same time or after the pulse crop, take advantage of the nitrogen in the soil generated by pulses. This allows farmers to reduce the use of nitrogen fertilizer, one of the most energy-intensive and polluting agro-chemicals used in farming systems. Including pulses in crop rotations therefore decreases the fossil fuel use in nitrogen fertilizer manufacture (a highly energy-intensive chemical process usually involving ammonia), transport, distribution and the N_2O emission from soils. The gases released when nitrogen fertilizer is taken up by the soil, called atmospheric nitrous oxide, are major GHG gases (Koroma et al., 2016).

Pulses can often give a boost to soil microbes, decreasing the risk of plant diseases and use of pesticides. Therefore, integrating pulses and other grain legumes in rotation with cereals or other crops can break pest cycles common to monocultures and is a key element of conservation agriculture and CSA. For example, perennial tree legumes such as pigeon pea are often used in agroforestry approaches.

BOX 11

The Purdue Improved Crop Storage (PICS) project: decreasing post-harvest losses

The PICS project, led by Purdue University (Indiana, USA) and now in its third phase ($PICS_3$), was launched in 2007. The programme aims to help improve storage of cowpea, common bean and cereal crops for smallholder farmers by using PICS bags to significantly reduce post-harvest losses due to weevil infestation and other pests. A sustainable public-private delivery model was developed to make the bags accessible and affordable, even in remote areas. The project creates employment for local manufactures producing PICS bags, in addition to the traders and business entrepreneurs that distribute them throughout West and Central Africa, including in Ghana and Uganda.[1]

1 See: https://ag.purdue.edu/ipia/pics/Pages/home.aspx.

123 Crop rotation is the successive cultivation of different crops in a specified order on the same fields, to avoid soil depletion and break pest life cycles and pest habitats

The mango VC

Key environmental impacts and externalities of the mango VC

In contrast with the five VCs discussed above, mango, especially in its processed form, is an important export product for a number of SSA countries. While all the aforementioned cases showed that, in many instances, the first and foremost concern of farmers is maximizing income to meet household demands, which generates environmental concerns, the production of mangoes is often carried out according to strict environmental and social rules.[124] In Ghana, for example, a certain amount of mango export is destined for the European market and the process falls under Global Good Agricultural Practice (GAP) certification, which is a private standard set by major European retail chains. The Global GAP standard is primarily designed to reassure European consumers about how food is produced on the farm, by minimizing detrimental environmental impacts of farming operations, reducing the use of chemical inputs and ensuring a responsible approach to worker health and safety. Traceability is also a key component in Global GAP certification.[125] Therefore, negative environmental impacts and externalities, at least on big, commercial farms, tend to be lower.

Soil degradation

Mango is a tap-rooted crop, which means that competition for nutrients with other crops on the same plot of land is quite high and this leads to low productivity — even suppressing the growth of other crops — and a decline in soil fertility as result (Honja, 2014).

Water deficits

Mango trees are well adapted to a wide range of tropical and subtropical environments. Mangoes can also be cultivated under dryland conditions: in some areas, moisture loss through transpiration and evaporation is so low (due to humidity, temperature and rainfall conditions) that the soil remains moist enough throughout the year to prevent trees from wilting. Mangoes can then be grown under dryland conditions, provided the soil is able to retain moisture that can be available to the plants in drier periods.[126] Mango is thus considered to be drought-tolerant and can survive for many months without rain or irrigation. However, water deficits during the reproductive cycle can adversely affect fruit retention and early fruit growth. In the case of irrigation, the overuse of water generates negative environmental externalities (Carr, 2014).

Poor management, leading to pests and diseases

During the production stage, mangoes suffer from poor orchard management. Especially in smallholder farms, mango trees are left to grow so that pest and disease management, harvesting and other field operations are difficult to implement. The most common pests are the mango weevil and fruit flies, and the most common diseases are powdery mildew and anthracnose (Mugwe et al., 1998, cited by ICRAF, 2007). Except in big or commercial farms, mango trees in SSA are normally scattered around the garden, ranging from 2 to 100 trees per household. This scattered nature makes mango a commonly neglected crop in terms of management and sustainability; it becomes important only during the harvesting season. In addition, mono-cropping of mangoes leads to soil erosion and a loss of biodiversity.

Post-harvest losses

Post-harvest losses of mangoes are considerably high: fruit damage is a common problem due to poor pest and disease management, poor harvesting practices and because mango is a highly perishable fruit. A lot of fruit is also lost after harvest, especially during the peak seasons, due to the limited capacity to store and process fruit. In addition, mango processing yields about 40–50 percent of by-products (i.e. mango peels, mango seeds) that are often wasted.[127] Food waste is further worsened by the poor roads and transport infrastructure to markets (FiBL, 2009).

124 In general, there are three main categories of mango VC models: 1) the traditional VC with fresh mango for local markets; 2) the modern urban/processing VC with fresh mango for modern urban markets or processed mango (dried/juice) for export markets; 3) the export VC with fresh/fresh-cut mango (van Melle & Buschmann, 2013).

125 See: http://www.intracen.org/uploadedFiles/intracenorg/Content/About_ITC/Where_are_we_working/Multi-country_programmes/Pact_II/National%20mango%20study%20-%20Ghana.pdf

126 See: http://www.nda.agric.za/docs/Infopaks/mango.htm

127 See: http://www.feedipedia.org/node/516

Climate change risks

Contrary to most of the crop VCs previously discussed, the impact of climate change on mangoes is showing an average increase of 1.6 percent of climatic suitability globally, with only 26 percent of the global suitable areas for mango production being negatively impacted. However, "under the influence of climate shift, early and delayed flowering will be a characteristic feature of mango. An early flowering under the sub-tropics may result in low fruit set because of several abnormalities caused due to low night temperatures. Late flowering also reduces the fruit set because of pseudo-setting leading to clustering disorder. In addition, high temperatures during panicle development cause quick growth and reduce the number of days when hermaphrodite flowers are available for effective pollination, which may lead to a satisfactory crop" (FiBL, 2009).[128] In addition, strong winds may also cause loss of flowers and fruit.

Overall, "predicting the impact of climate change on horticultural crops accurately on a regional scale is a big problem. Enhancing the adaptation of tropical production systems to changing conditions is a great challenge and would require integrated efforts and an efficient and effective strategy to be able to deliver technologies that can mitigate the effect of climate change on diverse crops and production systems. It can be accomplished only by a modelling approach through well-validated robust crop simulation models. Availability and development of good simulation models for horticultural crops are lacking in general. The perennial nature of large-sized fruit trees and shrubs is problematic in the study of the direct effect of various factors of growth, development and yield in a controlled environment. Innovative methods are thus required to develop simulation models for important horticultural crops like mango, citrus, banana, apple, guava and coconut. Once these simulation models are available, prediction of vulnerability of existing areas under these horticultural crops to climate change scenarios can be examined and new target areas for possible shifting of species and varieties/cultivars can be identified" (Sthapit, B. et al. 2012, p. 39).[129]

Good practices for the mango VC

Sustainable intensification

The research on environmental impacts and externalities of mangoes in SSA is limited, as compared to the other VCs previously discussed, except for cassava. Overall, the mango subsector is not considered to generate negative environmental impacts and externalities, when compared to rice or livestock, for instance. Interestingly, mango cultivation offers the potential to overcome negative environmental impacts and externalities generated by other crops or by livestock. One of the reasons for this is that trees are used in agroforestry practices.

The expansion of new crops, such as mango, can thus lead to sustainable intensification of other crops. "In Senegal, Mali, Burkina Faso and Benin, the spread of integrated plant and pest management (IPPM)…has led to the adoption of many types of approaches to sustainable intensification, including pest management, development of seed beds, use of composting, marketing groups and expansion of new crops (mango, cowpea and sesame)" (Settle & Hama Garba, 2011, cited by Pretty et al., 2011, p. 12).

New varieties are important for sustainable intensification, as illustrated in Box 12, which explains how mangoes have become a viable way for Kenyan farmers to move away from charcoal and how they have mitigation benefits. Furthermore, it is important to circulate these new practices and find ways to up-scale them among farmers. Box 13 explains how the World Agroforestry Centre (ICRAF) has up-scaled strategies for mango production in Kenya. In addition, smallholder farmers should also be well connected to global supply chains; one way to do this is by training and organizing farmers in collectives or cooperatives (see Box 14 for an example of Coca-Cola's Project Nurture that groups and trains farmers). Finally, assistance is needed to develop the cold chain logistics system against post-harvest losses along the VC.[130]

128 See: http://peoplefoodandnature.org/wp-content/uploads/2015/08/TropicalFruitTreeSpecies.pdf
129 See: http://peoplefoodandnature.org/wp-content/uploads/2015/08/TropicalFruitTreeSpecies.pdf
130 Comment by participant at UNDP/GEF Expert Validation Workshop, Debre Zeyit, Ethiopia, 9–10 May 2017.

On-farm diversification

The way forward for strengthening environmental sustainability and resilience in the mango subsector is through diversification. This can happen in three ways: 1) intercropping; 2) planting mangoes in border areas of cultivated fields; 3) mangoes in agroforestry or silvi-pastoral systems (FiBL, 2011).

First, mango trees can be intercropped with grain legumes such as beans, pigeon pea, green gram and cowpea so they benefit from nitrogen fixed by the legumes. Intercropping, beneficial for soil fertility, can also be done with other tree crops such as papaya and guava. Once the grain is harvested, the legume stover is used as mulch for the mango trees, thereby contributing to conserving soil moisture and improving soil fertility. However, mango

BOX 12

New mango varieties in Kenya for sustainable and resilient development

Research shows that in some arid areas in Kenya, farming mangoes has become a substitute for making charcoal. The latter has become an increasingly challenging practice, because while the demand for timber is stripping the countryside of its mature trees, charcoal making requires younger trees. The Government is also prohibiting logging and is regulating these practices. Mangoes are becoming a reliable cash crop, since grain farming has become extremely difficult due to increasingly erratic weather. The Kenya Agricultural Research Institute has therefore introduced mango varieties that can grow in arid areas and can produce 10 times more fruit than conventional varieties. In addition, mango trees, as with other trees, function as sinks: they can absorb carbon dioxide from the atmosphere. However, mango farming alone cannot support families: they need to "mix fruit cultivation with growing staple crops".[1]

1 See: http://africacenter.colostate.edu/content/arid-kenya-swaps-charcoal-burning-mango-farming

BOX 13

Up-scaling strategies for mango promotion in Kenya

Mango is being cultivated in increasingly large amounts, especially in the coastal zones of Kenya. Local successes have been up-scaled through a number of strategies, including provision of planting materials, farmer training and marketing assistance. Firstly, farmers in semi-arid areas are poor and cannot afford to purchase the seedling of grafted mango. Therefore, promotion agencies have taught farmers how to produce their own seedlings in a sustainable way, thereby increasing their resilience. Some were even able to sell their seedlings to neighbouring farmers. Another strategy has been to provide seedlings to farmers at subsidized prices, often thanks to the efforts of production and marketing self-help groups, which have increased the farmers' bargaining power to gain better access to markets. Secondly, the training initially started with extension officers learning how to propagate and manage trees, who in turn could train other farmers. This approach has been used in projects such as the Integration of Tree Crops into Farming Systems Project. Finally, marketing groups with committees that are responsible for searching for markets have been formed. They advise farmers on prices and how to achieve quality and manage the fruits. For instance, the Kamurugu Agricultural Development Initiative programme in Mbeere has recently developed a resource centre to demonstrate and train farmer groups on mango drying using solar dryers (ICRAF, 2007).

creates a lot of shade and is therefore not ideal for intercropping with light-demanding crops such as sorghum and millet. Farmers have thus started to grow improved dwarf varieties that have less negative interaction with crops than traditional, local varieties that develop huge crowns. In semi-arid areas, animal manure is the most commonly used input for fertilizing mangoes and crops, while inorganic fertilizers are rarely used. The manure applied is shared among the trees and the crops in a synergistic manner, because the food crops with shallow rooting systems use nutrients that the mango tree roots cannot reach (ICRAF, 2007). Box 15 illustrates how the company Malawi Mangoes has made efforts to move towards a sustainable and resilient production model, for example, by using crop residue and waste as organic fertilizers.

Second, as border trees, mango can improve diversification on the farm: they can protect the soil and other crops against wind, and ultimately, enhance the farmer's income (FiBL, 2009). Furthermore, fruit trees have been proven to provide vital defences against desertification. "Their foliage protects the ground from the impact of heavy rains and wind. Sloping areas are well suited to fruit trees, reducing erosion and adding organic matter. Bunding across the slope enables water harvesting to reduce drought risk, and is made even more effective by the deep, perennial root system of the trees. Vegetables and other crops can be cultivated between tree rows to generate income for the initial years until the trees bear fruit. Moreover, high-value fruit crops provide cash income for farmers so that they can afford to take additional steps such as terracing, levelling and mulching, which preserve the land. Many fruits mature in the dry season, when other income sources are scarce. This increases year-round employment and market value" (UNCCD, 2009).

Third, aside from mango trees, agroforestry systems can include other crops such as bananas, papayas, cocoa

BOX 14

Coca-Cola aiming for shared value with small-scale mango producers in Kenya and Uganda

Multinationals such as Coca-Cola are promoting sustainable and resilient VCs. The company, together with the Bill & Melinda Gates Foundation, launched Project Nurture (2010–2014) "to double the average income of 50,000 small-scale mango and passion fruit farmers in Uganda and Kenya, and help them connect into the Coca-Cola supply chain".[1] The $11.5 million partnership programme trained these smallholder fruit farmers on improved agronomic practices, working with financial institutions to facilitate farmers' access to credit, and creating market linkages. The project secures increased fruit volumes while generating positive social, economic and environmental impacts in fruit-growing communities. It did this by grouping farmers into collectives, known as Producer Business Groups, which aimed to strengthen local farmer networks, increase the effectiveness of training programmes and improve the economics of market interactions.

Project Nurture is part of The Coca-Cola Company's vision for the year 2020 to triple its global juice business. "In Kenya and Uganda, Project Nurture takes an innovative approach to encouraging this growth by establishing a local source of ingredients for juices in the company's beverage portfolio. To date, the project has mobilized and trained nearly 40,000 smallholder farmers, including 17,000 women, and facilitated the sale of over 18,000 metric tonnes of fresh fruit" (SAI Platform).[2]

1 See: http://www.coca-colacompany.com/coca-cola-unbottled/coca-cola-and-african-farmers-produce-shared-value-through-mango
2 See: http://www.saiplatform.org/projects/70/98/Project-Nurture-Sustainable-Mango-Production-in-East-Africa

©Allan Rickman

BOX 15

Malawi Mangoes' sustainable agricultural production model

To avoid mono-cropping that leads to soil degradation and a loss of biodiversity, Malawi Mangoes adopted the Rainforest Alliance (RA) standard for its plantations: the RA's certification body starts from the initial land acquisition stage, which allows EIAs to take place. All company employees have then been briefed on the importance of sustainable and resilient agriculture. It has made Malawi Mangoes the only African company to have RA-certified banana and mango. More concretely, the measures that have been adopted are: use of crop residue and waste organic matter from processing plant to reduce long-term reliance on synthetic fertilizers, use of certified plant material and robust physical measures such as protection zones and protected nurseries, to minimize risk of disease on the farm, and frequent crop rotation of banana to encourage fertility replenishment and reduce long-term loading of pests and diseases.[1]

1 See: http://malawimangoes.com/certifications/

and so forth. In silvi-pastoral systems, animals can be allowed to graze on pasture on the mango plantation (FiBL, 2009).

As previously mentioned, availability and development of good simulation models amid the changing climate for horticultural crops is lacking.[131] Geographies of crops are likely to change under future conditions, and in all likelihood, a place where onions can currently be grown may be suitable for mango production in the future. Thus, not only are varieties required but also a cost-benefit analysis (CBA) of whether it is worthwhile to develop a new variety to withstand future climates or if crop swapping can be easily done.

Summary table

Table 2 gives an overview of the selection criteria, environmental impacts and externalities, and climate change risk or impact, as well as the good practices to tackle environmental impacts and externalities and climate change.

131 See: http://peoplefoodandnature.org/wp-content/uploads/2015/08/TropicalFruitTreeSpecies.pdf

TABLE 2 Overview of selection criteria, environmental impacts and externalities, climate change impact, good practices and country examples, per selected VC (compiled by the authors)

VC	SELECTION CRITERIA	NEGATIVE ENVIRONMENTAL IMPACTS/EXTERNALITIES	GOOD PRACTICES	COUNTRY EXAMPLES
Livestock (meat and dairy)	Contribution to GDP; pressure on natural resources; strong policy attention	Various farming systems with various environmental impacts/externalities; GHG emissions high in low-productivity systems; biodiversity loss; soil damage; water contamination; high climate change impact (GHG emissions), but more exact data needed.	Sustainable intensification through improved feeding, breeding (e.g. cross-breeding), management and resource use efficiency; use of traditional pastoral management strategies, indigenous governance and dialogue structures; diversification focusing on mixed crop-livestock systems.	Senegal, Côte d'Ivoire, Burkina Faso, Tanzania, Swaziland, Ethiopia, Kenya
Rice	Staple food; strong policy attention (for national rice self-sufficiency)	Various agroecological zones for rice; GHG emissions; water pollution; air pollution; post-harvest waste; high climate change impact, especially on rain-fed systems, causing increase of diseases and weed infestation, all of which decrease yields.	Sustainable intensification with better seeds and rice varieties, improved water management (e.g. SRI), zero-tillage systems, use of rice waste for animal feeding and bedding; on-farm diversification (e.g. rice-wheat intercropping).	Senegal, Kenya
Cassava	Food security crop; highly resilient to drought; increased policy attention	Although a low-input crop, cassava has pre-production losses: soil degradation and loss of soil fertility; loss of biodiversity due to deforestation; processing methods create GHG emissions; post-harvest losses (e.g. waste); low climate change impact, because cassava is resilient against climate change.	Sustainable intensification through conservation agriculture and agroforestry techniques, the use of clean planting materials and better storage; on-farm diversification through intercropping cassava with maize, legumes and trees.	Nigeria
Maize	Food security crop (staple food); strong policy attention	Fertilizer and land clearing leading to GHG emissions and loss of biodiversity; mono-cropping leading to soil erosion and nutrient shortages; pests and diseases causing losses; high climate change impact, since maize only grows in rain-fed systems.	Sustainable intensification through better soil and water conservation methods, integrated nutrient management, better varieties and management techniques, and agroecology and agroforestry practices; diversification through intercropping and rotation of pulses and maize.	Ethiopia
Pulses	Drought	Fertilizer use on poor soils; land degradation, water stress, deforestation and biodiversity loss due to mono-cropping (e.g. soybean); post-harvest losses and pests and diseases; Rather low climate change impact, but differences among various pulses.	Sustainable intensification through conservation agriculture practices	Ethiopia, Nigeria, Burkina Faso, Tanzania, Ghana, Uganda
Mango	Nutritious; strong export potential, leading to mango production being under strict environmental rules; grows well in drylands	Water-use impacts; pests and diseases; post-harvest losses; mango trees can be sensitive to climate variability, especially with impact on mango flowering and fructification.	Mango trees used in agroforestry practice, leading to sustainable intensification; introduction of new varieties; importance of linking farmers with increased produce to (global) markets; diversification: 1) intercropping with grain legumes and other tree crops (e.g. mango); 2) mango trees as border trees; 3) agroforestry techniques.	Kenya, Uganda, Malawi

CHAPTER 4

Incentives for the private and public sector to make food VCs environmentally sustainable and resilient

KEY MESSAGES

The economic logic of shifting to sustainable practices along the VC is that there will be a higher return (in the long term), but this does not sufficiently take into account the balance between better prices of sustainably produced goods and, in many cases, their higher production cost. VC actors therefore often stick to unsustainable practices because the business case for sustainable practices still needs to be made clear, internalizing the costs of negative impacts and externalities. Yet, even if farmers and other types of micro-, small and medium enterprises (MSMEs) understand the benefits, they face many barriers, most notably the lack of basic access to organic fertilizer or seeds, the lack of organization and bargaining power to negotiate better prices, limited market access and the lack of government protection. The power in the VC is also concentrated within a small group of supermarkets and multinationals. Furthermore, the system in which VC actors operate provides 'disincentives' that are not conducive to sustainable practices, for instance, due to trade dynamics or market demand encouraging mono-cropping.

Therefore, positive incentives for the transition to sustainable food systems are needed, and in some cases, control and enforcement mechanisms to ensure that these incentives result in change. Incentives are grouped into four categories: 1) intrinsic motivation to protect livelihoods and promote public goods; 2) policy and legal incentives; 3) financial incentives; and 4) market demand and market arrangements. The various VC actors can create incentives or benefit from them, depending on their role within the VC.

The agricultural sector is exposed to various risks, including weather variability, pests and diseases and price volatility, which makes investment less appealing. The public and the private sector both play roles in de-risking, for instance, by means of loan guarantees, VC financing and insurance schemes.

The public sector has a key role to play in creating a proper policy and regulatory environment, providing financial incentives, and generating and disseminating market information, through targeted actions to incentivize cooperation between public and private actors.

LOSSES IN ECOSYSTEM SERVICES HAVE direct socio-economic repercussions that are systematically underestimated. Making the value of ecosystem services more visible to society provides evidence that can pave the way for more targeted and cost-effective solutions for improving the sustainability of a given food system, as shown by the examples of TEEB and TSA in chapter 2. However, the transition towards more sustainable and resilient VCs requires a concerted effort from all actors, public and private, involved in the VC. In this chapter, we examine incentives for actors along specific VCs to adopt more sustainable and resilient practices, focusing on the costs and benefits that will determine the potential net benefits (the 'carrots' in the 'carrot and stick' approach) of moving to more sustainable and resilient practices. At the same time, incentives do not always alter behaviour. New regulations on sustainable and resilient production may not be followed, for example. In these cases, control and legal enforcement (the 'stick') is required (Byiers & Bessems, 2015). The question is: which incentives have and have not worked, and why is that? For instance, can consumer demand for more sustainable and resilient practices influence the behaviour of companies?

Economic logic and CBAs consider a higher rate of financial return as the key incentive to changing behaviour. In this regard, models that calculate the profitability of environmentally sustainable and resilient investments are increasingly emerging. For example, the WEF has identified the 'triple supply chain advantage' within production, which refers to the ability of big

companies or multinationals to gain profit, while also protecting the environment and benefiting society.[132] This is also in line with the concepts of 'shared value' and 'social enterprises'.

However, the economic logic of shifting from unsustainable to sustainable practices that shows that there will be a higher return (in the long term), does not sufficiently take into account the balance between better prices of sustainably produced goods, and in many cases, their higher production costs. Elements such as societal cohesion and the protection of public goods are also crucial incentives for key actors such as local authorities and farming communities. Therefore, CBAs need to be enhanced with better information on incentives, to lead the much-needed transition discussed throughout this study. Generally, investing in sustainable and resilient agriculture is much more challenging for smallholder farmers and other types of MSMEs. Even if they understand that sustainable and resilient practices will lead to a higher return,[133] they face many obstacles and risks: they might have lower margins to commit to sustained investments; they lack basic access to organic fertilizer or seeds or have less bargaining power to negotiate better prices; they are not protected by government regulation (e.g. through certification), which impedes uptake and further up-scaling; or simply, the local and national food markets are not sufficiently differentiated to guarantee premium prices (and adequate profits) for those choosing sustainability. In addition, many VC activities in SSA take place in the informal economy, which makes it very challenging to reach the numerous vulnerable VC actors, such as farmers and processors, with the introduction of sustainable practices.

This chapter discusses the different types of incentives that actors along a specific VC face in deciding whether to adopt more environmentally sustainable and resilient practices. Using the examples from the VCs discussed in previous chapters, it highlights how certain incentives have — or have not — contributed to the adoption of more sustainable and resilient practices.

Categorizing incentives for respective VC actors

The transition to more sustainable and resilient food VCs requires a combination of efforts from a wide range of stakeholders involved in the various activities that bring food from farm to table. To achieve sustainable, resilient and inclusive food systems, it is important to understand the role that various VC actors play, and which incentives can and should be altered to facilitate the take-up of sustainable and resilient agricultural practices.[134] Since constraints to making VCs more sustainable and resilient are multifaceted, the interventions required to alter incentives towards effective change are complex. They can take various forms, for example, financial incentives from banks or policy incentives from the government, and often need some sort of coordination to resolve collective action problems. In this chapter, we answer the following questions: what are the incentives for seed suppliers, farmers, processors, retailers, transporters, banks, national authorities, development partners and others, to take up more sustainable and resilient practices? What mechanisms have been created to ensure sustainably produced food in SSA?

There are four categories of incentives, as presented in the following Box 16.[135]

132 Big multinationals are increasingly incorporating environmental sustainability aspects into their supply chain development. WEF developed the 'triple supply chain advantage' that enables companies to achieve profitability, while benefitting society as well as the environment. More concretely, WEF selected 31 proven practices to achieve the triple supply chain advantage (e.g. reduce weight and size of packaging material at the packaging stage or use alternative fuels for the distribution vehicles). Implementing these practices leads to environmental benefits; more concretely, a carbon gas reduction of 13 to 22 percent on the overall footprint of the company. In the long term, the triple advantage will lead to revenue growth, cost reduction, a better reputation and risk mitigation. See: https://www.weforum.org/reports/beyond-supply-chains-empowering-responsible-value-chains

133 Chapter 3 presented many sustainable and resilient practices that led to increased yields and income. For example, Box 3 explained how planting Leucaena trees on farms — trees that increase carbon sequestration in the soil and whose leaves can be used as fodder for livestock — have led to higher household incomes. There was also discussion on resource use efficiency with increased productivity and income as a result.

134 The key focus of this chapter is on the production phase of the VC, because at this stage there is most to gain in terms of sustainability, as discussed in detail in chapter 3.

135 The categorization of incentives is partly based on the research conducted by the International Institute for Environment and Development (IIED), which has set up a research initiative called 'Shaping Sustainable Markets' to explore how formal and informal rules are used to govern markets, termed market governance mechanisms (MGMs). IIED created a four-part typology of MGMs: economic, regulatory (hard), cooperation (soft) and information MGMs (see: http://shapingsustainablemarkets.iied.org/; see Annexes, Figure 11, for an illustration of the MGMs). Secondly, the categorization draws from the work conducted by FAO/INRA (2016) on 'innovative markets for sustainable agriculture' that looks at which institutional innovations lead to the creation of local markets for sustainably farmed agricultural products (FAO/INRA, 2016).

BOX 16

Four categories of incentives

CATEGORY 1

Intrinsic motivation to protect livelihoods and promote public goods: the building of resilience or the choice to take up environmentally sustainable and resilient practices (or not) are driven by a short- or long-term 'intrinsic motivation':

- **In the short term**, this motivation can be grounded in spiritual and/or cultural traditions (e.g. perception of risk at different scales and over different time frames), local business systems, local land management, or it can be based on the 'value added', i.e. the potential future profits that a sustainable agricultural investment can bring compared to current practices, or on an understanding that mechanization or new sustainable and resilient techniques will decrease the required labour (e.g. mechanical harvesting). In other words, the choice to alter behaviour is self-motivated.

- **In the long term**, the public sector (i.e. political elites) is driven by the need to ensure the long-term viability of livelihoods. Public actors seek 'political survival', based on social cohesion. If the productive base of natural resources is neglected due to mismanagement of natural resources, the public sector loses legitimization. The public sector depends on support (rural and popular) for political choices or policies, and therefore seeks recognition from the people.

CATEGORY 2

Policy and legal incentives: public sector support is needed to encourage the adoption of sustainable and resilient practices by private sector actors and to ensure that such practices are scaled up where appropriate. This necessitates the creation of an enabling regulatory policy and legal environment that legitimizes sustainable and resilient practices along the VC. According to FAO/INRA (2016), legitimization of new practices is the most important role for public actors at all levels, whether global, national or local. More specifically, legitimization happens through:

- **Environmental control and enforcement:** public sector activities to inspect the private sector for compliance with rules and regulations with regards to environmental sustainability and resilience. These measures are legally binding and set by governments to promote sustainable and resilient agro-food VCs. They promote behavioural change through the sanction of legal consequences in the case of non-compliance.

- **Norms, standards and principles:** these are another set of measures to legitimize, based on compliance procedures (e.g. the 'polluter pays' principle). They can also be voluntary guidelines or non-legal principles, such as the Principles for Responsible Investment in Agriculture and Food Systems (RAI) approved by the Committee on World Food Security (CFS) in 2014 (Committee of the FAO).

CATEGORY 3

Financial incentives: all measures that reduce input costs and other service costs (e.g. transport), such as subsidies and tariffs for actors to adopt sustainable and resilient practices, or that increase the costs of not adopting sustainable and resilient practices. These financial incentives can be positive mechanisms to reduce the risks of sustainable agricultural investments (e.g. payments for ecosystems services [PES]) or negative (e.g. carbon taxes). These include:

- **Taxes on unsustainable practices**, designed to encourage consumers and producers to adopt more sustainable and resilient practices by making unsustainable practices costlier;

CATEGORY 3

- **Loans, grants and subsidies** or payments to businesses and other organizations to make the adoption of sustainable and resilient practices, with regard to production and/or consumption of goods and services, more affordable. Subsidies can be direct (e.g. grants, credits or VC finance) or indirect (e.g. tax exemption or provision of goods below market price);

- **Carbon trading/cap and trade** to control pollution by providing economic (price) incentives to reduce it;

- **Conditional environmental financing** that includes payments for environmental services and potential offsets (e.g. PES);

- **Responsible investment funds** that are mechanisms for channelling private financial flows to achieve social and/or environmental returns.

CATEGORY 4

Market demand and market arrangements: ensuring the minimum levels of produce quality and quantity required to meet the market demand. This category is set by the rules of the market and based on market information, buyers' expectations and preferences, as well as market arrangements (e.g. institutions that create or enhance demand). It includes:

- **Rules of the market**: farmers and other private actors can increase their bargaining power in new or existing markets for sustainably produced food, by establishing platforms and providing certification for sustainability. These can take the form of:

  - brokering committees that bring together farmers, consumers, intermediaries and other VC actors, such as semi-formal price-setting committees. They can also use participatory guarantee systems (PGS) in national standards, as well as voluntary agreements and partnerships, with the intention of improving environmental sustainability, i.e. 'trust-building VC platforms' that can adapt national and international laws and frameworks to local realities (in order for incentives to work effectively at the local level), such as public-private platforms;

  - multi-actor innovation platforms or community-supported agriculture.

These types of dialogue platforms can lead to incentives being enforced, i.e. they can apply pressure to create standards and voluntary agreements or increase awareness among farmers. In addition, market rules, set by public actors, also include market channels created by the public sector that prioritize sustainable products in public procurement schemes, i.e. the setting and implementation of procurement policy that promotes positive social and environmental outcomes, or minimizes negative impacts and externalities. Procurement policy can alter the role of price signals in the marketplace by leading to purchasing decisions based on criteria other than monetary prices. Finally, property rights are crucial: private VC actors are incentivized to invest in sustainable and resilient practices, if they can claim that they are 'owner' of the natural resources in which they invest, i.e. the importance of decentralized natural resource management.

- **Market information:** this includes typical market information on the demand of food products and information to alter the behaviour of market participants (persuade, rather than compel), particularly consumers and investors, but also producers, through certification and private voluntary standards — this can be information on climate information services or financial services (e.g. credit, savings and insurances, market information systems that provide information on pricing, supply and demand of different commodities or consumer awareness schemes).

All VC actors, public or private, can create or receive incentives or disincentives to take up sustainable and resilient methods. "Public agencies and policies can enable positive action across the private sector through regulations and standards, knowledge management and extension, risk-management institutions, finance mechanisms (e.g. innovative financing, VC financing) and stable resource rights for smallholder farmers, among others" (IFAD, 2016). This is important because changing from unsustainable to sustainable practices is challenging — various VC actors tend to stick to current, unsustainable practices. There are two reasons for this: firstly, sustainable production does not always lead to increased profits or if it does, the increased profits are not guaranteed when making sustainable investments (at least not in the short term). Secondly, the system in which VC actors operate provides disincentives that are not conducive to sustainable practices, for instance, due to trade dynamics or market demand that lead to mono-cropping. Moreover, even when private actors know that sustainable and resilient practices will lead to a higher return, they face many obstacles and risks, including a lack of basic access to input, lack of bargaining power, the structure within the food chain that gives supermarket managers and multinationals a great deal of power, well-established cultural traditions, and so forth.

As illustrated by the cases in chapter 3, VCs are complex networks of actors with different interests, needs and limitations. To simplify these networks and discuss the respective incentives for each VC actor, we 'map the VC', making a distinction between different actors based on their key roles (i.e. providing input, output and demand). This differentiation is useful to shed light on some of the key incentives for each VC actor group, given that these differ depending on the roles they play. The following sections discuss key incentives, as well as limitations, per category of VC actors, illustrated by concrete case studies and examples. A summary table is presented at the end of this chapter.

Incentives for the private sector actors along the VC

Incentives for input providers

Seed, fertilizer and technology suppliers

Although political commitment to improving food security in SSA exists on paper, as discussed in chapter 1, farmers in SSA are systematically plagued by a lack of access to inputs, which hinders them from altering practices and moving to more sustainable or resilient methods. They face a lack of access to resilient, hybrid seeds,[136] organic fertilizer and new technologies. These are often too expensive to purchase, or not available due to insufficient infrastructure to support a formal seed system and limited smallholder farmer access to input and output markets. Yet, even if there is access to such inputs, it is important that these do not generate negative environmental impacts and externalities: large quantities of chemical fertilizers and pesticides, genetically modified or outdated hybrids and older open-pollinated seeds and low-quality technologies are detrimental to the environment in the long term. However, the profitability of adopting improved inputs (environmentally friendly or otherwise) will depend on the costs of these inputs (fertilizers, pesticides, planting material and, most importantly, labour) relative to prevailing market prices for the food products and the prices of other commodities that might be competing with household labour resources.

Evidently, input providers such as seed growers and fertilizer providers play an important role: they can provide quality seeds or organic fertilizer while training and supporting farmers in using these inputs. They can also support the efficient operations of local input markets and address the counterfeit input market. Lastly, they can collaborate with local governments, donors, scientists and communities to streamline logistics and input services, to ensure that there is physical and

136 Hybrid seeds are produced by cross-pollinated plants. They are predominant in agriculture and one of the main contributors to the dramatic rise in agricultural output during the last half of the 20th century. Open pollinated seeds, on the contrary, are seeds that are produced from natural, open pollination by wind, birds or insects, resulting in plants that are naturally varied. They are usually of lower quality than hybrid seeds. See: http://www.i-sis.org.uk/hybridSeed.php

©Harandane Dicko/UN Photo

institutional space for the emergence, take-up and growth of these new forms of input.

But what are the incentives for input providers to change course towards more sustainability? Input providers can be driven by the very idea that not investing in hybrid seeds or organic fertilizer may create risks for the environment and consequently, for the livelihood of communities (Category 1). Furthermore, investing in sustainable and resilient input products can open the door to new business opportunities (market demand) (Category 4). At the same time, input suppliers are operating within a regulatory and policy environment that sets the formal rules for engagement, such as the corporate social responsibility (CSR) framework (Category 2).

Farmers who purchase improved varieties such as new hybrid seeds, are often motivated by the expectation of higher yields and income, as illustrated by the case studies in SSA in Box 17.

Moreover, the provision of new technology by public or private actors that supports sustainable and resilient farming is an important incentive for farmers. In the case of drylands, the challenges of harsher droughts and more erratic rainfall due to climate change, demand new and appropriate technologies to strengthen resilience. These include low-cost water-management techniques or other types of irrigation schemes. Box 18 explains the success of the emergency rice initiative in Ghana, due to the farmers' conviction that change will be to their advantage, while involving minimal risk. It also shows that farmer-to-farmer diffusion of knowledge and technology is very important (Category 1 and 4).

Despite these success stories, Tittonell and Giller (2013) warn of the risk that the whole sustainable intensification movement in African agriculture, by promoting the use of mineral fertilizers, hybrid seeds, new crops, irrigation methods and so forth, could actually have the opposite effect: all these techniques "rely on substantial investment in inputs" that have been "seriously hampered by poorly developed input and output markets, but often also by the poor performance of technologies in the African context or their inadequacy to fit within smallholder systems." Therefore, the authors argue that "integrated approaches to soil fertility, pest or crop management that build on local knowledge" are the way forward. In other words: "Africa needs a 'uniquely African' strategy for the sustainable intensification of its agriculture, capitalizing on ecological processes and ensuring efficient use of scarce external inputs" (Tittonell & Giller, 2013, p. 77).

BOX 17

Hybrid seeds for increased maize production: evidence from countries in SSA

Maize is particularly well suited to production in diverse weather conditions, but maize yields in SSA are low: Africa accounts for 15 percent of the total maize area cultivated globally but contributes less than five percent to the global maize harvest (Grassini et al., 2013, cited by Gaffney et al., 2016).

Recent research by Gaffney et al. (2016) explains that hybrid seeds, along with technological advancements, can result in more efficient production of quality hybrid crops in Africa. Hybrid seeds used for crops such as maize are important for achieving food security, as well as agricultural sustainability goals in SSA.[1] In Nigeria, where maize hybrids have been introduced to the market over the past few decades, the yield advantage of the first hybrids introduced was 29 percent in white hybrid maize and 15 percent in yellow hybrid maize (Badu-Apraku et al. 2001, cited by Gaffney et al., 2016). Furthermore, in Kenya, hybrid maize growers also had higher household incomes and a higher value of total assets, and the level of poverty was less severe compared to farmers who grew open-pollinated varieties (OPVs) (Mathenge et al. 2014, cited by Gaffney et al., 2016). In Zimbabwe, small-scale farmers have planted hybrids since the 1960s but reverted to using OPVs and older hybrids during periods of instability in the country. This resulted in a drop in productivity starting in the late 1990s. The conclusion was that farmers did not need subsidies for adopting hybrid seeds, but required political and economic stability that encouraged research, production capacity and wide availability of hybrid seeds (Leiman and Behar, 2011, cited by Gaffney et al., 2016).

The success of hybrid maize in SSA has been driven more by government support and policy than by technology. However, lack of political commitment to support the formal seed system remains a barrier. More precisely, the problem is the continuing inconsistencies among country seed rules and regulations that undermine economies of scale and unencumbered movement of seed products over a wide geography. In fact, complex regulatory frameworks can slow down the commercial release of new hybrid seeds. In Kenya, for example, the Kenya Seed Company, a parastatal organization, maintained about 86 percent of maize seed sales as late as 2004 and continued to offer older hybrid seeds (Ariga and Jayne, 2010, cited by Gaffney et al., 2016). In Ghana, improved maize varieties and hybrids have been released but, without a formal seed system in place, there is limited supply and poor distribution (Sugri et al., 2013, cited by Gaffney et al., 2016). Farmers have recycled these varieties over many generations and as a result, contamination, degeneration and segregation have limited the variety's long-term performance (Gaffney et al., 2016).

In recent years, a number of successful initiatives have emerged to promote hybrid seeds: an effort developed by Alliance for a Green Revolution in Africa (AGRA) called Programme for Africa's Seed Systems (PASS) has worked on strengthening the VC, including investing in plant breeders and training agro-dealers who provide seed. Successes of this programme include the development of 464 improved varieties of 15 important crops and an increased production of seeds (AGRA, 2014, cited by Gaffney et al., 2016). Additionally, many national programmes, small seed companies and research institutes, such as CGIAR, are trying to improve the seed systems in Africa.

1 Evidence from the United States shows that the adoption of maize hybrids led to a steep rise in maize yield to average 10 MT/ha (Holland, 2009 and USDA NASS, 2015, cited by Gaffney et al., 2016). Moreover, maize hybrids support more efficient nutrient yield conversion for nitrogen, phosphorous and potassium (Ciampitti and Vyn, 2014, cited by Gaffney et al., 2016), and have contributed to the least amount of nutrient loss and greenhouse gas emissions relative to other major grain-growing regions of the world (West et al., 2014, cited by Gaffney et al., 2016).

©Marco Dormino/UN Photo

BOX 18

Rice farmers' increased access to technology for increased productivity: evidence from Ghana

The global rice crisis in 2008 led to the launch of the two-year Emergency Rice Initiative Project (ERIP) in Ghana to increase rice productivity, thanks to the collaborative efforts of the United States Agency for International Development (USAID), the International Fertilizer Development Center (IFDC), AfricaRice and the Ministry of Foreign Affairs, among others. ERIP has played a catalytic role in bringing improved varieties and production technologies to rice farmers (e.g. post-harvest technologies), thereby helping them to increase yield (farmers' income doubled) as well as improve integrated soil fertility management. Moreover, ERIP enabled farmers to diversify crops, for example, some maize farmers started to grow rice. In addition, the project made remarkable progress in strengthening partnerships among farmers' organizations, the private sector and NGOs. The speed with which farmers adopted new varieties and technologies is proof of their willingness to change when they know it is to their advantage (i.e. higher yields, better taste, early maturity, ease of storage) and when the risk is not too high.

ERIP used various methods to disseminate knowledge and technologies, including annual planting sessions, participatory on-farm demonstrations on fertilizer management, Training of Trainers courses and cooperation with extension staff and development agencies. However, some groups of farmers still had a lack of access to seeds, new technologies and information, especially in remote areas. Therefore, ERIP tried to reach them through community outreach programmes such as rural radios and audiovisual broadcasts.

An important spillover effect of ERIP has been the willingness and interest to share information on new technologies among beneficiary farmers and those who were not directly involved in the project. Farmer-to-farmer technology diffusion builds upon farmers' traditional transfer methods and is based on the observation that farmers prefer fellow farmers to be their primary source of information, even if they have alternative sources. Consequently, indigenous farmer-transfer mechanisms for disseminating new technologies may have a bigger impact than top-down dissemination efforts by public or private actors.

Policy incentives were also provided: the promotion of improved rice production technologies gained fresh momentum, following a recent policy on rice import restrictions, which equipped extension officers with new knowledge on crop production practices. To further facilitate effective adoption, appropriate linkages should be made between producers, extension agents, NGOs, processors and credit providers (Buah et al., 2011).

Access to finance from banks, investors or other types of financial services: risks, loan guarantees, VC financing and insurance schemes

Agriculture is exposed to various forms of risk, ranging from weather variability, pests and diseases to price volatility in output and input markets. This makes the agricultural sector unattractive for investors and financial institutions. In this regard, one suggestion is to create appeal beyond financial return, such as including social or environmental impact as an incentive for investment (Category 2). Moreover, poor agricultural households that rely on rainfall and face imperfect market conditions are particularly vulnerable. To them, the risks become even greater as they lack the means to manage risks effectively, for example, by investing in irrigation, buying insurance or using credit to improve income and consumption. And yet, trends show that loan guarantees, VC financing mechanisms, insurance and impact investments are increasingly opening doors for smallholder farmers and other types of MSMEs to invest in sustainable and resilient agriculture and improve their livelihoods.

Financial input providers are driven by various incentives: for international public supporters, these include the larger goal of promoting public goods through the protection of livelihoods, in the short term or the long term (Category 1), while for the private sector they relate to new business opportunities, based on market demand, governmental regulations, policies or innovative financing and the set-up of various platforms that increase trust and guarantee return. (Category 3 and 4).

First, loans are an important tool to promote sustainable and resilient food VCs. They can also facilitate scaling up, implementation and market growth, enabling a sector to become financially self-sustainable in the long run. Environmental finance loans include multimillion-dollar World Bank investments in national energy projects, as well as microfinance programmes that offer small loans to individual farmers (UNDP, 2013). As for the former, evidence shows that foreign investors, incentivized by principles of social responsibility and new business opportunities (Category 1, 3 and 4), are increasingly investing in African agriculture. For instance, the International Finance Corporation (IFC) — the private sector development arm of the World Bank Group — works towards inclusive supply chains, with a special focus on smallholder farmers, through the Global Agriculture and Food Security Program (GAFSP). The GAFSP was launched in 2010, bringing in donors such as Japan and the Netherlands to invest in agriculture, with the aim of reducing poverty and improving food and nutrition security. The GAFSP focuses specifically on linking smallholder farmers to markets by improving their access to finance, technology, expertise and inputs. The GAFSP creates incentives for private sector companies or commercial banks to invest in agriculture, through blending and providing a low interest rate — every investment made must meet certain environmental and social standards.[137] However, investments are not always successful: GAFSP invested in Malawi Mangoes (total of $10 million), but problems with the banana plantation and delays in delivery of mangoes have raised concerns over its future success.

In the case of small loans, promising initiatives are emerging in SSA, as illustrated further below. Loans are most effective when the market serves as the key entry point, and hence future contracts can be guaranteed. However, this is not always the case for the most vulnerable in the VC: access to credit for farmers remains very difficult because local financial institutions are reluctant or unable to extend loans for agricultural production. Support from development partners or other financial guarantees can mitigate this problem, but the uncertainty and risk of agriculture makes it an unattractive sector for lenders.[138]

Second, evidence shows that VC financing is an important tool for de-risking. This happens when one or more financial institutions link into the VC, offering financial services that build on the relationships in the chain: traders, processors, input suppliers and exporters provide short-term loans to growers, with the credit linked to the subsequent sale of the produce. This type of VC loan then trickles down to become a small or microloan for smallholder farmers (UNDP, 2013), as illustrated by the example of the soybean VC in Ethiopia in Box 19. Other examples of VC financing

137 See: http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/ifc+sustainability/our+approach/risk+management/performance+standards/environmental+and+social+performance+standards+and+guidance+notes#2012

138 See the work by Triodos Bank in Tanzania: https://www.triodos.com/en/about-triodos-bank/what-we-do/our-expertise-overview/

include private equity, that is, when a bank or another investor buys shares in a company to give it capital for use in investment, or leasing, when a "leasing company provides the farmer (or other borrower) with equipment for a few years on a contract basis, and the farmer pays off the lease in instalments. At the end of a lease period, the leasing company either repossesses the equipment or offers to sell it to the farmer. Leasing is less risky than a loan because the equipment remains the property of the owner, who can withdraw it easily if the farmer defaults on payments. With a loan, by contrast, it may be difficult to take possession of the collateral offered to guarantee a loan because of legal constraints and weak judicial systems" (KIT & IIRR 2010).

However, VC finance is only effective when there is strong demand and market access. There are other drawbacks to effective loan and VC financing programmes, including inadequate financial infrastructure, corruption and inattention to the risks inherent in a weather-dependent industry. Also, microfinance usually favours male farmers to the detriment of women, despite them outnumbering men in agriculture (Worldwatch, State of the World, 2011, cited by UNDP, 2013).

Third, insurance schemes, increasingly introduced in SSA, are a key way to mitigate risk for vulnerable households. When farmers have the security that they will receive payments, in case of losses caused by

BOX 19

Financing the soybean VC in Jimma zone, Ethiopia

The farmers in Jimma zone, in the region of Oromia in south-western Ethiopia, face many challenges: the soil is poor and many farmers cultivate maize, the staple food, year after year. They have no money to buy inputs such as seed and fertilizer, and they lack market access for their surplus, as well as the skills to sell it. Borrowing money is costly, with interest rates up to 120 percent annually. Farmers who own a few cattle do not benefit from a good milk supply because the cattle are of low quality. However, the cultivation of soybeans is promising: the pulse is well adapted to the local soils and improves soil fertility by fixing nitrogen. The bean can also be used for soy milk production and there is a market in Jimma for soy milk.

Therefore, an Ethiopian NGO, Facilitator for Change Ethiopia (FCE), and Jimma Agricultural Research Centre have jointly been promoting soybean in Jimma zone since 2006, putting effort into popularizing the crop. FCE played a key role in building and strengthening the VC and its main actors, including farmers, farmers' marketing organizations, informal self-help groups of poor women, retailers and consumers, providing training, seed capital, material support and technical and capacity-building support, always with support and involvement from the Ethiopian Government.

Harbu Microfinance Institution provided a number of financial services to the soybean VC: agricultural loans for farmers, enabling them to buy seeds and fertilizer, working capital loans for farmers' marketing organizations and loans and leases for women's associations. Most of the risks in financing the soybean VC were mitigated through the triangular cooperation among FCE development support, Harbu Microfinance Institution's financial services and the reliable business connections between the farmers and the women's associations, mostly involved in processing. Without this institutional architecture and these interlinkages, the risks and the costs would be too high and the soybean VC would not function adequately.

This project has generated a multitude of benefits: farmers in Jimma have created off-farm diversification (chapter 2) since they are no longer dependent on a single crop (maize), resulting in reduced poverty, strengthened rural-urban linkages, improved nutrition and empowered farmers and women (KIT & IIRR, 2010, pp. 164–173).

extreme weather, for example, they are likely to invest in more sustainable and resilient methods. In many cases, insurances schemes are set up through a collaboration of various partners, including private insurance companies and government institutions. Box 20 explains the index-based livestock insurance (IBLI) scheme in Kenya.

However, the insurance market still faces limitations, as shown by the case of the African Risk Capacity (ARC). The ARC is an AU initiative to fund disaster relief at the state level. However, when Malawi was affected by a severe and long-term drought, the weather models were showing inaccuracies and so the premiums are yet to be paid out.[139] Therefore, trust-building and meeting the payback requirement are essential to a success outcome.

Fourth, the impact investments industry has steadily grown in recent years. Impact investments refer to the allocation of capital to enterprises, funds and/or organizations with the expectation of a financial return and a positive environmental and/or social impact. More concretely, they have the potential to complement public spending and official development assistance (ODA), by crowding in private sector capital and skills to reduce African economies' vulnerability to external shocks, providing a market-based solution to address socio-economic needs. The agricultural sector is one of the main target areas for impact investment in SSA, in many cases, with a particular focus on SMEs (UNDP, 2015).

Finally, the credit market in SSA does not follow the same logic as in industrialized countries: simply giving out loans in the form of cash to be reimbursed, accompanied by a (low) interest rate, is not always common practice. The reality in SSA is that farmers and smallholders, who lack access to loans or other types of credit, end up using their own labour in return for access to inputs. For example, a farmer could pay back a loan through a combination of reimbursing a certain percentage of the loan and offering hours of labour or part of their land in return. Any system of input should take into account the specificities of how received inputs are reimbursed. Therefore, to encourage farmers to buy insurance, an exchange of physical labour for insurance has emerged as an incentive. For example, insurance company Swiss Re, in partnership with Oxfam America, launched the Horn of Africa Risk Transfer for Adaptation project in

BOX 20

How to insure livestock losses due to weather events?

Due to extreme weather events, systems to insure livestock losses, as compared to crop or yield losses, have been developed more recently. In 2008, the ILRI (a CGIAR centre) launched the IBLI mechanism in two pilot areas in Kenya and Ethiopia. They used remote sensing satellite data (available since 2000) to measure land available, indicators related to vegetation conditions and so forth. Using satellite imagery, IBLI provides insured pastoralists with funds to purchase forage and water for their livestock in times of severe drought. In addition, farmers are not insured individually; 'insurance units' have been created (e.g. 100 square kilometres) and the insurance is calculated based on these units. This has the benefit of reducing the transaction costs. In addition, IBLI works with local insurance companies, such as Takaful.[1] The aim is to support these local companies to set up insurance contracts in more remote areas.

In order to establish IBLI, household data had to be collected in each of the pilot areas, including data on number of livestock, health of livestock and socio-economic data, which is an extremely time-consuming task, and the challenge is to scale up IBLI-type of mechanisms.[2]

1 See: http://www.islamic-banking.com/takaful_insurance.aspx
2 See: https://ibli.ilri.org/2016/10/12/characterizing-regional-suitability-for-index-based-livestock-insurance/; interview, IBLI experts, ILRI, 14 October 2016, Nairobi, Kenya.

139 See: http://www.economist.com/news/finance-and-economics/21705856-worthy-insurance-scheme-goes-awry-arcs-covenant

Ethiopia, which enables cash-poor farmers to work for their insurance premiums by engaging in community-identified projects to reduce risk and build climate resilience.[140]

Incentives for output providers

Farmers

Smallholder farmers in food-insecure SSA are systematically limited by poor soil fertility and nutrient availability, two key barriers to production. Moving away from unproductive methods is constrained for various reasons:

- Intrinsic motivation constraints: survival as a primary motivation, to the detriment of natural resources; well-established cultural traditions; lack of financial or organizational capacity to move to different production models; driven by short-term incentives; women, as compared to men, face more challenges, especially in terms of mobility, access to assets and productive resources, access to market information and land (rights). Although women are known to be better 'stewards of the environment', these challenges result in greater difficulty to access and maintain profitable market niches, capture more income and apply sustainable and resilient practices.

- Policy and legal constraints: lack of institutional support and government action, e.g. certification, labels, sustainable marketing requirements; lack of extension services.

- Financial constraints: lack of access to organic, agricultural inputs, intense labour demands caused by lack of mechanization; lack of capital to invest in building productive soils in harsh environments.

- Market constraints: no awareness of demand for organic or sustainable products; no access to the market, due to infrastructure constraints such as lack or inadequacy of roads, slaughtering, processing and manufacturing facilities (that raise transaction costs, exacerbate information asymmetries between producers and traders, and discourage investment in processing), as well as inability to meet the quality and quantity standards of the formal market; small size and increasing fragmentation of farms; no availability of/no means to participate on information-sharing platform; lack of public infrastructure for VC logistics; gap between research and implementation of research (inability to reach quality and quantity standards).

Despite these limitations, smallholder farmers in SSA have naturally adapted to environmental and climatic changes over the centuries. In many cases, they already practise sustainable and resilient agriculture thanks to indigenous knowledge: they rely on organic inputs and multi-cropping techniques by historical necessity, though potentially

140 For more details, see: https://policy-practice.oxfamamerica.org/work/rural-resilience/r4/

with low productivity and limited marketability. These practices are intrinsically motivated by survival and reaping nature's benefits, which can only be done when living in harmony with nature and protecting natural resources (Category 1). It could therefore be argued that they do not need a particular external incentive to change behaviour, other than that of raising productivity in a sustainable and resilient manner. Box 21 gives an example of indigenous knowledge, while explaining its limitations: it shows how West African farmers are permanently covering the soil with native shrubs.

Although indigenous techniques can, in many cases, be labelled as sustainable or climate-smart, farmers are systematically constrained by lack of inputs or lack of market access, which impedes a more regular uptake of sustainable and resilient practices and a move away from subsistence farming. In Burkina Faso, for example, a traditional system to restore degraded drylands (usually for sorghum and millet) that concentrates run-off water and organic matter in small pits, known as the zaï technique, is commonly used. It is extremely labour-intensive, but "scientists from the National Institute for Environment and Agricultural Research in Burkina Faso recommended a 'mechanical zaï' that consists of making appropriate holes mechanically with animal-drawn tools. This reduces by more than 90 percent the amount of time required for making the pits" (Zougmoré et al., 2014). It also brings higher economic benefits (165,000 CFA compared to only 17,000 CFA per hectare with the manually dug zaï). However, this technique is unaffordable for most farmers. Therefore, local capacities within farmer communities should be strengthened to empower them to produce and sell basic agricultural equipment and to produce good-quality compost to contribute to solving the limited availability of animal manure (Zougmoré et al., 2014). Financial support is needed to help them. Another example was already discussed in chapter 3 by SRI: it proved too difficult to provide the additional labour required for the poorest farmers. Studies in Madagascar showed that the extra labour required was mostly needed at a time during the year when liquidity was low and labour intensity already high. In these cases, SRI practices were not appropriate for poor smallholders because of the seasonal, labour-intensive nature (Moser & Barrett, 2003).

Off-farm livelihoods and diversification of markets, including linking smallholders to input and output markets, is a sustainable (or climate-smart) measure, as presented in chapter 2 (Category 4). There is evidence that farmers with greater access to input and output markets benefit from a higher and more diversified use of inputs, such as (organic) fertilizer and greater productivity. Strengthening the quality and delivery of information services is also critical, particularly because sustainable and resilient practices are location-specific. The public sector plays a crucial role in linking farmers to the market (see *Incentives from the public sector to enable private sector action* on page 84).

BOX 21

The wealth of indigenous knowledge: the choice between livestock feed and manure, Burkina Faso

An article in Farming Matters (March 2015) explains that minimum tillage and crop diversification are agronomic techniques, along with stone bunds and mulches, long applied by West African farmers.[1] There is also evidence of practices to ensure permanent soil cover to increase soil fertility (one of the three principles of conservation agriculture). Crop residues can be used as mulch to cover the soil, but they are primarily used for animal feed. Local farmers in Burkina Faso (in Yilou, a village in the Central Plateau of Burkina Faso) saw that yields were stagnating and even decreasing because of the deteriorating soil quality. They solved this conflicting issue by using plants that cannot be used as animal fodder: they started cutting and adding branches of native shrubs, such as Camel's Foot, which grows in the surrounding landscape. This new approach is called 'slash and mulch' and it is kick-starting the process of rebuilding soil organic matter; as a result, yields (sorghum, in this case) have increased. However, to disseminate and further develop this technique, more action-oriented research is needed.

1 See http://www.fao.org/family-farming/detail/en/c/326204/

BOX 22

Adaptation strategies for maize leading to higher rate of return: evidence from Swaziland

Shongwe et al. (2013) conducted a CBA of climate change adaptation strategies on crop production in a certain area in Swaziland. These strategies included the introduction of drought-resistant varieties, switching crops, irrigation, crop rotation, early planting and intercropping, among others. The study showed that the internal rate of return increased substantially among farmers who substituted maize with drought-tolerant crops such as dry beans. For example, the return increased by 23.7 percent for farmers who switched from maize to dry beans and by 72.4 percent for those who substituted maize with groundnuts. These drought-resistant crops are marketable and could be sold by farmers, who could in turn buy maize as it is a staple crop. Furthermore, the farmers who carried out irrigation generated more revenue than those who did not. However, rural subsistence farmers could not afford the high initial cost to set up irrigation infrastructure, and would need loans and credit to do so. In the area investigated in Swaziland, these services would not be easy to provide because there is no collateral. There are no major rivers in the area, which would make irrigation too expensive. Therefore, households would need government interventions to mitigate the cost of constructing irrigation systems. Another case study showed that crop rotation with groundnuts and maize, as an adaptation strategy, led to a considerable increase of the internal rate of return between 72 and 96.2 percent. Ultimately, the study concluded that the government plays an indispensable role in supporting smallholders, not only through the provision of irrigation infrastructure, but also through strengthening extension services and subsidizing farm inputs in order to improve crop production (Shongwe et al., 2013).

It is often claimed that higher profitability based on CBA is a key incentive for farmers: if farmers are aware of higher yields and increased returns, resulting from investment in sustainable and resilient agriculture, they are likely to pursue these investments (Category 4). This is true in some cases: the maize case study in Swaziland (Box 22) shows that more resilient practices can lead to higher yields, but success stories are not yet widespread. This is because the reality is more complex than simple economic logic. Due to the causal links between the various levels (i.e. local, national, regional, continental, global), local-level CBA (i.e. generating evidence of a higher rate of return after sustainable investments) is, at best, only part of the story: "improved practices that increase yields at scale will shift the supply-demand equilibrium and in most cases reduce producer prices, which in turn will have a dampening effect on uptake of the new practices. This may explain low adoption rates of innovations, such as drought-resistant seed in SSA for example" (IFAD, 2016, pp.: 47–49).

For an economic assessment to be a strong decision-making tool, it needs to go beyond CBA for a more nuanced understanding of the drivers of, and incentives for, behavioural change (Category 1). More precisely, "smallholders' decisions are affected by many factors besides current material assets, cash flow and market signals, such as family, culture, tenure, local politics and perceptions of risk." Therefore, "a range of additional approaches that we can call 'adaptive behaviour analysis' (ABA) can improve the efficacy of CBA in targeting effective investments" (IFAD, 2016). To illustrate this, IFAD (2016) gives the example of alternate wetting and drying (AWD) in rice: despite the proven profitability benefits of this practice, uptake by farmers was slow. One of the reasons was that land management was not consolidated, when the practice was disseminated: "farmers who manage their land collectively, through some form of management agreement, are much better placed to save costs and undertake innovations. Furthermore, women are often

excluded from water-management institutions and from extension services…" (Basak 2016 & IRRI, 2016, cited by IFAD, 2016, p. 46).

Another shortcoming of the classic CBA is the assumption of standard conditions across years. Smallholders are often characterized as risk-averse, meaning that they have a greater interest in avoiding losses in bad years than in maximizing gains in good years. In other words, farmers' willingness to pursue innovations will depend on how the new practice or technology performs in good, average and bad years. Hence, "some form of risk analysis, for example, testing of farmers' behaviours or stated preferences across the spectrum of current (and/or future) climate variations, will improve the quality of any economic assessment" (IFAD, 2016, p.49).

Finally, the level of adoption and uptake of interventions to build resilience depends on the mode of design and delivery. Working with local institutions and local ownership often constitutes the key to success. Community-led approaches have resulted in improved adoption rates. Therefore, the IFAD Adaptation for Smallholder Agriculture Programme's (ASAP) investments are aimed at supporting local institutions with climate change adaptation and building the necessary infrastructure or technological hardware.[141]

Large companies and multinationals

Large companies and multinationals have shown an increasing interest in investing in sustainable and resilient VCs. They play a significant role in promoting sustainable and resilient agricultural practices throughout the agricultural VC. "This is underlined by the fact that annual global food retail sales total approximately $4 trillion (USDA, 2016), indicative of the scale of the financial influence of the food and agribusiness sector, compared to public climate finance in the region of $35 billion a year across all sectors" (ODI & Heinrich Böll Stiftung, 2016). A major incentive for private actors across the VC is the 'value at risk' concept, (i.e. the proportion of either their production or procurement at risk of being damaged or of failing altogether due to climate change effects)" (IFAD, 2016, p.50) (Category 1).

Unlike poor smallholders in SSA, multinationals do have the means to make sustainable investments, based on longer-term planning. "A PricewaterhouseCoopers analysis from 2015 indicates that across the three major crop categories included in the IPCC's Fifth Assessment Report (rice, maize and wheat), 32 percent of the annual crop was estimated at risk of failure in 2012; and by 2050, this number is projected to rise to 41 percent" (WBCSD, 2015, cited by IFAD, 2016, p.50). The other incentives are the market-based mechanisms (MBMs), discussed in section *Categorizing incentives for respective VC actors* on page 67. These include:

- Government policy, such as ISO 14000 environmental management standards and eco-labelling (Category 2).
- Public opinion, meaning that a negative public image can affect a company's reputation and market share (Category 4).
- Financial institutions and insurance agencies may also have a financial self-interest in ensuring that companies are integrating environment/sustainability in their core decision-making (Category 3).[142]
- Sustainable and resilient agriculture may also create new opportunities and generate new markets: for example, multinationals are working with small- and medium-sized suppliers to raise the environmental and social standards of their supply chain (Category 4).[143]

Collectors and processors

Processing can take place on the farm by smallholders, or the goods can be collected by middlemen, processed (e.g. by millers), packaged and sold. This second group of 'output providers', often more aware of market demand and more sensitive to consumer pressure, can take up sustainable and resilient practices: they can introduce renewable energy techniques to their processing facilities and can share knowledge of climate-resilient and sustainable practices with farmers.

141 See: https://www.ifad.org/topic/asap/overview
142 See UNEP Finance Initiative: http://www.unepfi.org/
143 See: http://www.eolss.net/sample-chapters/c14/E1-34-09.pdf

©Giacomo Pirozzi/UNDP Burkina

Incentives are increasingly coming from Europe-based MSMEs — investors or co-financers that are starting to launch business-to-business (B2B) initiatives to invest in MSMEs in developing countries. For example, the Belgian company Wakati provides (with the help of NGOs) low-cost, solar power-based food preservation techniques to smallholders in remote areas, to eliminate post-harvest losses. In their pilot project in Uganda, smallholder mango farmers saw their post-harvest losses decrease by 50 percent. As a result, they could sell fresh fruit on the market and they saw their income increase.[144]

This is just one of a growing number of examples, but the private sector-led B2B initiatives to support the supply and sustainability capacities of small producers and processors in SSA remain largely insufficient. This is due to the typical risks inherent to agricultural production (e.g. weather and environmental conditions); higher risks associated with smallholder production (e.g. lack of continuous supply); higher costs of doing business in small rural markets. The challenge ahead is to understand exactly how to scale up existing B2B good practices and increase investment in the rural sector of SSA that can simultaneously improve production and food security, while addressing environmental impacts and externalities and climate change.

Retailers, traders, transporters and supermarkets

When consumers demand sustainably produced and organic food, this creates an incentive for retailers and supermarkets to supply this demand, which will in turn lead to diversification and expansion of products on the shelf. Therefore, retailers, traders and supermarkets play an important role because they can adopt sustainability standards or certification schemes to encourage farmers to take up these standards in exchange for a price premium. They can do this by facilitating the organization of farmers to support them in accessing finance for investing in equipment and technology. They can encourage co-investment in the training of traders, processors and suppliers in sustainable and resilient technologies and practices (IFAD, 2016). They can also optimize systems to reduce waste in the VC, for example, by improving storage facilities or cooling systems in trucks.

The transportation sector of food products in SSA is characterized by high energy use and high GHG emissions: research explains that most transporters/truckers are operating a second-hand truck that is not registered and is non-compliant with vehicle standards. In Côte d'Ivoire and Burkina Faso, due to the dominant market conditions, informal truckers tend to be involved

144 See: www.wakati.co

in other activities and operate their businesses at barely break-even rates. Hence, the pressures to overload and use dilapidated vehicles. In Burkina Faso, tax relief systems have been applied to imported vehicles in order to incentivize fleet renewal, so as to meet environmental standards. In Côte d'Ivoire, a guarantee fund set up by the state in 2009 was "transformed into a commercial enterprise…in order to restore the confidence of the financial sector to engage with the transport industry and to develop a sustainable model of support for financing fleet renewal. Mutual guarantee funds can provide back-up support, but need to be balanced with risk reduction through proof of management and driving skills with truckers or entrepreneurs in a market environment in which the freight market is transparent and liberalized" (Saana Consulting, 2016, p.20).

Gender dynamics in food VCs

Women farmers are a key, but often invisible labour force in agriculture: most of the food produced in SSA is produced by women. However, gender-based discrimination means women farmers do not have equal access to resources, in particular land and credit. Yet, evidence shows that empowering women by increasing their human and financial capital is the most effective way to reduce poverty and food insecurity.[145] Women have proven to be better 'stewards of the environment' for a variety of reasons, such as their traditional roles in managing agriculture. Gender-sensitive VC development can also be an entry point to making VCs more sustainable and resilient, but a number of barriers need to be overcome, as explained in the case of sustainable dairy intensification in Kenya (Box 23). The way forward is to "ensure that the services and products proposed (e.g. vocational training, business skills development, small-scale processing machines, etc.) respond to the needs of women's groups and their capacity to acquire and use them", and to "develop an understanding of women's contributions to VC development to trigger responsive CSR strategies that improve women's position within VCs" (IFAD, 2014, p.19).[146]

However, it should be noted that when policies or programmes are targeting specific VCs where women play an important role (e.g. dairy in Eastern Africa, pulses in West Africa, both important nutritious components of household diets as well as income earners through selling and/or small-scale processing), one concern is that 'modernizing' or introducing new techniques to these VCs may have a negative impact on the control women have over the VC: they could lose control to the men in their communities as these VCs develop. This could have a domino effect on household nutrition and investment in education.

It is therefore crucial to understand the business ecosystem, since modernizing VCs can have both positive and negative effects on household income and diets. Both the Agricultural Research Centre for International Development (CIRAD) and CGIAR call for close monitoring of VC programmes to correct interventions to avoid unintended negative effects on household economy and nutrition.[147]

Demand as a key incentive: the role of consumers

Consumers create and determine market demand (Category 4). Therefore, they are in a position to trigger sustainably produced food, since they are an important determinant of prices, production and transport choices. For this reason, it is increasingly the transporters (e.g. multinationals such as Cargills) and retailers (supermarkets) who determine the production characteristics of food items. However, consumer choices can only be made when consumers can afford to make these choices, motivated by well-being and maintenance of the environment (Category 1). In general, consumer pressure in food-insecure SSA countries is less strong, nearly insignificant as compared to Europe or North America. Still, the growing middle class in SSA, especially in urban areas, prefers organic/

145 Generally, however, strong data on the role of women and empowerment is still lacking. The Women's Empowerment in Agriculture Index (WEAI) tries to overcome this: it captures empowerment in five domains, including decisions about agricultural production; access to and decision-making power over productive resources; control over use of income; leadership in the community; time allocation. It is the first comprehensive and standardized measure to directly capture women's empowerment and inclusion levels in the agricultural sector. WEAI was launched by IFPRI, Oxford Poverty and Human Development Initiative (OPHI), and the USAID Feed the Future initiative in February 2012 (see: https://www.ifpri.org/topic/weai-resource-center).

146 A useful guidebook is the World Bank (2009), Gender in Agriculture Sourcebook, that explains the link among gender and governance, rural finance, land policy, agricultural markets, water management, education, agricultural labour, crop agriculture and so forth, with a number of concrete case studies in SSA. See also: http://www.ifpri.org/publication/gender-agriculture

147 See: http://grainlegumes.cgiar.org/women-and-youth-in-pulse-value-chains-opportunities-for-inclusion-of-smallholders/

sustainable products, motivated by health concerns (quality and diet) and price.

Consumers buy sustainable products because of the comparative advantage that these products enjoy over conventional products, primarily in terms of quality. They prefer healthy, safely produced food because they do not want to run the risk of consuming residues of chemical inputs. In some cases, the excessive use of pesticides in conventional agriculture has led to nationwide concerns. "Therefore, the concept of 'safe food' carries a great deal of traction with consumers who are looking for food that poses minimal risks to their health. In…Uganda, safety was expressed in terms of safe food but also in terms of the safety of farmers who have to handle synthetic inputs" (FAO/ INRA, 2016, p.359). Despite these types of initiatives, the majority of consumers in West Africa, especially in urban areas, prefer imported Asian perfumed rice to low-quality, locally produced rice. However, the carbon footprint caused by long-distance transportation from Asia is huge. Therefore, any incentive to increase local production in SSA is important because it would reduce the global food trade carbon footprint. Furthermore, the proliferation of ecologically certified products, as happened in Europe, Asia, Latin America and North America, has been an indication of changing consumer preferences. Surveys show that the majority of consumers have more faith in companies that allow independent verification of their sourcing practices. Many labelling schemes arose in response to NGO campaigns, including RA-certified coffee.[148]

A second advantage the consumer is looking for is an affordable price of organic/sustainable products. With regards to both the importance of quality food and an attractive price, the Songhai model of integrated production in Benin, summarized in Box 24, presents concrete lessons learned.

BOX 23

Gender dynamics in sustainable dairy intensification in Kenya

Milk consumption in Kenya has increased considerably in recent years. This has opened up new employment and income-generating opportunities for milk producers along the livestock VC. In recent years, dairy intensification has become increasingly popular as a practice that has climate change mitigation potential. Intensification involves various new practices, such as the introduction of high-yielding cows and complementary feed production and feeding strategies, including improved fodder and better disease control.

The shift to sustainable dairy intensification requires access to complex technical knowledge and a range of services, including extension, credit and veterinary. It has strong gender and labour implications, as it involves a shift in traditional gender roles in the household. However, these are usually unavailable to women, since they are rarely targeted by extension and dairy development programmes. On the other hand, when women are effectively targeted by these programmes, and as their awareness and knowledge of intensification practices and benefits increase, they are more willing to switch to sustainable management practices and to find effective solutions to constraints they typically face, such as renting land for producing additional fodder varieties. Recently however, a number of gender-sensitive extension services have emerged in Kenya. They were all initiatives by government-related organizations or development partners such as FAO. "For instance, the Kenya Women's Veterinary Association has worked together with the government to build the capacity of women in livestock and disease management. It has improved women's capacity to control certain cattle diseases through the formation of women groups" (Gallina, 2016).

148 See: http://www.teebweb.org

BOX 24

The Songhai model of integrated production in Benin

The Songhai model of integrated production in Benin aimed to deal with environmental, social and economic sustainability challenges. The model was set up in the mid-1980s with the aim of providing training to farmers (e.g. on kraal manure), developing extension services, enabling inputs to farmers and other producers (e.g. high-quality seeds) and disseminating their activities through various communication channels, such as the radio. In doing so, the Songhai model created consumer demand for organic/sustainable products. Consumers recognize the products by the labels of the Songhai brand; some have the word 'bio' on them (FAO/INRA, 2016, pp. 259-279).

Incentives from the public sector to enable private sector action

How the public sector can drive sustainable and resilient food VCs

Governments

Governments are in a position to strengthen or weaken incentives. They can enforce implementation of policies (e.g. through monitoring and penalties) in the event of non-compliance. They also know whether the appropriate technical, financial, infrastructural and institutional capacity exists to mitigate risk and guarantee an acceptable return. In other words, governments should: 1) create an enabling policy and regulatory environment, based on laws, regulations, standards and fiscal policies; 2) provide financial incentives, such as blending mechanisms for loans and grants, market-based insurance schemes or feed-in tariffs; and 3) generate and disseminate market information by, for instance, linking supply and demand, creating private voluntary standards through targeted actions to incentivize cooperation, such as public-private partnerships (PPPs) for capacity-building to reduce financial risk in the context of sustainable investments.

As with the private sector, the public sector is driven by the 'value at risk' concept: ensuring sustainability and resilience is cost-effective in the long run. Preventing disasters, ensuring higher nutrition and health rates of the population, a greater availability of ecosystem services for future economic development and youth, and so forth, all lead to prosperous societies. Therefore, policymakers should assess investments based on their risk levels, to ensure financial return while being socially inclusive and environmentally sustainable and resilient (Category 1).

Supporting the most vulnerable farmers in the sustainability transition is especially relevant, as they have shorter-term profitability objectives and may have reduced financial means and capacity to make changes. More concretely, governments are in a key position to create an enabling environment, as follows:

- They can facilitate farmers' access to quality seeds, organic fertilizer and innovative technologies. More precisely, they can play a key role in breaking down the barriers to the successful implementation of a formal seed system and the deployment of robust hybrid breeding programmes. The formal seed system includes research and breeding efforts, disciplined increases of breeder's seed, foundation seed and certified seed, often through contractual agreements with farmers, followed by marketing and distribution of the improved seed to farmers and often to end users of the grain, which may include millers, livestock feeders or food and feed manufacturers. Combined with improved agronomic practices (e.g. organic fertilizers, optimum plant populations, land preparation, pest management and transgenic traits for herbicide tolerance and insect control), hybrid

crops have helped maximize agricultural production and yield potential (Category 3 and 4).

- They can set up climate-resilient infrastructure and services to ensure low transaction costs for input acquisition, produce marketing and access to ecosystem services (Category 3 and 4).

- They can invest in local capacity-building in research (Category 4).

- They can develop social safety-net programmes that will become more important with weather variability (Category 2).

- Policymakers are in a position to provide better legal recognition and protection of local and customary land rights, including improving land registries and records; this could incentivize farmers to invest in climate-smart technologies that provide returns in the longer term (Category 2 and 4).

- They can create a supporting regulatory and policy environment, since investors and project development companies are often reluctant to invest in African agriculture, not only because it is a weather-dependent business, but also because financial regulation, guidance and support are lagging in SSA (Category 2).

- There are various economic and financial instruments that the public sector can use to incentivize or disincentivize private sector actors. These include taxes, subsidies and tariffs, payments (e.g. PES, blended financing and other forms of innovative financing), grants, public finance management systems, investments in ecological infrastructure, conditional environmental financing, the set-up of investment funds, and so forth (Category 3).

A useful policy-related model, outlining four different categories of incentives for ecosystem services, ranging from regulatory to voluntary to be used by the public sector, was created by Garrett (2016). Across the spectrum of regulatory to voluntary, the four categories include mandatory regulations, flexible regulations, voluntary investments, linked or delinked to input (see Annexes, Figure 10).

Each category consists of specific incentives. For example, environment or green taxes and levied ecosystem bonds are mandatory incentives and can be used to modify current land-use practices. Subsidies are an example of flexible regulations: governments can provide them to those who implement SLM practices, or offsets can be made through biodiversity practices and traded in markets for emission reductions. PES fall under the third category of voluntary investments linked to input. Finally, voluntary investments that are delinked to input include rewards for ecosystem services, for instance, for protection or restoration projects (e.g. assistance with community projects).[149] Other incentives can be flexible or voluntary, but linked to input, such as market labels, product certificates, environmental standards and liability regimes. These can perform better when they are linked to pricing and compensation mechanisms, based on the 'polluter pays' principle to alter the status quo, for instance, which often leaves society to pay the price. In addition, they can also reform environmentally harmful subsidies — many subsidies that support production or consumption are in fact directly or indirectly promoting the burning of fossil fuels.

This section focuses in on the most common financial incentives: 1) subsidies, tariffs and taxes; 2) loans; 3) rewarding benefits through payments and markets; and 4) innovative financing, such as blending mechanisms:

1 'Market-smart' subsidies and tariffs, aimed at supporting the development of demand and participation in input markets using vouchers and grants, can be a way for the government to modify an incentive from the perspective of the consumer (FAO, 2011). In other words, because subsidies may lower prices, they may have a positive impact on consumption. However, subsidies can also have negative effects: examples of heavily subsidizing certain crops (where the seed suppliers benefit from these subsidies) to the detriment of sustainable multi-cropping practices can be found in SSA. For example, in Malawi and Zambia, the governments, driven by political concern over the respective populations' high dependence on maize as a staple food, subsidized maize production for decades, which resulted in an over-reliance on maize. This has led to shortages and other negative environmental impacts and

149 For more details, see: http://www.fao.org/in-action/incentives-for-ecosystem-services/toolkit/sources-of-incentives/en/

externalities linked to mono-cropping, as discussed in chapter 3. Recent policies on crop diversification have created renewed political and social interest in other crops, such as cassava. The numbers show an increase in demand and supply in the region in recent years. Furthermore, taxes can be disincentives to the production process of unsustainable products, for environmental (e.g. rice production in drought-prone areas), social or health reasons (e.g. red meat for the population's health). According to research by the International Food Policy Research Institute (IFPRI) and the Oxford Martin School on the potential consequences and trade-offs of levying carbon taxes on food, taxes have increased prices and reduced consumption, ultimately leading to reduced carbon emissions and reduced health impacts due to less food consumption. In industrialized countries in particular, a carbon tax on meat production, for example, has positive environmental and health impacts. However, increased food prices in poor countries would raise the number of food-insecure people. On the other hand, research shows that climate change itself will probably lead to price increases on a par with those modelled under the full tax scenario, and that it would lead to huge amounts of climate-related deaths worldwide. Therefore, more research is needed to prove the win-win potential of taxing red meat, especially in developing countries.[150]

2 Public finance is currently the main source of bank lending to smallholders in SSA. Total lending to smallholder farmers amounts to $56 billion, of which $25 billion is by informal/community-based financial institutions, and $17 billion by VC actors directly (who in turn finance their loans partly from their capital, partly from lending from public banks and partly from the private market, as either bonds or loans).[151] However, although state bank lending is important, it has limitations: every dollar of public funding or lending unlocks, even with the most optimistic of assumptions (that private financiers would not have funded agriculture at all, had it not been for the support of public finance), only about 10 cents of private finance. It is likely that commercial banks would have provided the little agricultural lending that they did anyway, and in net terms, public funding may even have displaced commercial finance (for example, because subsidized rates make it impossible for banks to compete). There is also no strong indication that public finance currently plays any significant role in incentivizing VC companies to fund smallholders. However, there are initiatives for innovative financing emerging through green, landscape bonds, as explained in Box 25.

3 Various options to reward benefits through payments and markets: in 2013, UNDP published an 'International Guidebook of Environmental Finance Tools',[152] in which eight key carbon-based finance mechanisms are discussed: fees, loans, PES and MBMs, clean development mechanisms and voluntary emission reductions, subsidies and taxes.[153] In the case of sustainable and resilient agriculture (crops and livestock), loans and fees predominate. According to this Guidebook (UNDP, 2013), PES and other MBMs are rarely used in the case of sustainable and resilient agriculture. They are more common in cases of protected areas of sustainable forestry.[154] Progress to achieve anticipated revenue levels through PES has been slow, despite considerable amounts of investment.[155] PES transactions aim for behavioural change at the individual level that maximizes environmental protection, such as not farming on protected land. MBMs are usually large-scale, either voluntary or involuntary, with the potential for long-term financial sustainability. But evidence shows that the flow of revenue from MBMs is vulnerable to global trends (e.g. droughts) and drastic price fluctuations, which makes it a risky tool.

150 See: http://pim.cgiar.org/2016/11/22/taxing-red-meat-may-cut-emissions-and-disease/

151 By contrast, lending by formal financial institutions is only $14 billion, with around $9 billion coming from state banks, $3 billion from microfinance institutions, $1 billion from commercial banks (mostly through value chain and warehouse receipt finance), $350 million from social lenders and non-governmental organizations for a smaller amount. See: http://blending4ag.org/en/about.html?enabled=1

152 For this Guidebook, more than 100 environmental finance case studies from over 30 developing countries were reviewed across four sectors, including pro-poor energy, protected areas, sustainable agriculture and sustainable forestry (UNDP, 2013a). However, in most cases only three tools — loans, fees and subsidies — are frequently used. See: http://www.undp.org/content/gcp/en/home/library/reports/international-guidebook-of-environmental-finance-tools.html

153 Grants also fall under the common denominator of environmental finance tools, but they are not discussed in this study. The key focus is loans.

154 Protecting habitat or forests and encouraging their restoration often requires financial flows from the collection of fees from users, e.g. tourists, to encourage preservation (UNDP, 2013a).

155 For a successful story of PES, see: TEEB, 2015: 55.

4 Innovative financing modalities, such as blending mechanisms, are becoming increasingly popular. Blended finance is a hybrid fund structure that combines public, private and sometimes philanthropic capital: the non-commercial capital acts as a first-loss cushion, with the objective of leveraging larger volumes of private finance into markets where risks are high and financial returns uncertain, but there is the possibility of major positive social impact.[156] Until present, blended finance of SSA governments and private actors has been limited. The first lessons learned can be found in the circles of development partners. For example, the Danish Climate Investment Fund provides risk capital to climate-related projects in emerging and frontier markets, while promoting the use of Danish climate technology. Backed by the Danish Government, the fund has successfully catalysed private capital from Danish pension funds. The fund expects an annual return of 12 percent, including a preferred return for private investors, and it will invest in projects that reduce GHGs, such as renewable energy and energy efficiency, as well as projects that help communities to improve their resilience in the face of climate change, such as those related to coastal management and disaster preparation.[157]

The potential of PGS, multi-actor innovation platforms and community-supported agriculture cannot be underestimated. These are institutional innovations,

BOX 25

Innovative financing through landscape bonds

"Bonds are a type of financial product in which an 'issuer' receives a lump-sum investment, called the 'principal', in exchange for a promise to repay the principal with interest to the investor at a later date. Landscape bonds are a new, innovative approach to drive large-scale private investment from the capital markets into sustainable landscapes. They can help bridge the gap between the financing available for single projects and the finance needed for coordinated investments across the landscape.

The Unlocking Forest Finance project, led by the Global Canopy Programme…is operating at the scale of subnational regions (e.g. Acre, Brazil; not yet in SSA)…to stop the conversion of tropical forest and transition towards sustainable modes of development, while also generating a financial, environmental and social return on investment. The portfolio of activities spans supply chains, conservation and livelihoods in an integrated way. The total investment cost is hundreds of millions of dollars. The project is then aggregating these projects into a coordinated investment mechanism that will issue bonds in combination with public investment and tools for risk mitigation.[1]

Bonds could be issued by a development finance institution (DFI), which then lends directly to intermediaries investing in agroforestry projects, in combination with climate/donor finance targeted at technical assistance and training. The returns on investment in the aggregated portfolio of projects can repay the bond. Critical to success is building a consortium of potential implementing partners, such as DFIs, local banks, regional governments, producer associations and community associations. The ultimate goal is that the consortium of partners, led by regional governments, can access much larger volumes of capital for sustainable development" (GCP et al., 2015, p. 120).

1 See: http://financingsustainablelandscapes.org/

156 See: https://www.growafrica.com/groups/blended-finance-can-unlock-agriculture-potential-africa-0
157 See: http://dalberg.com/blog/?p=3565

essential in transitions to sustainable and resilient food systems. They are often led by the private sector or research organizations (e.g. ILRI has set up innovation platforms in Tanzania), but they require policy support.[158] Successful agricultural innovation platforms are structured, business-focused alliances among institutional actors to enable and sustain mutual benefits.[159] Each of these actors derive clear benefits based on their critical and unique roles — marketing, credit, investment, new agricultural technologies, reduced input costs — and interact with policy decision makers. Their collaboration results in customized solutions that address fundamental farming constraints. Furthermore, research evidence from the SIMLESA project sites shows that farmers who operate collectively are more likely to use sustainable intensification practices. Innovation platforms are critical for sustainable and effective scaling up among hard-to-reach populations in remote areas. In addition, it is important to retool extension workers to enhance their capacity for facilitating innovation platforms and to mainstream the innovation platform approach in the budgeting and planning process. Moreover, the legal framework for collective action should be strengthened and a review of the agricultural education curriculum is necessary to ensure capacity-building in innovation platform approaches. Finally, providing safety nets can help build farmers' confidence to try new crop varieties and agricultural practices.[160]

The lack of progress on adopting and applying policies and standards in weak institutional environments is often blamed on the lack of political will or on capacity constraints. This applies for a wide range of policy areas but is particularly relevant for policies promoting sustainability, where the objective is long-term change with benefits that are hard to define or very widely spread.[161] In the SSA's hierarchical political systems, it is therefore crucial that the officials at the highest political level are involved in the process and are convinced by the benefits. In other words, the success of interventions often depends on the involvement of those at higher political levels, limiting the bargaining power and ability to make changes of less influential divisions or ministries, such as the Ministry of Livestock or Environment.

Civil society organizations (CSOs), farmers' organizations and youth groups

CSOs as well as farmers' organizations can play the role of advocating for the adoption and implementation of environmentally sustainable VC programmes, policies and practices. Youth groups, which may become increasingly active in the agribusiness sector in SSA, are also in a position to demand and apply agricultural development models that are productive, sustainable and inclusive.

Policy and regulatory incentives in SSA

Continental level

In SSA, policy and regulatory incentives exist at the levels of the AU, the RECs and national governments. First, the AU sets wider policy goals or decides on approaches for the continent; it is increasingly setting continental goals towards sustainable and resilient agriculture (see chapter 1). One of the first milestones dates back to 2009, when "at the thirteenth AU Summit in Sirte, Libya, African leaders stressed the urgency of addressing the multiple objectives of food security, development and climate change, which led to the adoption of the AUC-NEPAD 'Agriculture Climate Change Adaptation-

158 For more details, see: FAO (2016) http://www.fao.org/documents/card/en/c/0c18221f-81d6-4f70-90d0-fbb2f4e189f9/

159 According to Corbeels et al., (2014), uptake of conservation agriculture (CA) techniques has been slow, due to the lack of immediate yield increases, and farmers usually have short-term time horizons. In addition, CA projects often focus on agronomic field-scale interventions, without taking into consideration other scales, such as the farm or village scale and the regional scale, which leads to difficulties in dealing properly with issues arising at these other scales. What is important therefore, is to take a multi-stakeholder approach, based on an innovative network that brings together farmers, extension agents, researchers, input suppliers, service providers, traders and policy-makers that can foster synergies for joint learning to develop viable CA practices (Corbeels et al., 2014).

160 See: http://simlesa.cimmyt.org/

161 Political will encompasses a range of aspects of the domestic political settlement and key interests that ultimately influence how political stakeholders engage in different policy debates and implementation. The study of how leaders, elites and their followers interact in a particular context, to address collective action problems while trying to safeguard their political incumbency partners (e.g. Khan 2012), provides useful insights for both reformers and external actors hoping to promote reform. Such analyses take political survival as the key motivation for ruling elites (often ruling coalitions). This underpins decision logics and policy choices on public sector support for the productive sector, (Moore and Schmitz, 2008; Khan, 2012; Whitfield and Therkildsen, 2011), thereby affecting the willingness of states to control or enforce regulations, for example, to impose environmental standards. Faced with the choice between their own political survival and longer-term interests in stability and collective development at the national or regional level, in many countries, governments tend to prioritize the former in ways that may undermine or compromise the latter.

Mitigation Framework' in 2010. This was a response to the fact that the AU Maputo Declaration (2003) … lacked climate change dimensions. The Framework outlines a set of principles, actions, roles, responsibilities and financing recommendations to guide engagement at all levels in Africa, from continental to national, in implementing adaptation and mitigation programmes in the agriculture sector" (Knaepen et al., 2015, p.5). The AU Malabo Declaration of 2014 also announced a new 'CSA target' for African countries, as discussed in chapter 1. Lastly, the AU draws attention to some of the key VCs of this study. In recent years, the AU has increasingly been promoting cassava as a major food security crop for the continent, due to its relative advantages, such as being a drought-resistant crop. In October 2016, the AU organized a regional workshop on cassava VC development in Kigali, Rwanda to discuss issues of processing and access to the market by SMEs.[162] Convinced of the socio-economic potential of cassava, the AU will now encourage its Member States to create more awareness about cassava, as it is used in many industries such as beverage, confectionary, bakery and mining, among others. Since this is a fairly recent initiative, it is too early to assess its effectiveness.

The AU's initiatives show promising intentions, but there are shortfalls: there is a general lack of vertical coordination between continental, regional and national levels resulting in implementation gaps for the AU's initiatives. "This is often caused by complex bureaucratic loopholes [...] The AUC may try to harmonize as much as possible, but ultimately the implementation responsibility lies at the national level. Adding to this coordination challenge is the weak capacity of the AUC to follow up on all new information on climate change, as well as on all regional and national developments and programmes on CSA. Many observers perceive AUC traction as being weak, while it could more effectively support national and regional leadership and initiatives in various ways" (Knaepen et al., 2015, p.8).

Regional level

African RECs or other regional organizations have come up with policy and regulatory incentives to promote sustainable and resilient agricultural practices. For instance, ECOWAS has put in place a variety of policy instruments, most notably the ECOWAP and its derived Regional Agricultural Investment Plan (RAIP) to support sustainable and resilient agriculture based on effective and efficient family farms and the promotion of agricultural enterprises through the involvement of the private sector. RECs are also increasingly trying to align different policy agendas, such as water, agriculture and trade, as stated in Box 25. Furthermore, COMESA is working towards the harmonization of seed laws, with the so-called COMESA Seed Harmonization Implementation Plan (COMSHIP). More precisely, the COMESA Member States have recognized the uneven regulations that exist among countries and the artificial barriers created for breeding, production and distribution of improved seeds, and have created a regional release system. The goal of the harmonization plan is to create a vibrant, high-growth seed industry, resulting in improved crop yields for 80 million smallholder farmers in 19 countries. Seed companies and breeders register their varieties in the COMESA catalogue, enabling commercialization in the 19 COMESA Member States.[163]

National level

The NAIPs are increasingly taking up climate-smart agricultural practices. For example, Uganda's National Agriculture Policy (September 2013) is evidence of an increasing tendency towards setting up PPPs, as well as ensuring the sustainable use and management of agricultural resources. RECs can also decide on trade regulations that incentivize trade of certain food products. For instance, the EAC developed quality standards for cassava to promote regional trade among its five Member States.[164] This is a positive development since cassava is usually traded informally. However, while food is still produced in the informal sector, environmental standards cannot be applied. Progress and traction at the REC level remains limited (Knaepen et al., 2015). One of the reasons for this is the segmentation of policy agendas at the regional level, as illustrated by the case of SADC (Box 26).

Governments in many SSA countries may, compared to the AU and RECs, have more direct impact on change when creating incentives. However, government

162 See: http://au.int/en/pressreleases/31551/beyond-policy-making-african-union-commission-field-get-grounding-agro-allied-industries
163 See: www.comesa.int
164 See: http://allafrica.com/stories/201006030265.html

©Albert Gonzalez Farran/UN Photo

BOX 26

Fragmentation of policy agendas as a key barrier

Agricultural production and VCs rely heavily on ecosystem services (e.g. up to 70 percent of freshwater resources are used for agriculture). How VCs are organized, the environmental impact they have at their various stages (pre-production, production and post-production) and how agricultural products are being traded (locally, regionally or globally) is de facto having an impact on ecosystems.[1] "SADC regional water policies have long since acknowledged the importance of water for agricultural production and the promotion of intraregional trade. This has taken the form of the conceptualization of water in terms of 'comparative advantage in water availability' between countries or of the 'embedded' water content in various stages of the production chain for traded agricultural and other commodities, goods and services" (Rampa and van Wyk, 2014, p. ix). Rampa and van Wyk conducted a study on the importance of Improved Agricultural Water Management (AWM) to achieve regional food security in the SADC region. They found that regional food security would particularly benefit from the alignment of development agendas among water, agriculture and trade sectors that are currently fragmented. This is because agriculture is the largest consumer of water in the region and the majority of the SADC population depends on agriculture for its food and livelihood. Although the SADC RAP already incorporates water resources for agriculture as a key policy issue, the three agendas (water, agriculture and trade) need to be better aligned. This alignment in the RAP may be enhanced for implementation through most of its key priority areas, including: 1) improved sustainable and resilient agricultural production, productivity and competitiveness; 2) improved regional and international trade and market access; 3) improved private- and public sector engagement and investment in agricultural VCs. It is promising that the SADC regional water policies have acknowledged the importance of water for agricultural production and the promotion of intraregional trade (see Annexes, Figure 11 – Water, agriculture and trade: a potential three-sided sectoral synergy for regional food security in SADC).

However, not only in the SADC example, but more broadly, there remains a gap between trade dynamics and trade rules and their potential to be environmentally sustainable and resilient. The Nairobi Ministerial Declaration, adopted on 19 December 2015 in Nairobi (World Trade Organization (WTO) tenth session), has the potential to create a level playing field for linking issues such as environmental standards and trade.[2] In addition, the ongoing negotiations on Africa's Continental Free Trade Area (CFTA) can also offer entry points, although significant improvement is required here.[3]

1 Refer to the debate on the 'water footprint of trade': http://waterfootprint.org/en/water-footprint/national-water-footprint/virtual-water-trade/
2 See: https://www.wto.org/english/thewto_e/minist_e/mc10_e/nairobipackage_e.htm
3 See also: https://www.wto.org/english/res_e/booksp_e/aid4tradeglobalvalue13_e.pdf

support can also be counterproductive. According to Reij & Winterbottom (2015), “in many countries in Southern Africa, such as Malawi, governments subsidize fertilizers to lower costs for farmers. However, fertilizer does not reach all smallholder farmers, and even when it does, it does not always increase crop yields. Fertilizer use efficiency depends on the quantity of soil organic matter, which is currently low in many soils” (Reij & Winterbottom, 2015, p. 24). However, regreening — an agroforestry practice that emphasizes the intercropping of trees directly in crop fields and grazing systems, thereby maintaining a permanent green cover — has proved successful in Niger: since 1985, farmers regreened five million hectares, almost 50 percent of the country’s total cultivated land. Part of the success is explained by the farmers having “exclusive and legally confirmed rights to use and benefit from [the trees]”, thanks to “policy reforms launched in the 1990s to support decentralized natural resource management (Reij & Winterbottom, 2015, p.41).

However, experience with cassava in Eastern and Southern Africa shows that for decades, governments have heavily subsidized maize production to the detriment of cassava. Due to this one-sided approach, the production of maize did not always meet the demand. In recent years, these heavy subsidies have gradually been removed. Then, in response to the 1980s droughts, the Zambian and Malawian Governments started to promote cassava for many of the reasons already listed (e.g. its drought resistance). It was with the help of the IITA that they both started to move away from solely maize cultivation (Abass et al., 2013).[165] In contrast to Eastern and Southern Africa, cassava has been more widely produced and consumed in West and Central Africa, with Nigeria being the largest producer — according to FAO STAT (2010), around 3.5 million hectares are planted in Nigeria, as cited by GIZ, 2013. In 2007, Nigeria produced 46 million tonnes. Nigerians tend to believe that cassava is a very viable crop, with a potential to ‘inject 10 trillion naira into the economy’ (see Box 27).[166] However, despite this growing conviction of many African countries in SSA, cassava has long been neglected by African governments and Western donors.[167] That said, according to FAO, there will be a growing urban demand for cassava, which increases the potential for small- and medium-scale processors to improve their income by investing in better quality, safety and packaging in order to respond to this demand (FAO, 2015). Strong investment and more incentives by governments are needed to build this potential.

In the livestock sector, governments have also at times failed to create a conducive environment for the private sector: “[...] past investments, both from the private and public sectors, in the development of the livestock sector have been largely project-based and disjointed, with little regard to long-term institutional development. Moreover, private sector investments in the sector, which should drive accelerated and equitable growth, stimulate growth in other sectors and galvanize widespread socio-economic transformation, have been subdued by the lack of supportive policy environments, the lack of appropriate infrastructure and the non-availability of reliable supplies of essential inputs and services, thereby making the sector uncompetitive and thus unattractive to investors” (AUC, DREA, 2015, p. 12). On the contrary, a promising government initiative can be seen in Kenya, where the Government introduced a livestock insurance scheme in partnership with private insurance companies, which is free for farmers (see Box 28).

165 See also:ftp.fao.org/docrep/fao/008/ae748e/ae748e00.pdf

166 See: http://ncgaonline.org/. In other countries, the interest in cassava has grown as well: for example, in the early 1990s, the Malawian government and NGOs initiated the ‘Accelerated Multiplication and Distribution of Cassava and Sweet Potato Planting Materials as a Drought Recovery Measure in Malawi’ that has led to rapid cassava adoption through the multiplication of planting materials. Under the Department of Agricultural Research, there is a Technical Committee on Cassava. The main bottleneck they (as well as other Malawian entities) face is the lack of continuous funding. The International Potato Center hosts a Department on Roots and Tubers, where the national cassava platform (2010) has been placed. This platform achieved a number of objectives, including a feasibility study on national cassava starch and the re-engagement of the private sector. Malawi’s Agriculture Sector Wide Approach (ASWAp) puts cassava forward as a crop in which investment is required to increase food security (Malawi Government, 2010). Due to its drought-resistant characteristics, the Government is currently rolling out a cassava production programme, targeting several districts. In addition, the National Agriculture Policy has been criticized for its over-reliance on maize as a staple food and more attention is being given to the promotion of cassava, although this is happening at a slow pace. Research organizations, NGOs and private actors are lobbying to ensure that cassava is taken up in the next National Agricultural Investment Plan (2016–2021) (Interview with CAADP Focal Point, Ministry of Agriculture, Lilongwe, Malawi, 17 February 2016.)

167 See: https://www.ft.com/content/7c051676-5dc8-11e3-95bd-00144feabdc0

Incentives created by development partners to enable private sector action in SSA

Multilateral and bilateral development partners have important roles to play in providing incentives for private sector action. Concretely, they can undertake the following actions:

- They can develop the capacity of VC actors to manage environmental impacts and risks, through raising awareness on these and providing technical assistance for risk and impact analysis (Category 1 and 3).
- They can set up partnerships with local government and/or the private sector to facilitate access to and efficient management of critical resources for VC activities, such as water (Category 4).
- They can strengthen the enabling environment, by integrating the VC approach and management of environmental sustainability and resilience into broader policies and systems. In this regard, the existence and effectiveness of safety-net programmes and environmental risk-management systems are critical (Category 2).
- They can promote knowledge-sharing to ensure that private sector approaches to sustainable and resilient agriculture are aligned with global standards and methods, such as the SDG indicators. For instance, international climate and land-use financing

BOX 27

Nigeria's promotion of cassava: failures and successes

Nigeria is a front runner in cassava production, thanks to improved cassava varieties: since the mid-1970s, the IITA in Ibadan, Nigeria, has specialized in developing new and resilient cassava with improved virus and mealy-bug resistance that have led to 40 percent higher yields. Cassava is also widely praised for its drought-resistance features in the Nigerian drylands. In addition, the IITA research has focused on better small-scale processing technologies, such as mechanized peelers and chippers, which have led to higher economic returns for smallholder farmers. From 1997, this IITA package started to be diffused in Nigeria (FAO, 2015). However, attempts to move from small-scale to large-scale processing have given rise to problems, mostly at the level of aggregation and coordination of supply. Processing plants usually operate at 40 percent of their capacity or less due to the inadequate supply of roots. Development partners are increasingly trying to tackle the supply issue: for example, in 2009, USAID partnered with IITA and Ekha Agro Processing Ltd., Nigeria's largest producer of glucose syrup, to cluster large groups of farmers. However, the capacity of the company only grew from 10 to 50 percent (FAO, 2015).

This improved research on cassava ran parallel with political decisions to promote the crop: in 2005, the Presidential Initiative on Cassava Production and Export was agreed. One of the objectives was to add 10 percent of high-quality cassava flour (HQCF) to bread, as a measure to reduce the country's reliance on imported wheat. Farmers started to invest heavily in cassava processing, but bakers were unfortunately reluctant to substitute wheat with HQCF, fearing a lack of quality control of HQCF. As a result, farmers were stuck with no market for their expanded production; by 2010, the initiative was considered a failure. Since then, the government has invested heavily in tighter quality control and an additional 65 percent ad valorem tax was imposed on imported wheat. The idea is not only to use HQCF in baking products, but also to start producing cassava-based alcohol. However, challenges remain because side-selling is rampant and contractual compliance is viewed by many farmers as optional. In addition, there is poor coordination for linking farmers to processors. In 2013, the brewer SAB-Miller launched the production of a cassava-based beer in Nigeria — "this is a major test of the ability to design improved contractual arrangements" (FAO, 2015, p. 233).

and other types of donor programmes can align application criteria, agree on common metrics and share monitoring tools to facilitate access to finance and to engage businesses and smallholder farmers more actively (Category 2).

BOX 28

A government-led livestock insurance programme in Kenya

The Government of Kenya launched the Kenya Livestock Insurance Programme (KLIP) in 2015, a promising initiative to make insurance widespread. The Government will purchase drought insurance from private insurance companies on behalf of vulnerable pastoralists, in one of the first PPP schemes. Satellite data is used to estimate the availability of pasture on the ground and triggers pay-outs to pastoralists when availability falls. KLIP is a social programme: it is free for farmers who own up to five cows. For more than five, they will have to pay for the insurance. Critics, however, fear that setting up a 'free insurance system' may cause problems: many farmers may not even be aware that they are covered and experience with insurance in developing countries has shown that small contributions create awareness. It may also create dependency among farmers on this system, in which case a self-sustainable Kenyan insurance programme (it is now sponsored by the World Bank and other development partners) may be more viable.[1]

1 Interview, IBLI experts, ILRI, 14 October 2016, Nairobi, Kenya. For crops, the Kenya Agricultural Insurance and Risk Management Programme was introduced in March 2016: similar to IBLI, it is based on an 'area yield' approach: farming areas are divided up into insurance units — if average production in one of the units falls below a threshold, all insured farmers in the unit receive a pay-out. It is too early to assess its effectiveness but the World Bank, which is supporting this Programme, aims to reach 33 countries by 2020. See: http://www.worldbank.org/en/news/press-release/2016/03/12/kenyan-farmers-to-benefit-from-innovative-insurance-program

- They can generate evidence on the costs and benefits of investing in environmentally sustainable and resilient practices. "Building national capacity in monitoring and reporting systems is another key role for development partners to enable private sector performance on climate mitigation and adaptation to be monitored independently" (IFAD, 2016, p.52).

Apart from the regulatory, knowledge-sharing and capacity-building roles that development partners play, they can also provide financial incentives, such as grants and loans, or enable innovative financing through, for example, blended financing and investments in ecological infrastructure (Category 3).

The UNDP is coordinating the Biodiversity Finance Initiative (BIOFIN), which aims to address biodiversity financial challenges in a comprehensive and innovative way (2012–2018). It enables countries to measure their current biodiversity expenditures, assess their financial needs and then identify the most suitable finance solutions to leverage increased biodiversity investments. In doing so, it works with the national ministries of finance, economy, planning and environment; it also brings in the private sector.[168] Uganda for instance is now developing a comprehensive finance strategy to ensure funds for conservation. It will build on the work done by the Bwindi Mgahinga Conservation Trust (BMCT), founded in 1994, with the aim of providing financing for sustainable development in two protected areas. The funding has helped ecological research and community development projects, among others. Currently, BMCT is working in partnership with the private sector in a €2.1 million project to provide safe drinking water and promote sustainable use of water.[169]

In the area of ODA, increasing attention has been given to the possibility of using public finance to leverage other funding. The idea that public funding, rather than being used to finance an entire project or transaction, can be more efficiently used to unlock private sector finance — thus achieving leverage — is not new. In infrastructure, the concept (often under the guise of PPPs) was developed actively from the 1990s onward. Under the new name of blending, it received a boost in recent years with the work of the Organisation for

168 See: http://www.biodiversityfinance.net/
169 See: http://www.bwinditrust.ug/

Economic Co-operation and Development (OECD) / WEF 'Redesigning Development Finance Initiative' (RDFI), which promoted blended finance as public-private cooperation. "These kinds of initiatives can help catalyze domestic and foreign private capital at much greater scale by mitigating the risks that impede investors from pursuing otherwise attractive infrastructure and industrial investment opportunities" (Financial Tribune, 2015). Blended finance covers both investment and working capital/trade finance, as from the perspective of farmers and other actors in the VC, the two are complementary, and the logic of blending can be equally applied to both. "To be attractive to the private sector, finance systems will need to be simple, willing to take on feedback, transparent in governance, geographically flexible to match the value-chain coverage of the programme with that of the private sector company, and have clear co-investment criteria and guarantees of the leverage this could result in" (IFAD, 2016, p. 52).

In October 2014, the RAI were approved by the CFS. Principle 6, 'Conserve and sustainably manage natural resources, increase resilience, and reduce disaster risks', links responsible investment in agriculture to taking measures, as appropriate, to reduce and/or remove GHG emissions.[170]

However, when discussing the specific role that development partners play, it is important to keep in mind the challenges that arise from aid incentives and the responses from aid recipients. These may result in governments adapting to donor preferences, even if these do not match with those of the recipient. They may also result in emulating institutional reforms that mimic good-practice donor models. Policymakers on the receiving end may want to signal their sustainability intentions to donors, and do so by mimicking the form of envisaged reforms, without necessarily engaging on the difficult and costly task of improving how they function in practice. Unrealistic expectations about the nature of institutional reforms often inform donor support strategies, as if such reforms are merely technocratic measures (in reality, reforms require a combination of political leadership and commitment, as well as managerial and organizational capacity), and as if everything is a priority (when no choices are made, nothing gets done). Such practices create what Andrews et al. have called capability traps (Pritchett et al., 2012; Andrews, 2013). This is a dynamic in which governments — but this can also apply to intergovernmental or international organizations — "constantly adopt 'reforms' to ensure ongoing flows of external financing and legitimacy yet never actually improve" (Andrews et al., 2012, p. 3).

Summary table

Table 3 delineates the key private sector VC actors. It mentions key incentives, limitations of moving to sustainable and resilient practices, and country examples of transitions to sustainable and resilient practices in VCs and their constraints, as discussed in this chapter. As we have established, VCs are complex: for example, the input and output chains usually comprise more than one channel and these channels can also supply more than one final consumer market. In order to simplify our analysis, a distinction is made between 1) the actors that provide various forms of input, including seeds, fertilizers, new technologies or various types of credit; 2) the actors that are responsible for the actual output, with a special focus on smallholder farmers; and 3) the consumers, who purchase food. The four categories of incentives follow the same order as the four categories presented in Box 16.

170 See: http://www.fao.org/3/a-au866e.pdf

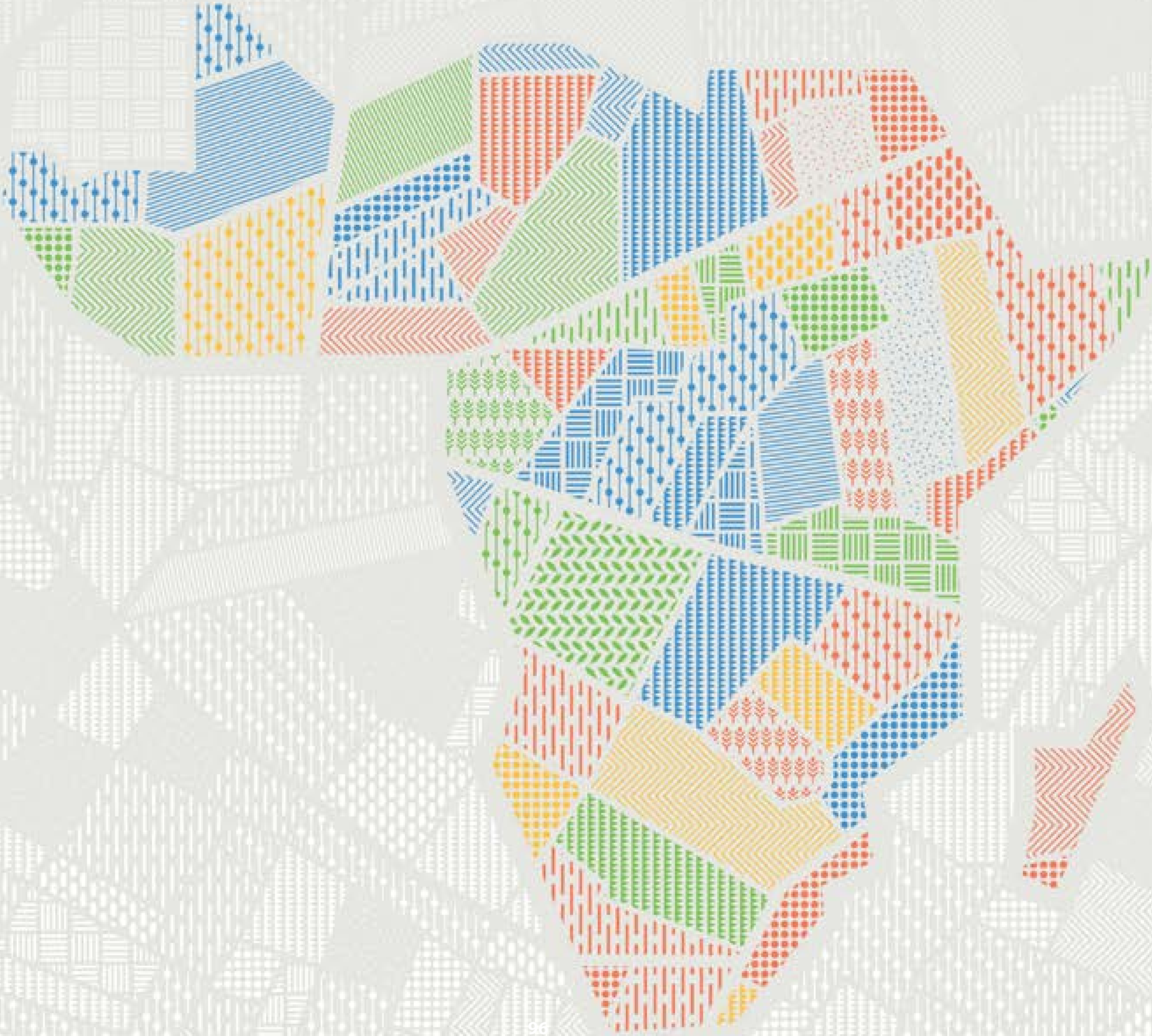
TABLE 3

Mapping key private sector VC actors, incentives to take up sustainable and resilient practices, limitations of moving to sustainable and resilient practices and VC examples (compiled by the authors)

VC ACTORS	INCENTIVES	LIMITATIONS	COUNTRY EXAMPLES
Seed, fertilizer and technology input	Intrinsic: Survival of business Policy/legal: Environmental control and enforcement by government (e.g. penalties in cases of non-compliance) Financial: Conditional environmental financing, investment funds Market demand/arrangement: Business opportunities; innovative platforms; public procurement	Mono-cropping Fragmented policy agendas Lack of enforcement mechanisms No market	Ghana, ERIP: low risk, new techniques (e.g. multi-cropping), better varieties, results in success of project. Radio communication and farmer-to-farmer knowledge-sharing are key
Banks, investors, financial services	Intrinsic: Protection of public goods; survival of business Policy/legal: Environmental enforcement Financial: Conditional environmental financing, investment funds Market demand/arrangement: Business opportunities; innovative platforms; public procurement	Investments risks Inability to make profit Inadequate financial infrastructure, corruption	Kenya, Ethiopia: IBLI mechanism (ILRI): in cases of drought, pastoralists receive funding to buy food/water Ethiopia: soybean VC financing in Jimma zone, involving key VC stakeholders Ethiopia: Swiss Re and Oxfam — insurance in return of physical labour
Farmers	Intrinsic: Traditional practices, local governance systems, culture; protection of public goods; survival of business (in some cases) Policy/legal: Environmental control and enforcement; norms, standards and principles; legal rights (e.g. property rights) Financial: Access to finance (e.g. microloans) Market demand / arrangement: Business opportunities; innovative platforms (e.g. PGS); public procurement	Lack of information on demand for organic food Lack of access to input to take up new practices Lack of political buy-in to promote sustainable and resilient practices Short-term profitability objectives, changing behaviour over time and scale and risk-averse behaviour	Niger: successful agroforestry practices thanks to decentralized natural resource management (since 1990s) Burkina Faso: 'slash and mulch' to rebuild soil organic matter (indigenous knowledge), but constraints to scale up experiences Burkina Faso: mechanical zaï is not affordable for farmers Madagascar: SRI failed due to farmer's required labour input elsewhere Swaziland: adaptation for maize leads to higher return Kenya: women dairy farmers' empowerment Nigeria: Government's cassava promotion
Consumers	Intrinsic: Protection of environment Policy/legal: Sustainability standards based on eco-labelling and other forms of public awareness on sustainable production processes Financial: Taxes, subsidies Market demand/arrangement: Sustainability standards, eco-labels and other certification schemes	Lack of public awareness	Benin: Songhai integrated production model created a consumer base for organic food

CHAPTER 5

Conclusion: a Four-Pillar Framework for Action



©JC McIlwaine/UN Photo

IN RECENT YEARS, A NUMBER OF POLICIES to promote environmentally sustainable, resilient CSA have emerged in SSA. They have, however, not always led to the envisaged and necessary change. In many cases, this was due to a lack of knowledge, research and data, a lack of organization, policy incoherence and limited financial means (chapter 1). Before understanding how to tackle negative environmental impacts and externalities along food VCs, it is important to measure and assess them. There are many tools and approaches to measure different impacts — increasingly popular are systems approaches that enable the measurement of negative impacts and externalities along the entire VC. Once the causes for negative impacts and externalities are understood, it is possible to find solutions. There are three courses of action to move towards environmentally sustainable and resilient food VCs, and ultimately sustainable food systems, including: on-farm diversification, sustainable intensification of agriculture, and off-farm livelihoods and diversification of markets. These can be implemented through existing good practices, borrowing from SLM, ILM and CSA (chapter 2). This study looked specifically at the negative environmental impacts and externalities of the livestock (meat and dairy), rice, cassava, maize, pulses and mango VCs, including GHG emissions, biodiversity loss, soil degradation, water depletion and post-harvest losses. Furthermore, for each respective VC, good practices to intensify sustainably and to achieve on-farm diversification have been presented. Although there are many good examples, sustainable and resilient food VCs are not yet a reality in SSA (chapter 3). Achieving sustainable and resilient VCs, and ultimately sustainable food systems, is impeded by the fact that the business case for sustainable practices, internalizing the costs of negative impacts and externalities, is still unclear. However, even if VC actors want to make the transition towards environmentally sustainable and resilient food VCs and to achieve off-farm livelihoods and diversification of markets, they face many barriers, including lack of access to organic fertilizer or limited market access. Moreover, the system in which VC actors work features economic business models that counteract the adoption of more sustainable practices. Trade dynamics, the power of the distribution and transformation actors within the VC and market demand lead to standardized production and preference for large quantities over quality but niche markets, as well as the need to increase profits via cost reductions, thus encouraging unsustainable practices such as over-reliance on mono-cropping. Positive incentives are needed to ensure the effective promotion of environmentally sustainable and resilient food VCs, as well as stronger control and enforcement mechanisms to make sure that these incentives lead to positive change. These incentives were grouped into four categories: 1) intrinsic motivation to protect livelihoods and promote public goods, 2) policy and legal incentives, 3) financial incentives, and 4) market demand and market arrangements. However, the agricultural sector remains exposed to various risks, including weather variability, pests and price volatility, which makes the prospect of investing in agriculture less attractive, especially in sustainable CSA. Ultimately, the public and private sector play key roles in de-risking with the help of loans, VC financing and insurance schemes (chapter 4).

Concrete, action-oriented pillars

This concluding chapter puts forward four pillars, or areas of intervention, that can further promote and scale up practices for environmentally sustainable and resilient agro-food VCs by reinforcing each other and providing the necessary incentives. These can be brought together in a widely applicable framework, consisting of four pillars that pertain to information, resources, policies and implementation support:

- **'Information'** provides VC actors, especially smallholder farmers and SMEs, with the awareness, knowledge, technology and expertise required to make the move towards sustainable and resilient food VCs and food systems. This first pillar also refers to communication systems and networks — including education and media — that allow information and knowledge to be strengthened, harmonized and shared, as well as progress to be monitored.
- **'Resources'** are the public and private financial means needed along the whole VC to make it more environmentally sustainable and resilient, such as greening VCs, innovative financing, donor and banking schemes, and microfinancing.
- **'Policies'**, and related laws and regulations, play a critical role in overcoming the various challenges to environmentally sustainable and resilient food VCs, such as poor regulatory conditions and onerous administrative procedures. Policies can refer to public policies as well as private regulation.
- **'Implementation support'**, through capacity-building and technical assistance, helps translate systemic models into ground-level reality, to achieve environmentally sustainable and resilient food VCs. In other words, it allows new initiatives and intermediaries to be set up and/or the implementation support capacities of existing actors or within existing organizations to be built. Furthermore, infrastructure development (e.g. good roads) and the facilitation of investment infrastructure for sustainability and resilience purposes are also important forms of implementation support.

The transition towards sustainable and resilient food VCs is an iterative process, consisting of four pillars, as depicted in Figure 3. This process does not follow a specific 1-2-3-4 sequence. Instead, it constitutes a recommended ideal model that, if applied properly, could lead to a successful transition towards sustainable and resilient food VCs, and ultimately sustainable food systems. For each of these pillars, there are recommended entry points for change and actionable solutions. These are not necessarily limited to a specific commodity or geographical area, but rather based on the most important needs highlighted in previous chapters. The following sections discuss the four pillars and their required, key actions in more detail, while making a distinction between the roles of the key VC actors, including companies, governments, development partners, CSOs and research institutions. The key actions are non-exhaustive.

Eventually, the actions under the four pillars can propel VC actors towards solutions to achieving environmentally sustainable and resilient food VCs and broader sustainable food systems. A final, key step is to bring them all together through multi-stakeholder engagement, or more specifically, an inclusive 'multi-stakeholder platform': this enables all VC actors and stakeholders, public and private, to continually engage in a collective process of promoting innovation, planning joint strategies for priority setting, lobbying, influencing, monitoring, learning and evaluating, and ensuring implementation of policies and mutual accountability. The logic and set-up of a multi-stakeholder platform is discussed towards the end of this chapter.

Information

This first pillar refers to a call for information, relevant knowledge, research, awareness, technology and communication networks, since these are the foundations of any environmentally sustainable and resilient food VC activity.

Collecting and contextualizing data, generating statistics and generally having access to data are significant challenges in SSA countries. Furthermore, many VC actors, especially smallholder farmers, do not

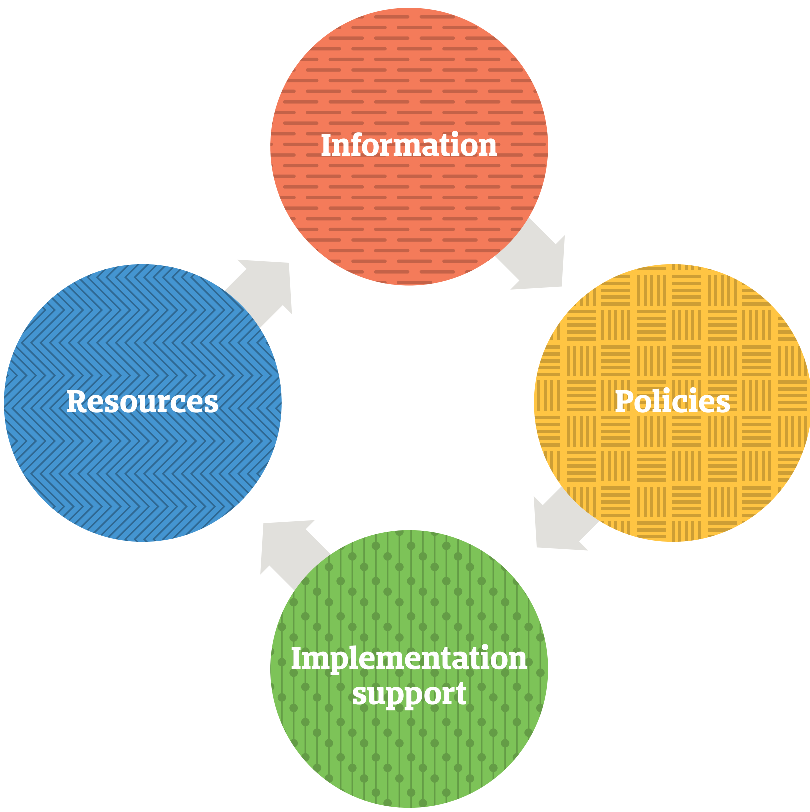
experience the benefits of having access to information, new knowledge and research findings, such as the long-term rewards of investing in sustainable agricultural practices. At the same time, indigenous knowledge and good practices are often not available to decision makers, and there is an absence of information and 'intermediaries' such as consultancies, think-tanks or research institutes.

Each VC actor and institution has a role to play in terms of knowledge generation and data sharing, by forming bridges between knowledge, new technology and data, and smallholder farmers and other disadvantaged VC actors. The following key actions, listed in Table 4, should be undertaken by the various relevant actors to strengthen, harmonize and share information, as well as monitor progress, for the benefit of smallholders and other types of MSMEs.[171]

Resources

Smallholder farmers in SSA produce most of Africa's agricultural output, but they face a multitude of challenges, most notably a lack of access to loans and development partners' funding schemes, and the lack of insurance schemes. Resources are the public and private financial resources required along the entire VC to make it more environmentally sustainable and resilient, including innovative financing, microfinancing, donor and banking schemes, 'green' investments and catalytic funding for effective participation, especially targeting smallholder farmers and SME intermediaries. Table 5 brings together the key actions per group of actors to contribute to the resources pillar.

FIGURE 3 **Four pillars for action to make food VCs more environmentally sustainable and resilient (compiled by the authors)**



171 This list of priority actions per group of actors, as well as the other lists under the following pillars, is not exhaustive.

TABLE 4 Opportunities to contribute to the information pillar, by actor

ACTOR TYPE	KEY ACTIONS
Media	Organize broader campaigns to promote sustainable development and practices.
Companies	**1** Interact with the research community to make the business case for sustainable practices; **2** Provide specialized market research services for the low-income market; **3** Provide technology licences to enable local development of inclusive businesses.
Government	**1** Mainstream environmental sustainability into the school curricula; **2** Strengthen and implement EIA; **3** Harmonize research results; **4** Play an extension role in disseminating information, for example, by making market data (e.g. from household surveys) accessible to the private sector; **5** Support public research institutions to collaborate with the private sector, and create reward schemes to promote sustainable and resilient food systems (PPPs and 'action-oriented research' are important to reach these five sets of goals).
Development partners	**1** Fund market research and research on the merits of innovative integrated frameworks such as SLM, ILM or CSA; **2** Organize workshops, policy dialogues and PPP platforms to disseminate information; **3** Carry out technical backstopping and promote technology transfer; **4** Share cross-country lessons; **5** Set up flexible procedures.
CSOs	**1** Share interests and outputs of development partners and governments at the local level, and link them with local knowledge; **2** Expand outreach and partnerships through PPPs.
Research community and academic institutions	**1** Create localized knowledge on the practices of SFVC activities and the actors that support them (action-oriented research); **2** Shed light on the 'costs of inaction' in terms of unsustainable practices; **3** Support collaborative work between research and development; **4** Offer education and training on these types of activities; **5** Generate evidence-based research. More precisely, research and knowledge generation should support the business case for sustainable practices, through a systematic review of the positive results of sustainable practices and through the generation of big, transparent data that can identify and fill the knowledge gaps; **6** Harmonize various research outputs.

TABLE 5 Opportunities to contribute to the resources pillar, by actor

ACTOR TYPE	KEY ACTIONS
Governments	**1** Invest in sustainable agricultural transformation, for instance, by ensuring that the 10% investment requirement of the Malabo Declaration goes to sustainable agriculture development; **2** Encourage evidence-based financing (e.g. the AU's Partnership for Aflatoxin Control has been successful, thanks to evidence on the impacts on health);
Governments and development partners	**1** In response to declining ODA, use public resources to stimulate private investment by investing in irrigation or road infrastructure, with the aim of benefiting smallholder farmers, thereby creating an enabling environment for sustainable investment, value addition and trade; **2** Focus on sustainable financing mechanisms along the VC, for instance, by using the 'polluter pays' principle and the PES for VC development (PES enables the combining of public and private sector actions); **3** Provide de-risking instruments such as loans or insurance schemes; **4** Assist in building synergies between agriculture and climate financing, since agriculture and food systems are not only impacted by, but also drive climate change (see Box 29 for an example on the Green Climate Fund [GCF]).
Companies	**1** Co-finance sustainable financing mechanisms and pilot new sustainable production, processing and trading techniques; **2** Up-scale private sector cost-sharing cases; **3** Engage in VC financing (e.g. contract farming can be collateral for banks) and provide other types of de-risking instruments; **4** Engage in agricultural foreign direct investment (FDI) in Africa, which has increased in recent years, while ensuring that three guidelines are integrated into all policy and financing instruments for private sector investment in agriculture in SSA: (i) the 'Voluntary Guidelines on the Responsible Governance of Tenure', (ii) RAI and (iii) the 'OECD-FAO Guidance for Responsible Agricultural Supply Chains' (Mackie et al., 2017).
Financial sector	**1** Engage in environmentally responsible lending, including training companies for such lending and generating new good practices; **2** Set up green credit lines and microcredit mechanisms, for instance, for the waste and transportation sectors; **3** Invest in the entire VC, not only the production phase, through VC financing mechanisms, and provide other de-risking instruments such as insurance schemes.

Policies

Policies and regulations, and related to this, political will and good governance principles to ensure implementation, create the enabling environment needed to provide incentives for the move towards SFVCs and sustainable food systems. They play a critical role in overcoming the various challenges to environmentally sustainable and resilient food VCs, such as poor regulatory conditions and onerous administrative procedures. The public sector plays an important role in developing and implementing enabling regulatory and policy frameworks, but other actors, such as the private sector, can also contribute. Table 6 gives an overview of key actions per group of actors.

Policies and regulations must, at times, be accompanied by enforcement mechanisms to create positive change, especially to overcome informal trade barriers or to strengthen mechanization. Flexibility is also important: a policy framework should allow for iterative adaptation to problem-solving (see section *Solutions to policy failures* on page 18.

BOX 29

The GCF: financing the climate-agriculture nexus

The GCF, aiming to mobilize $100 billion by 2020, offers potential to achieve these synergies: a specific share of GCF should be formally committed to "achieving sustainable and resilient agriculture" (the GCF has included CSA as one of its four priority areas).[1] The largest contributors to UNFCCC climate finance mechanisms, including the EU and the G7, could commit to dedicate an agreed share of allocations of the GCF to sustainable and resilient food VCs in developing countries (many of the world's countries most vulnerable to climate change are located in Africa, yet they receive a relatively small percentage of international climate funding, and only a portion of that is focused on agriculture).[2] A specific commitment could be made to facilitate using a share of the GCF to support strategic and effective disbursement of the $30 billion to be raised by the initiative for the Adaptation of African Agriculture (launched at Conference of the Parties 22 (COP22) in November 2016).[3] Although the GCF could constitute an entry point for agriculture-related climate financing in SSA, the actual commitment and disbursement of climate funding has been less than promising. Delays can be explained by differences in requirements in SSA (adaptation) and priorities for industrialized countries (mitigation). Both development partners and governments should ensure that a share of the GCF goes towards African agricultural adaptation. They have two duties to carry out — lobbying and financing.

1 The GCF, launched at the Cancun Climate Change Conference (2010) aims to mobilize $100 billion by 2020. The idea is to evenly split the funding between mitigation and adaptation. So far, it has passed its first capitalization target of $10 billion. See: http://www.climatefundsupdate.org/listing/green-climate-fund. The GCF will focus on CSA because it aims to contribute to agricultural development and food security. It can also involve private and community-level actors (with an additional focus on women) and can encourage agribusinesses and larger producers to support mitigation and wider food security benefits (GCF, 2015).

2 A few African countries have received funding from the GCF, including Malawi, which will receive $12.3 million to scale up the use of modernized climate information and early warning systems — this will be important for 85 percent of the country's population that relies on agriculture. Senegal will benefit from $7.6 million to improve the resilience of ecosystems and communities, through the restoration of the productive bases of salinized land. See: http://www.diplomatie.gouv.fr/en/french-foreign-policy/climate/2015-paris-climate-conference-cop21

3 Global climate financing offers potential, but is also characterized by a number of bottlenecks. During COP22 (December 2016, Marrakech, Morocco), an agreement was reached on the launch of new financing instruments (e.g. the Marrakech Investment Committee for Adaptation), but no major decision was taken to address three major problems that affect climate financing: 1) who will be the beneficiaries of the increasing resources devoted to climate adaptation and mitigation, in terms of sectors and stakeholder groups (i.e. how much will go to smallholder farmers in SSA?)? 2) who is going to contribute to the huge Paris Agreement pledge and how will those funds be accounted for? 3) what are the financial mechanisms and disbursement procedures to be used for climate financing (especially considering the complaints by African administrations and farmers' organizations that current access procedures are too complicated, and therefore render the funds inaccessible)? (Rampa, 2016).

TABLE 6

Opportunities to contribute to the policies pillar, by actor

ACTOR TYPE	KEY ACTIONS
Government	**1** Formulate and implement the right policies, including public (green) procurement, smart subsidies, sustainable certification schemes (e.g. PGS), trade policies (e.g. import substitution, shortening of VCs, higher tariffs), allowing for a wide range of benefits, such as strengthening price-setting, setting up small-scale, off-grid, green energy, strengthening quality standards to create a comparative advantage to form a buffer against price competition, and creating fiscal policies for sustainable practices; **2** Encourage the creation of sustainable business by outsourcing services, such as waste collection; **3** Embrace and encourage innovative business approaches in the private sector; **4** Scale up advocacy (e.g. from Prime Minister's Office); **5** Bridge the agriculture sector and the climate change discussion (see Box 30 on how agriculture is being mainstreamed into country climate plans in SSA).
Development partners	**1** Work with SSA governments (e.g. through policy dialogue) at regional, national and local levels to design transparent policies (e.g. technical advice) and to ensure implementation and continuous monitoring; **2** Support the development of local monitoring and certification bodies in favour of sustainable and resilient food VCs.
CSOs	Support and implement standards and certification schemes.
Companies	**1** Stimulate sustainable and resilient practices by setting and enforcing standards that reward sustainable and resilient practices (e.g. through PGS); **2** Set corporate incentives to provide direction and enable collaboration with the informal market (e.g. procurement policies).

BOX 30

Agriculture featuring in SSA country climate plans

In SSA countries, agriculture and climate policy frameworks have shown positive evolutions: with the support of FAO and UNDP, agriculture is being integrated into the National Adaptation Plans (NAPs) process. The aim is ultimately to mainstream climate adaptation measures for agriculture into national planning and budgeting processes. So far, the FAO/UNDP initiative has been implemented in Kenya, Uganda and Zambia, of the SSA countries. Furthermore, in the majority of the Intended Nationally Determined Contributions (INDCs) of countries' post-2020 climate action plans, agriculture features prominently in meeting national mitigation and adaptation goals. This clearly shows that agriculture sectors, such as crops and livestock, are central to the response to climate change and contributing to sustainable development. CSA is often highlighted as contributing to both adaptation and mitigation. In fact, 32 countries, including 40 percent of the least developed countries, refer to CSA in their INDCs. Countries also explain how they will mitigate climate change or adapt to it. Uganda, for example, mentioned that it will use microfinance as a way to adapt to climate change in the crops and livestock sectors. The country will also expand value addition (diversification), post-harvest handling and storage, and access to markets within the framework of adaptation. However, Uganda and other countries in SSA will not be able to deliver on these goals without global support (FAO, 2016d).

Implementation support

Implementation support, through capacity-building and technical assistance, helps to translate systemic models to ground-level reality, to achieve environmentally sustainable and resilient food VCs. More concretely, it facilitates setting up new initiatives and intermediaries and/or building implementation support capacities of existing actors or organizations. In addition, an important aspect of implementation support is infrastructure development, or more concretely, the development of transformative corridors and adequate logistics (e.g. good roads and smooth transportation that can ensure the continued quality of fresh produce). Furthermore, implementation support can refer to the facilitation and de-risking of investment infrastructure development for sustainability and resilience purposes. Table 7 gives an overview of key actions per actor type.

TABLE 7

Opportunities to contribute to the implementation support pillar, by actor

ACTOR TYPE	KEY ACTIONS
Government	**1** Create frameworks that enable public agencies, such as extension services, to collaborate with the private sector; **2** Encourage the organization of smallholders into collectives and allow for scaling up local practices; **3** Invest in infrastructure and corridor development on multiple levels (regional, national, local) and through public-private collaboration.
Development partners	**1** Play a key role in creating incentives by building the capacities of VC actors, such as farmers (see Box 31 for examples of the GEF and partners) and suppliers of organic seeds, or funding and facilitating platforms for collective action, through developing standards or investing in more sustainable and resilient market infrastructure; **2** Invest in infrastructure development (e.g. through public-private cooperation; **3** Provide environmentally sustainable and resilient technologies to VC actors and organize trainings on how to use them.
CSOs	**1** Build capacities of VC actors, especially the most vulnerable such as women, smallholder farmers and local processors, to be able to apply more sustainable techniques (e.g. help create better access to new technologies); **2** Assist VC actors by connecting them to the market; **3** Advocate for (or invest in) better infrastructure development and technological innovation.
Companies	**1** Pilot new technologies for sustainability; **2** Invest in infrastructure development, in coordination or cooperation with the public sector; **3** Create micro- and small enterprise spin-offs that provide environmental support services; **4** Develop information and communications technology (ICT) systems that facilitate business in poor communities, while supporting environmental practices.
Research institutes	Provide training and assist in extension services.

©Rod Waddington

BOX 31

The GEF and partners: capacity-building in the Kagera River Basin and in Ethiopia

The GEF has a long history of addressing the important nexus between agriculture, environment and climate change, including through projects on agrobiodiversity, water management and land degradation. For example, with GEF funding, farmers in the Kagera River Basin are turning degraded areas into productive land: through innovative farmer field schools and participatory diagnostic approaches at the landscape level, communities have been analysing and addressing their land, water and livelihood requirements. The Kagera Transboundary Agroecosystem Management project works with local farmers reliant on the river basin's resources, which are shared by four countries (Burundi, Rwanda, Tanzania and Uganda). Farmers learn integrated soil fertility management techniques, crop and livestock integration management, and so forth. This has resulted in more than 3,000 male and female graduates from field schools working at scale to strengthen the resilience of their communities. It is important to build on these experiences.[1]

The Resilience, Adaptation Pathways and Transformation Assessment (RAPTA) framework provides another relevant example: it was developed to guide the practical application (integration) of these three concepts (i.e. resilience, adaptation and transformation) in planning and implementing sustainable development projects to achieve systemic change and transformation. The seven components of RAPTA are: scoping; engagement and governance; theory of change; system description; system assessment; options and pathways; and learning. The framework can be applied in different settings and contexts — it has been tested in supporting the design of two food security and sustainable livelihood projects in Ethiopia in 2016. The Stockholm Resilience Centre and UNDP assisted with evaluating the approach at the country level, helping to develop a project document of the GEF Food Security IAP, and at the local level, with the Telecho community in the Welmera district, Oromia region, Ethiopia. As for the latter, one of the objectives was to build capacity among community members in design, implementation and assessment for resilience, adaptation and transformation. In order to achieve this, several multi-stakeholder workshops were held, including a familiarization workshop, a project design workshop and a workshop to explore options and pathways. During the latter workshop, participants had to identify 1) key interventions and 2) for which actors (e.g. farmers, households headed by women) these are important. One of the concrete solutions that emerged was to establish non-farm livelihood opportunities, especially for the landless or households headed by women. This could reduce pressure on the environment from subdividing land. Other pathways that emerged for achieving RAPTA were to improve the resilience of rain-fed agriculture, while expanding small-scale irrigation and specialization in horticulture and bee-keeping, and finally, negotiating decent jobs for the landless and youth.

1 See: www.thegef.org

Multi-stakeholder platform: connecting the four pillars

The implementation of the key actions under the four pillars requires an inclusive and action-based multi-stakeholder platform, to facilitate the process towards environmentally sustainable and resilient food VCs and sustainable food systems. A multi-stakeholder platform enables all VC actors and stakeholders, public and private, to engage in a collective process of sharing information, promoting innovative solutions, planning joint strategies for priority setting, lobbying, influencing, monitoring and evaluating, and ensuring implementation of policies and mutual accountability. A key point is to set realistic expectations and time-frames and to organize regular consultations to compare results over time. This will improve the monitoring of the development process and the long-term capacities. The platform should also facilitate continuous learning.

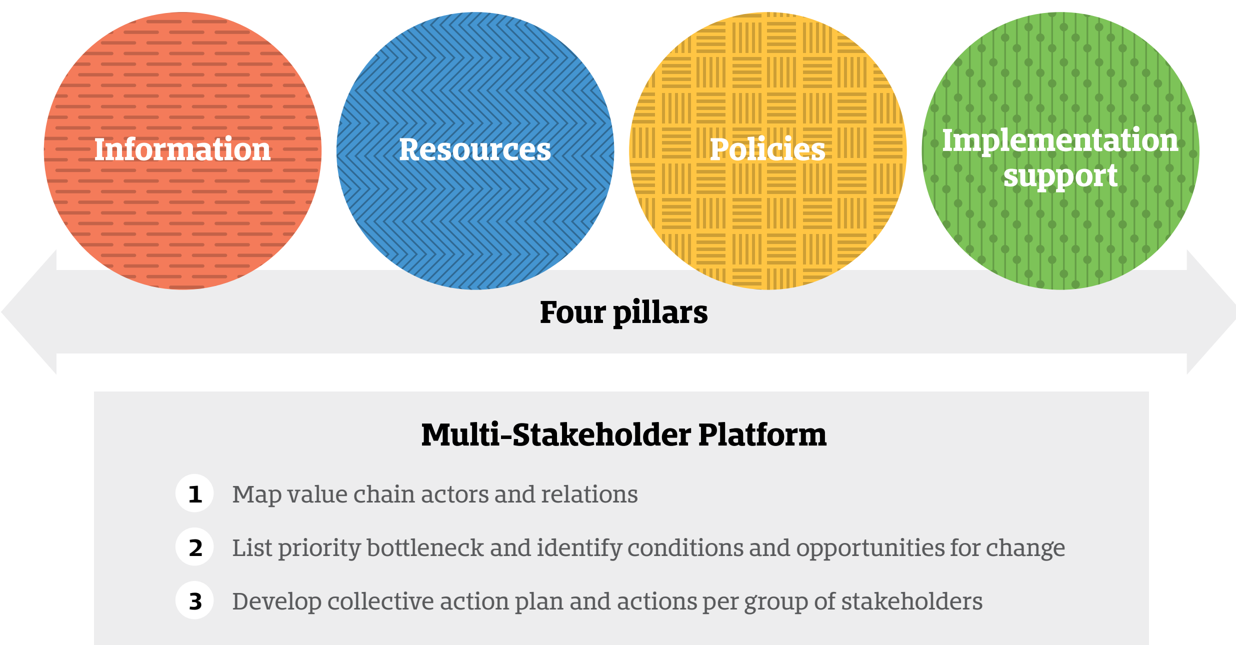
Setting up and effectively coordinating a multi-stakeholder platform, which addresses systemic issues and is mutually reinforcing, involves a logical approach comprising of three key steps: 1) map VC actors and relations; 2) list bottlenecks and identify conditions and opportunities for change; and 3) develop collective action plan and actions per group of stakeholders (see Figure 4).

Step 1 – Map VC actors and relations

The first step of the process to build a multi-stakeholder platform is to understand who is involved in the VC activities, how these actors are interlinked in terms of information flows, access to information, access to resources, and so forth.

The subsequent grouping of VC actors can take various forms: they can gather through an inclusive business

FIGURE 4 **Full implementation of the four pillars for action through a multi-stakeholder platform (compiled by the authors)**



alliance, other types of sector associations or a public-private dialogue (PPD). It is important that these types of platforms and alliances work towards a clearly defined vision and set of objectives. For example, within the framework of COMESA's Regional Investment Programme in Agriculture II (RIPA-II), which aims to remove barriers to agricultural trade and link farmers to markets, dialogue has been encouraged through the set-up of PPDs. These PPDs were bottleneck-based, providing a mechanism to ensure transparency and accountability, clarify land rights, engage smallholder farmers in design and development projects and ensure that investors adhere to the highest international standards of practice. Although there are risks pertaining to a lack of inclusion, an inclusive PPD set-up can give smallholder farmers the opportunity to voice their needs. Another example is the VC Learning Alliances in Ethiopia, which specifically invited groups of farmers to take part in and benefit from a combination of training, on-the-job coaching and the sharing of experiences. On-the-ground experiences were then relayed back to higher political levels, including the Prime Minister's Office. This intervention also had a strong monitoring component, requiring time-bound feedback by different ministries.[172]

Step 2 – List bottlenecks and identify conditions and opportunities for change

In the second step, key issues and bottlenecks for various VC actors under the four pillars should be identified. It is also important to keep in mind that most bottlenecks are created by the asymmetrical power relations in agro-food VCs: decisions on performance requirements (e.g. quality standards), functional divisions of labour and pricing are, to a large extent, made by the group of powerful actors — typically large retailers and processors — and relayed to the vulnerable ones, such as smallholder producers, other types of MSMEs and traders. This dynamic places tight constraints on other actors' room for manoeuvre. For instance, large farmers facing strict quality standards and price pressure may react by unilaterally restructuring their labour-sourcing regimes at workers' expense, passing costs and risk on to the most vulnerable.

This type of platform can be used to stimulate a frank discussion on the bottlenecks the VC actors face and the specific policy reforms and investments required to overcome the most significant obstacles to viable, sustainable and resilient VC development in SSA, and the appropriate role of all stakeholders in supporting these interventions (see Step 3). The advantage of this approach is that it can help build trust among stakeholders to identify and implement the key actions needed to promote sustainable and resilient food VC practices.

Step 3 – Develop collective action plan and identify actions per group of stakeholders

As mentioned, a multi-stakeholder platform should be action-based. Platforms and alliances should create a space to discuss farmer participatory methods and the barriers they face, come up with solutions, be innovative and stimulate the transfer of knowledge and technology. Based on these exercises, the various stakeholders can develop a common vision and common objectives, and produce a collaborative action plan and a joint strategy with priority setting and strategies for lobbying and influencing, as well as monitoring and evaluation. Multi-stakeholder engagement can facilitate capacity-building by bringing new information on resilience, weather events, new organic seeds and so forth to farmers, through various communication channels, such as mobile networks. For each intervention, smallholders should be at the centre of policy so that agricultural research, development and extension services meet the needs of the farmer. Therefore, the tactic in both cases is to increase the interests of powerful stakeholders in the conditions of the producers.

Furthermore, the 10 guiding principles to develop SFVCs, as developed by FAO (2014), form a useful framework to understand which policy/project/programme strategies should be adopted to achieve SFVCs in a particular country. Not only does this SFVC framework reduce environmental externalities, it can also contribute to salary increases, net profits for asset owners, tax revenues and consumer surplus. The 10 principles, including economic, social and environmental sustainability, and end-market driven and governance-centred approaches, are spread out over three key stages of the SFVC development: measuring, understanding and improving performance (FAO, 2014). They can serve as guiding principles for the creation of the collective

172 See: https://www.cordaid.org/en/publications/learning-and-earning-how-value-chain-learning-alliance-strengthens-farmer-entrepreneurship-ethiopia/

©Isaac Billy/UN Photo

action plan; they can also be a good starting point for the move towards sustainable food systems, in which the various VCs in a particular country are integrated into one single concept. A key example is the research on the potential of integrating neglected and underutilized species (NUS) and more conventional, largely supported and mass-produced crops, such as maize or rice. In addition, interventions will be more successful when a landscape approach is used, as this will facilitate a wider systems perspective, rather than the narrower farm-focused approach. There are various knowledge gaps that can be bridged by using a landscape approach: these include the integration of traditional (indigenous) knowledge and science, research and data on consumer behaviour and the integration of conventional and organic agriculture.

According to Reij and Winterbottom (2015), the way forward is to start from the bottom and scale up local-level initiatives: "a grassroots movement must be built that catalyzes the processes of regreening" (Reij and Winterbottom, 2015, p.34) and shows the success of sustainable and resilient practices. More concretely, producers may improve their performance and leverage through collective actions, such as group certification to a sustainability standard, joint marketing of their produce, or the formation of larger associations to lobby for their interests. This is often a precondition for increasing performance, improving linkages and accessing resources.

Lastly, the platform should allow for greater intra-collaboration and technical support from the United Nations agencies and programmes working on the nexus of development, environment and resilience, such as UNDP, UNEP, FAO, United Nations Industrial Development Organization (UNIDO), World Food Programme (WFP), and World Meteorological Organization (WMO) to deliver effective solutions in this area.

A call to action

In order to further advance the 'Framework for Action' and support the needed shift transition towards environmentally sustainable and resilient food VCs and food systems in SSA, all VC actors must engage in stronger cooperation and coordination through a multi-stakeholder platform. This platform can simultaneously facilitate sharing information, creating the right policies and regulations (thus the right incentives), providing various types of resources and supporting implementation (including specifically through stronger mutual accountability). The lessons learned of from this study prompt three additional recommendations:

©Harandane Dicko/UN Photo

- There is a **strong need to continue and broaden evidence-based research of key food VCs in SSA to lead to a more general application of the principles of sustainable and resilient agro-food VCs and food systems**. The many case studies discussed in this study show that sustainable, resilient and climate-smart techniques and methods are still very scattered among countries in SSA. Further research can therefore analyse the overlapping characteristics of these (often similar) interventions, to optimize production under new conditions and generate a database of options for SSA. For instance, mixed farming systems were discussed as viable options for the livestock sector, but more research should be done on options for (nomadic) pastoralism, where soils and the lack of water do not enable farming. Options such as supplementary feeding, creating new water points, and setting up enclosures and the pros and cons of promoting traditional rangeland management systems can be further investigated. The AU and the RECs in particular have key roles to play in bridging these knowledge gaps because of the oversight they have.

- Further analysis should be done on **how the increased commercialization of food products can be used efficiently to drive the transition towards sustainable food systems**. For example, big companies can support SMEs that provide support services in their sustainable development or they can develop ICT systems that facilitate businesses in low-income communities. Good practices have been discussed in this study; the next step is to dig deeper into the required mechanisms for general application. Developing these types of appropriate responses will require testing of new institutional relationships between public and private actors.

- **Further political economy analysis (PEA) is required to understand the strength of incentives and their potential to alter behaviour**. This is especially true in the complex area of environmental sustainability, resilience and food VCs and food systems, which involves a wide array of actors with different interests, complex decision-making, culture, norms, the necessity for top-down and bottom-up learning and so forth. An innovative approach to PEA is the use of five analytical lenses. The five lenses help systematize information and data to analyse the drivers of and constraints to specific policy areas according to: 1) foundational and structural factors; 2) formal and informal institutional aspects; 3) actors and their interests; 4) specific sector characteristics; and 5) external factors and influences. This encompassing approach that looks at actors' relationships, dynamics, windows of opportunities for change, among other aspects, is especially relevant given the complexity involved in making food VCs environmentally sustainable and resilient in SSA (Byiers, Vanheukelom & Kingombe, 2015). In other words, PEA will be relevant to answering the key question that warrants more attention: how to link farmers to markets within their specific VCs, while taking into account the complexity of the specific context of each SSA country.

Abass, A.B. et al. 2013. *Potential for Commercial Production and Marketing of Cassava: Experiences from the Small-scale Cassava Processing Project in East and Southern Africa*. Ibadan, Nigeria: IITA. www.iita.org.

Adjei-Nsiah. S. 2012. Role of Pigeonpea Cultivation on Soil Fertility and Farming System Sustainability in Ghana. In: *International Journal of Agronomy*. Vol. 2012: pp. 1–8.

AfD, CIRAD, IFAD. 2010. *Framework for Involvement in Rainfed Food Crop Supply Chains Development in West and Central Africa: Elements of Analysis and Proposals*. http://www.fidafrique.net/IMG/pdf/CVPaout2010_en.pdf.

AfDB. 2016. Feed Africa. *Strategy for Agricultural Transformation in Africa, 2016–2025*. Abidjan, Côte d'Ivoire: African Development Bank.

AfDB and WWF. 2012. *Africa Ecological Footprint Report: Green Infrastructure for Africa's Ecological Security*. African Development Bank and the World Wide Fund for Nature.

Africa Rice Center (AfricaRice). 2016. *African Rice Center (AfricaRice) Annual Report 2015: Investing in Rice Research and Innovation for Africa*. Abidjan, Côte d'Ivoire.

AGRA. 2016. *Africa Agriculture Status Report 2016 — Progress towards Agricultural Transformation in Africa*.

Agricultural Transformation Agency (ATA). (n/d). *Agricultural Transformation Agenda Progress Report GTP I: 2011–15 in the GTP I period*. www.ata.gov.et.

Ajayi. J.O. 2015. Effects of Climate Change on the Production and Profitability of Cassava in the Niger Delta Region in Nigeria. In: *Agris on-line Papers in Economics and Informatics*. Volume 7, issue 2: pp. 3–11.

Akibode, S. and M. Maredia. 2011. *Global and Regional Trends in Production, Trade and Consumption of Food Legume Crops*. Report Submitted to SPIA. Michigan: Department of Agricultural, Food and Resource Economics, Michigan State University.

Alkemade, R. et al. 2012. Assessing the Impacts of Livestock Production on Biodiversity in Rangeland Ecosystems. In: *Proceedings of the National Academy of Sciences of the United States of America*. Vol. 110, No. 52, pp. 20900-20905.

Andrews, M. 2012. *The Limits of Institutional Reform in Development*. New York: Cambridge University Press.

Andrews, M., L. Pritchett, and M. Woolcock. 2012. *Escaping Capability Traps through Problem-Driven Iterative Adaptation (PDIA)*. CGD Working Paper No. 299.

Alpizar, F. and A. Bovarnick. 2013. *Targeted Scenario Analysis: A New Approach to Capturing and Presenting Ecosystem Service Values for Decision Making*. UNDP.

Ashburner, J., T. Friedrich, and J. Benites. 2002. *Opportunities and Constraints for Conservation Agriculture in Africa*. www.fao.org.

AU. 2015. *The Livestock Development Strategy for Africa (LiDeSA) 2015 – 2035: The Roadmap to a Successful Livestock Sector*. Department of Rural Economy and Agriculture, African Union Commission. http://www.au-ibar.org.

AU. 2016. *Country CAADP Implementation Guidelines under the Malabo Declaration*. www.au.int.

Bahl, P.N. 2015 Climate Change and Pulses: Approaches to Combat its Impact. In: *Agric Res*. Volume 4, no. 103.

Barratt, N. et al. 2006. Cassava as Drought Insurance: Food Security Implications of Cassava Trials in Central Zambia. In: *Agrekon*. Volume 45, no.1: pp. 106–123.

Bekele-Tesemma, Azene. 2007. *Profitable Agroforestry Innovations for Eastern Africa: Experience from 10 agroclimatic zones of Ethiopia, India, Kenya, Tanzania and Uganda*. Regional Land Management Unit (RELMA in ICRAF project), World Agroforestry Centre.

Boix-Fayos, C. et al. 2006. Measuring Soil Erosion by Field Plots: Understanding the Sources of Variation. In: *Earth-Science Reviews*. Volume 78: pp. 267–285.

Bryan, E. et al. 2013. Can Agriculture Support Climate Change Adaptation, Greenhouse Gas Mitigation and Rural Livelihoods? Insights from Kenya. In: *Climatic Change*. Volume 118: pp. 151–165.

Buah, S., S.K. Nutsugah, R.A.L Kanton, and K. Ndiaye. 2011. Enhancing Farmers' Access to Technology for Increased Rice Productivity in Ghana. In: *African Journal of Agricultural Research*. Volume 6, no. 19: pp. 4455–4466.

Byiers, B. and J. Bessems. 2015. *Costs If You Do, Costs If You Don't: Promoting Responsible Business and Reporting — Challenges for Policy Makers*. (Discussion Paper 176). Maastricht: ECDPM.

Byiers, B, J. Vanheukelom and C. Kingombe. 2015. A Five Lenses Framework for Analyzing the Political Economy in Regional Integration. In: *AfDB Africa Economic Brief*, Volume 6, Issue 3.

Cairns, J.E. et al. 2013. Adapting maize production to climate change in sub-Saharan Africa. In: *Food Security*. Volume 5, Issue 345: pp. 345–360.

Carr, M.K.V. 2014. The Water Relations and Irrigation Requirements of Mango (Mangifera indica L.): A Review. In: *Experimental Agriculture*. Volume 50, no. 1: pp. 1–23.

CDE. 2009. *Benefits of Sustainable Land Management*. Centre for Development and Environment. http://www.unccd.int/.

Chamberlin, J., T.S. Jayne, D. Headey. 2014. Scarcity amidst abundance? Reassessing the potential for cropland expansion in Africa. In: *Food Policy*. Volume 48: pp. 51–65.

Chea. A.C. 2012. Sub-Saharan Africa and Global Trade: What Sub-Saharan Africa Needs to Do to Maximize the Benefits from Global Trade Integration, Increase Economic Growth and Reduce Poverty? In: *International Journal of Academic Research in Business and Social Science*. Volume 2, no. 4: pp. 359–384.

CIRAD. 2016. *West Africa: innovative practices for restoring soil fertility and capturing carbon*. www.cirad.fr.

Cook, D. 2016. Presentation at Pulses (Webinar): The Heroes of Nutrition and Agricultural Sustainability. Douglas-cook_securenutrition-bbl_pulses_october-2016.

Corbeels, M. et al. 2014. Understanding the Impact and Adoption of Conservation Agriculture in Africa: A Multi-Scale Analysis. In: *Agriculture, Ecosystems and Environment*. Volume 187: pp. 155–170.

Crutzen, P.J., A.R. Mosier, K.A. Smith, and W. Winiwarter. 2008. N_2O Release from Agro-biofuel Production Negates Global Warming Reduction by Replacing Fossil Fuels. In: *Atmospheric Chemistry and Physics*. 8: pp. 389–395.

CSM (Civil Society Mechanism). 2016. *Connecting Smallholder to Markets: An Analytical Guide*. http://www.csm4cfs.org/.

Daly, H. E. 1990. Toward some operational principles of sustainable development. In: *Ecological Economics* 2: pp. 1–6.

Daryanto S., L. Wang and P.-A. Jacinthe. 2015. Global Synthesis of Drought Effects on Food Legume Production. In: *PLoS ONE*. Volume 10, no. 6: pp 1–16.

Davies J. et al. 2012. *Conserving Dryland Biodiversity*. IUCN (International Union for Conservation of Nature).

Defoer, T. et al. (n/d) *Rice-based production systems for food security and poverty alleviation in sub-Saharan Africa*. www.fao.org.

De Jager, Ilse. 2013. *Literature study: Nutritional benefits of legume consumption at household level in rural areas of sub-Saharan Africa*, www.N2Africa.org,

De Vries, M, C. E. van Middelaar and I.J.M. de Boer. 2015. Comparing environmental impacts of beef production systems: A review of life cycle assessments. In: *Livestock Science*. Volume 178: pp. 279–288.

Dickhöfer, U., K. Butternack-Bahl, and D. Pelster. 2014. What is Needed for Reducing the Greenhouse Gas Footprint? In: *Rural21*, 48(4):31–33.

Downs, S. and J. Fanzo. 2015. *Chapter 1.3: Managing Value Chains for Improved Nutrition*. https://www.karger.com/Article/Pdf/452374.

ECOWAS. (n/d). *Les légumineuses : les plus solides aux changements climatiques*. http://climatechange.ecowas-agriculture.org/node/49

ECOWAS. (n/d). *Codex Standard for Certain Pulses*. http://www.fao.org/fao-who-codexalimentarius/codex-home/en/

Ehlers, J. 2016. *Giving smallholders in Africa a stronger pulse!* http://iyp2016.org/news/268-giving-smallholders-in-africa-a-stronger-pulse

Eisler, M. et al. 2014. Agriculture: Steps to sustainable livestock. In: *Nature*. Volume 507, issue 7490.

Ekbom, A. 2009. Africa Environment and Climate Change Policy Brief. Brief written at the request of SIDA by A. Ekbom, Department of Economics, University of Gothenburg.

European Commission - Joint Research Centre - Institute for Environment and Sustainability. 2010. *International Reference Life Cycle Data System (ILCD) Handbook - Framework and Requirements for Life Cycle Impact Assessment Models and Indicators*. First edition March 2010. EUR 24586 EN. Luxembourg. Publications Office of the European Union.

European Environment Agency. 2012. *Streamlining European Biodiversity Indicators 2020: Building a Future on Lessons Learnt from the SEBI 2010 Process*. EEA Technical Report, No. 11.

FAO. 2006. *Livestock's long shadow. Environmental issues and options*. Rome: FAO.

FAO. 2010. *Greenhouse Gas Emissions from the Dairy Sector: A Life Cycle Assessment*. Rome: FAO

FAO. 2010. FAO statistical database. Rome: FAO.

FAO. 2013. *Save and Grow: Cassava. A Guide to Sustainable Production Intensification*. Rome: FAO.

FAO. 2014. *Developing sustainable food value chains — Guiding principles*. Rome: FAO.

FAO. 2015. *Agricultural Growth in West Africa - Market and Policy Drivers*. Rome: FAO.

FAO. 2016a. Diversification under Climate Variability as part of a CSA Strategy in Rural Zambia. ESA Working Paper No. 16–17. Rome: FAO.

FAO. 2016b. *How Do Markets Encourage the Adoption of Sustainable Practices? The Role of Institutional Innovations in Developing Countries*. Rome: FAO.

FAO. 2016c. *Sustainable agricultural development for food security and nutrition: what roles for livestock? A report by The High Level Panel of Experts on Food Security and Nutrition*. Rome: FAO.

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. and A. Agostini (eds.). Environment and Natural Resources Management Working Paper No. 62. Rome: FAO.

FAO. 2016e. *The State of Food and Agriculture*. www.fao.org.

FAO and IFAD. 2001. *Strategic Environmental Assessment: An Assessment of the Impact of Cassava Production and Processing on the Environment and Biodiversity*. Rome: FAO & IFAD.

FAO/INRA. 2016. *Innovative Markets for Sustainable Agriculture: How Innovations in Market Institutions Encourage Sustainable Agriculture in Developing Countries*. A. Loconto, A.S. Poisot & P. Santacoloma (eds.). Rome, Italy: FAO/INRA.

FiBL. 2009. *African Organic Agriculture Training Manual. A Resource Manual for Trainers*.

Fiksel, J. 2003. Designing Resilient, Sustainable Systems. In: *Environ*. Sci. Technol. Volume 37: pp. 5330–5339.

Financial Tribune. 2015. WEF to Unlock Billions to Realize UN Goals. https://financialtribune.com/articles/world-economy/21390/wef-to-unlock-billions-to-realize-un-goals

Gaffney, J. et al. 2016. Robust Seed Systems, Emerging Technologies, and Hybrid Crops for Africa. In: *Global Food Security*. Volume 9: pp. 36–44.

Gallina A. 2016. Gender dynamics in dairy production in Kenya: A literature review. CCAFS Working Paper no. 182. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. www.ccafs.cgiar.org.

Garrett, L. and Neves, B. 2016. *Incentives for Ecosystem Services: Spectrum*. FAO: Rome.

Gasparri, N. I. et al. 2016. The Emerging Soybean Production Frontier in Southern Africa: Conservation Challenges and the Role of South-South Telecouplings. In: *Conservation Letters*. Volume 9: pp. 21–31.

GCF. 2015. *Analysis of the Expected Role and Impact of the Green Climate Fund*. www.gcfund.org

GCP (Global Canopy Programme), Ecoagriculture Partners, IDH, TNC and WWF. 2015. *The Little Sustainable Landscapes Book: Achieving Sustainable Development through Integrated Landscape Management*. http://globalcanopy.org/.

Gerber, P.J. et al. 2013. *Tackling climate change through livestock — A global assessment of emissions and mitigation opportunities*. FAO: Rome.

GIZ. 2013. *The Ecological Footprint of Cassava and Maize Post-Harvest-Losses in Nigeria - A Life Cycle Assessment*. Bonn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Gliessman, Stephen R., 2006. *Agroecology: The Ecology of Sustainable Food Systems, Second Edition*. CRC Press.

Global Pulse Confederation. (n/d). *The Many Nutritional Benefits of Pulses*. http://iyp2016.org/resources/documents/factsheets

Gomez, M.I. et al. 2011. Research Principles for Developing Country Food Value Chains. In: *Science*. Volume 332, no. 6034: pp. -1155.

Haggblade, S. et al. 2012. Staple Food Market Sheds in West Africa. MSU International Development Working Paper 121, Michigan State University, East Lansing.

Harris, D. and A. Orr. 2014. Is Rainfed Agriculture Really a Pathway from Poverty? In: *Agricultural Systems*. Volume 123: pp. 84–96.

Hellin, J. and M. Meijer. 2006. *Guidelines for Value Chain Analysis*. www.fao.org.

Herrero, M. et al. 2013. Biomass use production, feed efficiencies, and greenhouse gas emissions from global livestock system. *Proceedings of the National Academy of Sciences*. Volume 110, no. 52: pp 20888–20893.

Honja, T. 2014. Review of Mango Value Chain in Ethiopia. In: *Journal of Biology*, Agriculture and Healthcare. Vol. 4, No. 25: pp. 230–239.

Howeler, R. H. 2001. Nutrient Inputs and Losses in Cassava-based Cropping Systems - Examples from Vietnam and Thailand. Working Paper for International Workshop on Nutrient Balances for Sustainable Agricultural Production and Natural Resource Management in Southeast Asia, Bangkok, Thailand. www.ciat-library.ciat.cgiar.org.

Hsieh, Y.P., K.T. Grant, and G.C. Bugna. 2009. A Field Method for Soil Erosion Measurements in Agricultural and Natural Lands. In: *Journal of Soil and Water Conservation*. Vol. 64, No. 6: pp. 374–382.

Huyn B.L. et al. 2014. *Genomic resources applied to marker-assisted breeding in cowpeas*. http://www.slideshare.net/GCProgramme/pag-xxii-cowpea-molecular-breeding-huynh-et-al/3

IFAD. 2007. *Value Chains, Linking Producers to the Markets. Livestock Thematic Papers: Tools for Project Design*. Rome: IFAD.

IFAD. 2014. *How to do Note - Commodity Value Chain Development Projects: Sustainable Inclusion of Smallholders in Agricultural Value Chains*.

IFAD. 2016. *The Economic Advantage: Assessing the Value of Climate-Change Actions in Agriculture*. Rome: IFAD.

IIED and SOS Sahel. 2010. *Modern and Mobile: The Future of Livestock Production in Africa's Drylands*. International Institute for Environment & Development & SOS Sahel UK.

ILO. 2016. *World Employment and Social Outlook 2016: Trends for Youth*. Geneva: International Labour Office (ILO).

ILRI (n/d). Mixed farming systems in sub-Saharan Africa. http://www.fao.org/wairdocs/ilri/x5462e/x5462e0e.htm

IPES-Food. 2016. *From Uniformity to Diversity: A Paradigm Shift from Industrial Agriculture to Diversified Agroecological Systems*. International Panel of Experts on Sustainable Food Systems. www.ipes-food.org.

ITC (International Trade Centre). 2014. *Kenya: Road Map for Developing & Strengthening the Processed Mango Sector*. www.intracen.org.

IUCN. 2016. *An Introduction to the IUCN Red List of Ecosystems: The Categories and Criteria for Assessing Risks to Ecosystems*. Gland, Switzerland: IUCN.

Jarvis, A. et al. 2012. Is Cassava the Answer to African Climate Change Adaptation? In: *Tropical Plant Biology*. Volume 5: Issue 1: pp. 9–29.

Kaul, I., I. Grunberg and M. Stern (eds). 1999. *Global Public Goods: International Cooperation in the 21st Century*. New York and Oxford: OUP for UNDP.

Keerthisinghe, G. (n/d). *Regional strategies for sustainable rice-based production systems in Asia and the Pacific: challenges and opportunities*. www.fao.org.

Khan, M. 2012. The Political Economy of Inclusive Growth. In: OECD and the World Bank (eds.) *Promoting Inclusive Growth: Challenges and Politics*. Paris: OECD.

Kissinger, G. 2016. *Pulse crops and sustainability: A framework to evaluate multiple benefits*.

KIT and IIRR. 2010. *Value Chain Finance: Beyond Microfinance for Rural Entrepreneurs*. Amsterdam: Royal Tropical Institute; Nairobi: International Institute of Rural Reconstruction (IIRR).

Knaepen, H., Torres, C. and F. Rampa. 2015. Making agriculture in Africa climate-smart: From continental policies to local practices. Briefing Note 80. Maastricht: ECDPM.

Kolawole, O.P. 2014. Cassava Processing and the Environmental Effect. World Sustainability Forum 2014. Conference Proceedings Paper. The 4th World Sustainability Forum (1–30 Nov. 2014).

Koroma, S. et al. 2016. *Promoting regional trade in pulses in the Horn of Africa*. Accra: FAO.

Kueffer, C. et al. 2012. Enabling Effective Problem-oriented Research for Sustainable Development. In: *Ecology and Society*. Volume 17, Issue 4: article 8.

Legg, J. et al. 2014. A Global Alliance Declaring War on Cassava Viruses in Africa. In: *Food Security*. Volume 6: Issue 2: pp. 231–248.

Liniger, H.P., R. Mekdaschi Studer, C. Hauert and M. Gurtner. 2011. *Sustainable Land Management in Practice — Guidelines and Best Practices for Sub-Saharan Africa*. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO).

Loh, J. 2015. *Initiative for Biodiversity Impact Indicators for Commodity Production*. Convention on Biological Diversity Secretariat (SCBD), Mainstreaming, Partnerships and Outreach (MPO) Division. www.cbd.int.

Mackie, J., M. Deneckere, and G. Galeazzi. 2017. Matching means to priorities: Challenges for EU-Africa relations in 2017. *Challenges Paper Issue* No. 8. Maastricht: ECDPM.

Manyatsi, A. M. and N. Mhazo. 2014. *A Comprehensive Scoping and Assessment Study of Climate Smart Agriculture Policies in Swaziland*. www.fanrpan.org.

Mapfumo, P., F. Mtambanengwe, K. Giller, and S. Mpepereki. 2005. *Tapping indigenous herbaceous legumes for soil fertility management by resource-poor farmers in Zimbabwe*. www.wur.nl.

Maredia, M. 2012. Global Pulse Production and Consumption Trends: The Potential of Pulses to Achieve 'Feed the Future' Food and Nutritional Security Goals. Presentation at the Global Pulse Researchers Meeting, Rwanda, Feb 13–19, 2012.

Maru Y. et al. 2017. *Making 'resilience', 'adaptation' and 'transformation' real for the design of sustainable development projects: piloting the Resilience, Adaptation Pathways and Transformation Assessment (RAPTA) framework in Ethiopia*. Australia: CSIRO.

Mati, Bancy M. (n/d). *System of Rice Intensification (SRI): Growing More Rice while Saving on Water*. http://sri.cals.cornell.edu/countries/kenya/extmats/Kenya_SRI_Manual2012.pdf

Mbanasor, J. et al. 2015. Impact of Climate Change on the Productivity of Cassava in Nigeria. In: *Journal of Agriculture and Environmental Sciences*. Vol. 4 (1): 138–147.

Ministry of Agriculture, Livestock and Fisheries, Republic of Kenya. 2013. *Strategic Plan 2013–2017 (Revised 2015)*. www.kilimo.go.ke.

Moore, M. and H. Schmitz. 2008. Idealism, Realism and the Investment Climate in Development Countries. Working Paper 307. Brighton: IDS

Moser, C. and C. Barrett, C. 2003. The disappointing adoption dynamics of a yield-increasing, low external-input technology: the case of SRI in Madagascar. In: *Agricultural Systems*. Volume 76, Issue 3, pp. 1085–1100.

Mulvaney, R. L., S.A. Khan, and T. R. Ellsworth. *The Browning of the Green Revolution*. Urbana: University of Illinois.

Nedumaran, S. et al. 2015. Grain Legumes Production, Consumption and Trade Trends in Developing Countries. Working Paper Series No. 60. ICRISAT Research Program, Markets, Institutions and Policies. Patancheru 502 324, Telangana, India: International Crops Research Institute for the Semi-Arid Tropics.

NEPAD, 2009. *CAADP Pillar III Framework for African Food Security (FAFS)*. www.nepad-caadp.net

NEPAD, 2010. *Growth and Food Security Through Increased Agricultural Productivity and Trade. A Medium-Term Investment Plan for Kenya's Agricultural Sector: 2010–2015*. www.nepad-caadp.net.

Norman, J.C. and B. Kebe. *African smallholder farmers: rice production and sustainable livelihoods*. www.fao.org.

Nugent, C. 2009. Review of environmental impact assessment and monitoring in aquaculture in Africa. In *FAO. Environmental impact assessment and monitoring in aquaculture*. FAO Fisheries and Aquaculture Technical Paper. No. 527. Rome, FAO.

Oakland Institute and AFSA (Alliance for Food Sovereignty in Africa). 2014. *Drought Prone Malawi and Zambia Turn to Cassava. Agroecology Case Studies*. www.afsafrica.org.

Obayelu, O.A., O.O. Akintunde, and A.E. Obayelu. 2015. Determinants of On-farm Cassava Biodiversity in Ogun State, Nigeria. In: *International Journal of Biodiversity Science, Ecosystem Services & Management*. Volume 11, no. 4: pp. 298–308.

Odongo, D. 2016. *Greenhouse Gas Emissions from African Cattle Excreta Less than Estimated*. Mazingira.ilri.org.

OECD/FAO. 2016. *OECD-FAO Agricultural Outlook 2016–2025*. Paris: OECD Publishing.

Oxfam. 2016. Making Maize Markets Work for All in Southern Africa. Oxfam Briefing Note. www.oxfam.org.

Poulton, C. et al. 2014. The Comprehensive Africa Agriculture Development Programme (CAADP): Political Incentives, Value Added and Ways Forward. Working Paper 077. www.future-agricultures.org.

Pretty, J., C. Toulmin and S. Williams. 2011. Sustainable intensification in African agriculture. In: *International Journal of Agricultural Sustainability*. Volume 9, no. 1: pp. 5–24.

Ramirez-Villegas J. and P.K. Thornton. 2015. Climate change impacts on African crop production. CCAFS Working Paper no. 119. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. www.ccafs.cgiar.org.

Rampa, F. 2016. Stuck in the middle: agriculture and climate change at COP22. ECDPM Talking Points weblog, 23 September 2016. Maastricht: ECDPM.

Rampa, F. and L.-A. Van Wyk. 2014. *Regional food security and water in SADC: The potential for sectoral-synergies within CAADP for the implementation of the SADC Regional Agricultural Policy*. ECDPM Discussion Paper 159. Maastricht: ECDPM.

Reij, C. and R. Winterbottom. 2015. *Scaling Up Regreening: Six Steps to Success - A Practical Approach to Forest and Landscape Restoration*. www.wri.org.

Reynolds, T.W. et al. 2015. Environmental Impacts and Constraints Associated with the Production of Major Food Crops in Sub-Saharan Africa and South Asia. In: *Food Security*. Volume 7, Issue 4: pp. 795–822.

Riisgaard, L. et al. 2010. Integrating Poverty and Environmental Concerns into Value-Chain Analysis: A Strategic Framework and Practical Guide. In: *Development Policy Review*. Volume 28, no. 2: pp. 195–216.

Rockström, J. et al. 2017. Sustainable Intensification of Agriculture for Human Prosperity and Global Sustainability. In: *Ambio*. Volume 46, Issue 1: pp. 4–17.

Rodenburg, J. et al. 2013. Sustainable rice production in African inland valleys: Seizing regional potentials through local approaches. In: *Agricultural Systems*. http://dx.doi.org/10.1016/j.agsy.2013.09.004.

Royal Society. 2009. *Reaping the Benefits: Science and the Sustainable Intensification of Global Agriculture*. London, UK: Royal Society.

Saana Consulting. 2016. *Part 2: Political Economy Analysis - Transport and Port Sectors. Accelerating Trade in West Africa (ATWA) Stage 2 Report*. Danida/Dutch Ministry of Foreign Affairs.

Safriel, U. and Z. Adeel. 2005. Dryland Systems. In: *Ecosystems and Human Well-Being: Current State and Trends. Millennium Ecosystem Assessment Board*, pp. 623–662. www.unep.org.

SEI (Stockholm Environment Institute). 2015. *A Review of Environmental Impact Assessment Frameworks for Livestock Production Systems*. Stockholm: SEI. www.sei-international.org.

Sharma, B., D. Molden. and S. Cook. 2015. Water-Use Efficiency in Agriculture: Measurement, Current Situation and Trends. In: IDEAS Working Paper Series from RePEc, 2015. St-Louis: IWMI Books, Report.

Shongwe P., M. B. Masuku, and A. M. Manyatsi. 2013. Cost Benefit Analysis of Climate Change Adaptation Strategies on Crop Production Systems: A Case of Mpolonjeni Area Development Programme (ADP) in Swaziland. In: *Sustainable Agriculture Research*. Volume 3, No. 1: pp. 37–49.

Silici, L. 2014. *Agro-ecology: What it is, what it has to offer, and how agroecological practices could be more widely adopted*. IIED Issue Paper. London: IIED.

Snapp S. S. et al. 2010. Biodiversity can support a greener revolution in Africa. In: *PNAS*. Volume 107, no. 48: pp. 20840–20845.

Sopov, M. et al. 2015. Investment Opportunities in the Ethiopian Soy Sub-Sector. Business Opportunities Report Soy #9 in the series written for the "Ethiopian Netherlands business event, 5–6 November 2015, Rijswijk, The Netherlands.

Sthapit, B., V. Ramanatha Rao and S. Sthapit. 2012. *Tropical Fruit Tree Species and Climate Change*. Bioversity International, New Delhi, India

Suenaga, H., D.K.Y. Tan and P.M. Brock. 2016. Towards a Greener Rice Production System in Developed and Developing Nations (with the Example of Lao PDR, Japan and Australia). Brief for Global Sustainable Development Report (GSDR). University of Sydney & NSW Department of Primary Industries.

TEEB. 2015. *TEEB for Agriculture & Food: interim report*. United Nations Environment Programme, Geneva, Switzerland.

Thaxton, M. et al. 2015. Landscape Partnerships for Sustainable Development: Achieving the SDGs through Integrated Landscape Management. A White Paper to discuss the benefits of using ILM as a key means of implementation of the Sustainable Development Goals, produced by the Landscapes for People, Food and Nature Initiative.

Tittonell, P. and K. E. Giller. 2013. When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture. In: *Field Crops Research*. Volume 143, no 1: pp. 76–90.

Tittonell, P. et al. 2008. Yield gaps, nutrient use efficiencies and response to fertilisers by maize across heterogeneous smallholder farms of western Kenya. In: *Plant Soil*. Volume 313, no. 1: pp. 19–37.

Thornton, P. and M. Herrero. 2015. Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa. In: *Nature Climate Change,* Vol 5, 830–836 (2015) doi:10.1038/nclimate2754

Tondel, F., H. Knaepen, and L.-A. Van Wyk. 2015. Africa and Europe combatting climate change: Towards a common agenda in 2015. Discussion Paper 177. Maastricht: ECDPM.

Torres, C., J. van Seters. 2016. Overview of trade and barriers to trade in West Africa: Insights in political economy dynamics, with particular focus on agricultural and food trade. Discussion Paper 195. Maastricht: ECDPM.

United Nations. 2011. *Global Drylands: A UN System-Wide Response*. www.unccd.int.

UNCCD. 2009. *African Drylands Commodity Atlas*. www.unccd.int.

UNDP. 2013a. *International Guidebook of Environmental Finance Tools. A Sectoral Approach: Protected Areas, Sustainable Forests, Sustainable Agriculture and Pro-Poor Energy*. www.undp.org.

UNDP. 2013b. *Realizing Africa's Wealth: Building Inclusive Businesses for Shared Prosperity*. www.undp.org.

UNDP. 2015. *Impact Investment in Africa: Trends, Constraints and Opportunities*. Addis Ababa: United Nations Development Programme Regional Service Centre for Africa.

UNEP. 2008. *Carbon in drylands: desertification, climate change and carbon finance*. www.unep.org.

Vadez, J. B. et al. 2012. Adaptation of grain legumes to climate change: a review. *Agronomy for Sustainable Development*. Springer Verlag/EDP Sciences/INRA. Volume 32, no. 1, pp.31–44.

Van den Broek et al. 2014. *Legume Value-Chains in Ethiopia - Landscaping Study*. Prepared by Resilience and Shayashone on behalf of the Bill & Melinda Gates Foundation.

van Melle, C. and S. Buschmann. 2013. Chapter 10: Comparative Analysis of Mango Value Chain Models in Benin, Burkina Faso and Ghana. In: *Rebuilding West Africa's Food Potential*, A. Elbehri (ed.s.). Rome: FAO/IFAD.

Walsh, B. 2013. *The Triple Whopper Environmental Impact of Global Meat Production*. science.time.com.

Waruru, M. 2016. *Taking Stock of Africa's Livestock Emissions*. www.celep.info.

Weiler, V. et al. 2014. Handling Multi-Functionality of Livestock in a Life Cycle Assessment: The Case of Smallholder Dairying in Kenya. In: *Current Opinion in Environmental Sustainability*. 8: pp. 29–38.

Whitfield, L. and O. Therkildsen. 2011. What drives States to support the development of productive sectors? Strategies ruling elites pursue for political survival and their policy implications. Danish Institute for. International Studies (DIIS) Working Paper No 15. Copenhagen: Danish Institute for International Studies.

World Bank. 2006. *Sustainable Land Management. Challenges, opportunities, and trade-offs*. Washington, D.C.: The International Bank for Reconstruction and Development - The World Bank.

World Bank. 2009. *Gender in Agriculture - Sourcebook*. Washington, D.C.: The International Bank for Reconstruction and Development - The World Bank.

World Bank. 2011. *Strategic Environmental Assessment in Policy and Sector Reform — Conceptual Model and Operational Guidance*. Washington, D.C.: The International Bank for Reconstruction and Development - The World Bank.

World Bank Institute (n/d). *Sustainable Rice Intensification (SRI): Achieving more with less. A new way of rice cultivation*. Washington, D.C.: The International Bank for Reconstruction and Development - The World Bank.

World Commission on Environment and Development. 1987. *Our Common Future*. Oxford University Press: Oxford.

Zougmoré, R., A. Jalloh and A. Tioro. 2014. Climate-smart soil water and nutrient management options in semiarid West Africa: A review of evidence and analysis of stone bunds and zaï techniques. In: *Agriculture and Food Security*. Volume 3, no. 16: pp. 1–8.

Agroecology: the application of ecological concepts and principles to the design and management of sustainable agroecosystems. Agroecology is based on three pillars: it is a scientific discipline involving the holistic study of agroecosystems; a set of principles and practices to enhance the resilience and ecological, socio-economic and cultural sustainability of farming systems; and a movement seeking a new way to consider agriculture and its relationships with society (Silici, 2014).

Climate-smart agriculture (CSA): a holistic approach that "integrates the three dimensions of sustainable development by jointly addressing food security and climate challenges. It is composed of three interlinked pillars: 1) sustainably increasing agricultural productivity and incomes; 2) adapting and building resilience to climate change and; 3) reducing and/or removing greenhouse gas emissions, where possible" (FAO, 2013).

Conservation agriculture: this allows nature to regenerate and retain soil structure, thus improving water and nutrient availability for plants and reducing soil erosion. Additional benefits include reduced costs of machinery use and reduced need for agro-chemicals, among others (World Bank, 2012; FAO, 2013). It also increases water-use efficiency, reduces land and water pollution and leads to reduced greenhouse gas emissions (Dumanski et. al., 2006), builds up soil organic matter, improves soil fertility and stimulates soil microbial activity (FAO, 2001).

Diversification: this refers to maintaining multiple sources of production and varying what is produced across farming landscape and over time (IPES-Food, 2016).

Eco-agri-food systems complex: a collective term encompassing the vast and interacting complex of ecosystems, agricultural lands, pastures, labour, infrastructure, technology, policies, culture, traditions and institutions (including markets) that are variously involved in growing, processing, distributing and consuming food (TEEB, 2015).

Ecological footprint: this measures the amount of biologically productive land and water area required to produce the resources an individual, population or activity consumes and to absorb the waste it generates, given prevailing technology and resource management. This area is expressed in global hectares (hectares with world average biological productivity) (see: http://www.footprintnetwork.org).

Ecosystem (or ecological system): the entire assemblage of organisms, including plants, animals and other living beings, living together in a certain space with their environment, or biotope, functioning as a loose unit. Together, these components and their interactions with and relationships to each other form a dynamic and complex new whole, functioning as an 'ecological unit', with additional characteristics that cannot be found in the individual components. Nor could any organism live completely on its own without involving any other species of organism.

Ecosystem services: defined by the Millennium Ecosystem Assessment in the early 2000s as "the benefits people derive from ecosystems", grouping ecosystem services into four broad categories: provisioning, such as the production of food and water; regulating, such as the control of climate and disease; supporting, such as nutrient cycles and crop pollination; and cultural, such as spiritual and recreational benefits. To help inform decision makers, many ecosystem services are being assigned economic values (see: http://www.millenniumassessment.org/en/index.html).

Environmental Impact Assessment (EIA): the process of identifying, predicting, evaluating and mitigating the biophysical, social and other relevant effects of development proposals, prior to major decisions and commitments being made (see: http://www.iaia.org/).

Environmental sustainability: the rates of renewable resource harvest, pollution creation and non-renewable resource depletion that can be continued indefinitely (Daly, 1990).

Externality: a state where: 1) the actions of one economic agent in society impose costs or benefits on other agent(s) in society and 2) these costs or benefits are not fully compensated for and thus do not factor into that agent's decision-making. An environmental externality is when this externality has an impact on the natural environment, e.g. contamination of the soil or the air.

Global public goods (GPG): a good or service in which the benefit received by any one party does not diminish the availability of the benefits to others, and where access to the good cannot be restricted. GPGs have strong characteristics of publicness i.e. they are marked by non-rivalry in consumption and non-excludability of benefits. The second criterion is that their benefits are quasi universal in terms of countries, people and generations (Kaul et al., 1999).

Resilience (of ecosystems): the ability to function and provide critical ecosystem services under changing conditions (Duru & Therond, 2014).

Strategic Environmental Assessment (SEA): a systematic decision-support process, aiming to ensure that environmental and possibly other sustainability aspects are considered effectively in policy, planning and programme making.

Sustainable development: development that meets the needs of the present without compromising the ability of future generations to meet their own needs (World Commission on Environment and Development, 1987).

Sustainable food system: a food system that delivers food security and nutrition for all, in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised (see: www.unep.org).

Sustainable food value chain (SFVC): "the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources" (FAO, 2014, p. vii).

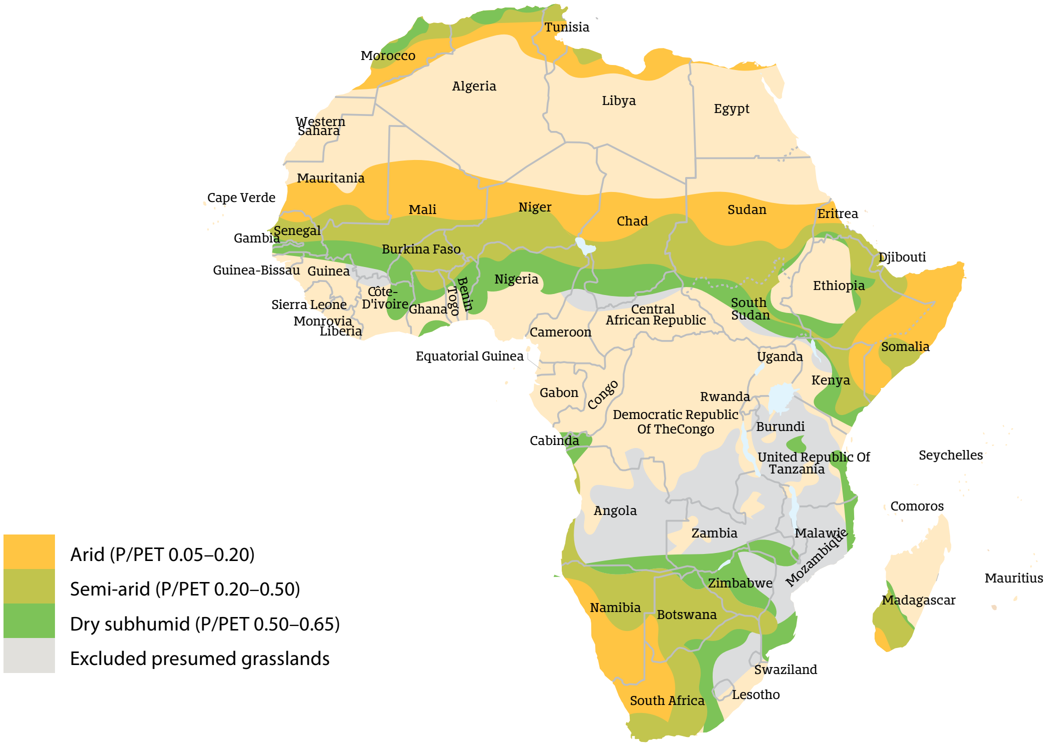
Sustainable intensification: a process whereby "yields are increased without adverse environmental impact and without the cultivation of more land." It includes a range of farming practices, from specific agroecological methods to practices used in commercial agriculture, to biotechnology. This is because a key idea in the concept is that "no techniques or technologies should be ruled out" (Royal Society, 2009, p. ix).

Sustainable land management (SLM): the full range of practices and technologies that aim to integrate land management, water, biodiversity and other environmental resources to meet human needs, while ensuring the long-term sustainability of ecosystems, services and livelihoods (Liniger et al., 2011).

Value chain (agriculture) (VC): a vertical alliance of enterprises collaborating to varying degrees along the range of activities required to bring a product from the initial input supply stage, through the various phases of production, to its final market destination (IFAD, 2014); in other words, an agricultural value chain refers to the whole range of goods and services necessary for an agricultural product to move from the farm to the final customer (see: http://img.teebweb.org).

FIGURE 1

Map of the drylands in Africa



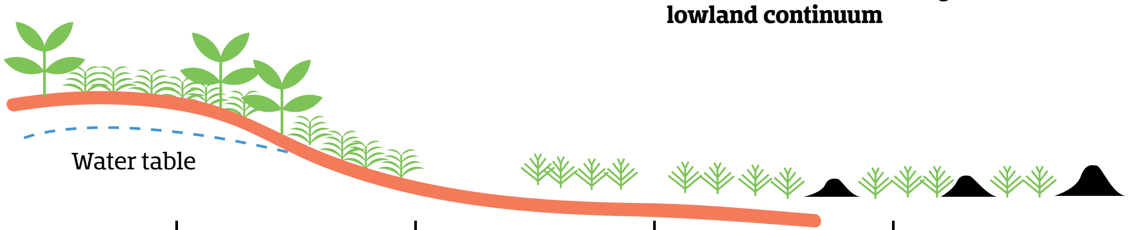
Source: http://www.fao.org/3/a-i5616e.pdf, p. 2.

FIGURE 2

Rice cultivation zones

Upland-lowland continuum

Intensified rainfed to irrigated lowland continuum



Upland	**Hydromorphic**	**Lowland**	**Intensified lowland**	**Irrigated lowland**
Main water supply				
Rainfall	Rainfall and watertable	Rainfall and watertable and floodwater	Regulated floodwater	Irrigation
Agro-ecological zone				
Guinea savannah to humid forest zone	Guinea savannah to humid forest zone	Sudan savannah to humid forest zone	Sudan savannah to humid forest zone	Sahel to humid forest zone

Source: Defoer, T. et al. (n/d).

BOX 1

Strategies to be utilized under LiDeSA related to environmental sustainability (AU, 2015)

Strategy 6.1.4.1: Develop and implement policies that safeguard public goods against negative externalities. A monitoring mechanism for such adverse effects is critical, and investment policies must include response provisions to safeguard public goods that could be affected.

Strategy 6.2.3.1: Re-characterization and assessment of the potential and comparative advantages of the different agroecological zones to best match production systems and environments at national and regional levels. This could include promotion of 'organic' products derived from indigenous breeds. Intraregional trade can drive optimal use of areas with high livestock production potential to supply areas that are not suited for livestock production but that have high demand for livestock products.

Strategy 6.2.3.2: Securing access to natural resources (pasture and water) is critical for livestock production at national and regional levels. An important requirement for the pastoralist livestock production system is mobility. Mobility, holistic resource management and community-managed grazing practices will be important features of any such initiatives.

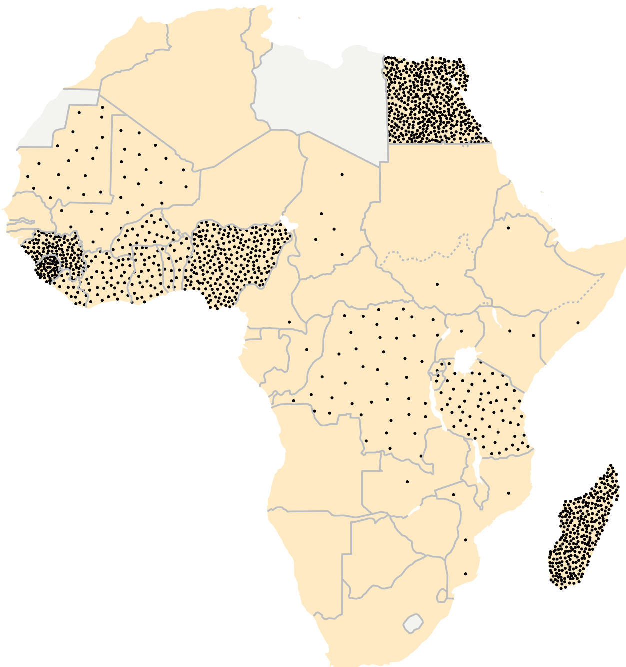
Strategy 6.2.6.2: Creating an enabling environment and incentives for diversification of livestock livelihoods and productive and sustainable exit/entry into alternative livelihoods. Complementary livelihood options should be explored, as has been seen with the numerous community-based conservation programmes involving additional income from tourism by practising integrated livestock wildlife management.

Strategy 6.2.7.1: Develop an enabling environment and promote innovation, incentives and partnerships to reduce GHG emissions, land degradation and other negative impacts. Rangeland management is a serious challenge in the absence of governance structures controlled by and for the livestock owners. The conservancies of northern Kenya, the 'Communal Areas Management Programme for Indigenous Resources' (CAMPFIRE) in Zimbabwe and the community-managed livestock wildlife areas of Namibia are good examples of the effective governance structures and partnership arrangements needed to create the required enabling environment for sustainable and progressive management of the rangeland resource.

Strategy 6.2.7.2: Create an enabling environment to institutionalize and generate incentives for enhancing livestock ecosystem services, including biodiversity services, carbon credits, nutrient recycling and contribution to water recharge systems. Community-managed conservation schemes provide valuable lessons for how to institutionalize and generate incentives for enhancing livestock ecosystem services, with particular reference to: conservation and enhancement of flora and fauna biodiversity; approaches to enhancing carbon sequestration that can be used to gain carbon credits; increased rangeland productivity through nutrient recycling and restoring land cover in support of water recharge systems.

FIGURE 3

Rice production in SSA



Each dot represents 20,000 tonnes

Source: Cornell University, http://www.slideshare.net/SRI.CORNELL/1602-scaling-up-climate-smart-rice-production-in-west-africa

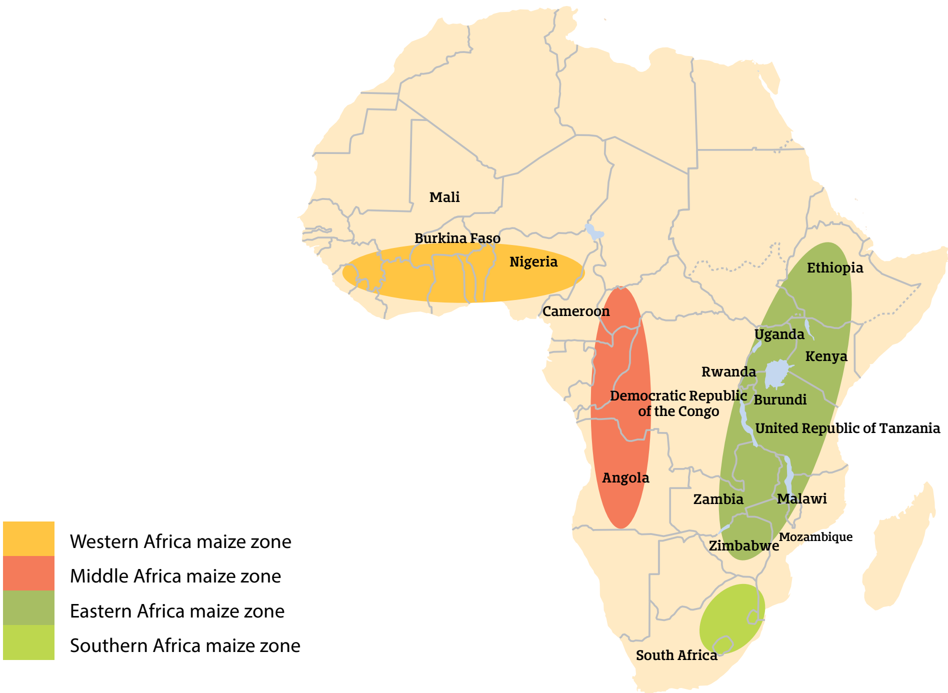
FIGURE 4

Structure of the Nigerian cassava VC

Raw material	Primary processing (Processing)	Secondary processing (Processing)	Market
Cassava fresh roots	Traditional African food processing (grating, pressing, sieving, cooking	→	Gari, lafun, fufu
	Flour production (chipping, drying, milling)	Bakery and confectionary baking	Bread, candies, cakes, ice cream
	Chips production (chipping, drying)	Pellets extrusion	Animal feed
	Crude ethanol production (liquifaction, saccharifac-tion, fermentation, distilling	Distilleries final distillation	Fuel, ethanol, other industries, beverage, pharm
	Native starch production (filtering, setting, starch, washing, drying, milling)	Processed food bouillons	Soups, sauces, sausages
		Textile industry	Garments
		Pharmaceuticals	Pills, capsules and syrups
		Dextrin into paper and wood	Furniture
		Other modified starches	Other industries
Logistics transportation	Transport, handling, packaging, quality, storage quality		

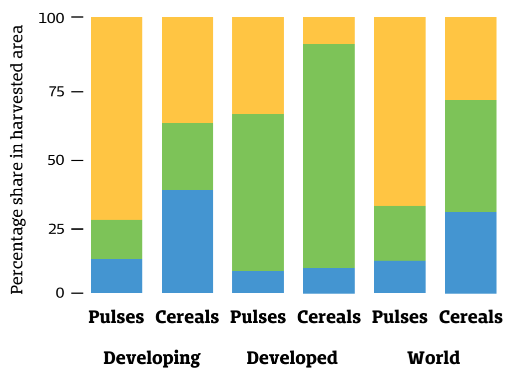
Source: Federal Government of Nigeria, 2006, cited by FAO, 2015.

FIGURE 5 Major maize-growing regions of SSA



Source: http://aciar.gov.au/files/mn-158/s5_4-maize-sub-saharan-africa.html

FIGURE 6 Production systems where pulse crops are grown compared with cereal crops (m ha)



	Developing Pulses	Developing Cereals	Developed Pulses	Developed Cereals	World Pulses	World Cereals
Rainfed, low-input	43.15	178.03	3.08	18.09	46.24	196.13
Rainfed, high-input	8.45	113.21	5.02	153.2	13.47	266.41
Irrigated	7.31	174.76	0.7	17.06	8.01	191.82

Source: HarvestChoice (SPAM database circa 2000), Maredia, 2012.

TABLE 1 World's major mango producing countries (ITC, 2014)

RANK	COUNTRY	PRODUCTION (TONS)
1	India	15,188,000
2	China, mainland	4,350,000
3	Thailand	2,600,000
4	Indonesia	2,131,139
5	Pakistan	1,888,449
6	Mexico	1,827,314
7	Brazil	1,249,521
8	Bangladesh	889,176
9	Nigeria	850,000
10	Philippines	800,551

BOX 2

Overview of key pulses

The most important pulse crop in Africa is cowpea — *niébé* in francophone countries — accounting for more than 95 percent of total global production. It is grown mostly by smallholders in the semi-arid tropics (drought-prone savannahs and in the Sahel), where it is well adapted to the high temperatures, low rainfall and poor soil conditions. Nigeria is the largest producer in the world, accounting for more than half of global production, producing a total of almost four million tonnes annually between 2012 and 2014 (FAOSTAT). In Nigeria, for farmers selling cowpea fodder during the dry season, this means a 25 percent increase of annual income. Small-scale processing, and selling cowpea-based snacks and green pods of cowpea is a significant source of income for women.

The other main pulse crop produced in SSA is beans (Nedumaran, 2015): beans are the primary staple for more than 200 million people there. Production is concentrated in Eastern Africa with Tanzania being the largest producer, but production and yields in Rwanda and Ethiopia are growing fast (FAOSTAT). Kenyan supermarkets emerging across Eastern Africa's major cities and towns source their pulses primarily from Ethiopia (Van den Broek, 2014). Generally, however, yields for common bean are very low, but have been increasing in recent years. This increase is partly due to the work of the Pan-Africa Bean Research Alliance (PABRA), an alliance of CGIAR centres and national research institutions: they developed high-yielding climber bean varieties that are well adapted to warmer, lower altitudes. In Rwanda, this has led to surplus production and the development of a seed VC for these improved varieties of climber beans. Furthermore, "there are three main production systems for common bean: the most common is the semi-subsistence system where beans are part of multiple cropping systems, combined with maize and cassava for example. Commercial farms in the Central Rift Valley and some farms in Malawi and Tanzania produce in highly productive systems. Highly subsistence systems are also widespread, e.g. in Eastern Kenya" (Katungi, 2009, p. 28). Integration of beans in multiple cropping systems like maize, beans and cassava is very common in Eastern and Southern Africa. Maize, beans and cassava are all major staple crops. They are usually produced by mixed crop-livestock smallholders under rain-fed conditions. According to the CGIAR CCAFS programme, this type of farming system is vulnerable to seasonal weather variability, partly because maize and beans are relatively sensitive to climate change.

The faba bean is grown in temperate and subtropical regions. In Africa, it is mostly grown in Ethiopia, Egypt and Sudan, at higher altitudes. Ethiopia is the second largest producer in the world after China, and with 920,000 tonnes between 2012 and 2014, accounted for 21 percent of global faba production. Urbanization is a key driver in the increasing demand for faba bean in Sudan. Growing urban middle classes, aware of the health benefits associated with consumption of pulses, could become another driver of increased consumption of pulses. Most importantly, regional flows are from Ethiopia to Sudan, with an estimated value of more than $17 million in 2013 (ITC Trade Map).

Chickpea is one of the most nutritious pulse crops, with higher levels of protein than most other legumes. It ranks second in area and third in production among pulses worldwide. Originally, chickpeas were grown in temperate regions, but newer varieties are adapted to tropical and subtropical climates in Africa. In Ethiopia, it is grown in mixed crop-livestock farming systems. It is usually produced in rotation with wheat or teff, the main Ethiopian cereal. It is a crop favoured by smallholder farmers for both household consumption and as a cash crop in Ethiopia because of its low labour requirements and relatively high yields. It is estimated that 40 percent of produce is consumed by the farmers, 10 percent kept as seed for the next season and 50 percent sold to regional and central markets (Van den Broek, 2014).

Soybean is the most produced legume crop in the world, accounting for annual production of 276 million tonnes between 2012 and 2014. Only a small portion of total production is directly consumed as food. Most of it is processed to produce soybean oil and soybean meal or cake. Soybean oil is one of the most used cooking oils. Soybean meal is the largest source of protein feed in the world and one of the key ingredients of animal feed. African production pales in comparison to the production capacity in the Americas where the USA, Brazil and Argentina together, are responsible for 85 million tonnes, 4 percent of annual production. There is, however, a growing interest for soybean production in Africa. According to more recent figures from ICRISAT, Nigeria is now producing more soybean than South Africa. Trade Map data shows that Ethiopia was Africa's largest soybean exporter in 2015.

One of the few legume crops that has received a lot of attention from crop research and development is soybean. Drought- and heat-tolerant soybean varieties have had reasonable success in SSA. Thanks to these innovations and the strong market pull, yield and productivity of soybean in Africa have increased in the last years. Nigeria and South Africa have been relatively big producers of soybean in recent years. Areas of expansion are Southern Africa, in countries such as the Democratic Republic of the Congo (DRC), Zambia, Zimbabwe, Malawi, Rwanda and Burundi. Still, the local market for soybean in countries such as Nigeria is small, with many people not knowing how to process the beans or prepare meals with them, so the incentive for farmers to grow it is weak. The IITA encourages soybean consumption and has adapted farming techniques to reduce labour. They also developed various soybean processing machines and a wide range of soybean food products. This resulted in an increase in consumption and production and increased income for the manufacturers.

Finally, groundnut is the fifth most widely grown crop in SSA after maize, sorghum, millet and cassava. Nigeria is Africa's main producer of groundnut; West and Central Africa account for 70 percent of total African groundnut production. The total production of groundnut on the African continent between 2008 and 2013 was 11 million tonnes.[1] However, after years of stable growth, yields of groundnut in SSA have been rapidly declining in the last few years, mainly due to erratic rainfall and terminal drought. One of the main problems in groundnut production and post-harvest management affecting food safety and export of groundnut is aflatoxin. International agricultural research estimates that about one third of the groundnut produced globally is eaten and two thirds are crushed for oil (cooking oil and many industrial applications). Residue from the oil-pressing process is used as animal feed and fertilizer. Groundnut stems and leaves are used as fodder. Groundnut is a popular rotation crop with cotton, maize, sorghum or other cereals.

1 See: http://harvestchoice.org/commodities/groundnut

BOX 3

Assessing EIA frameworks for livestock production systems: a review by the Stockholm Environment Institute (SEI), (SEI, 2015)

SEI (2015) conducted a literature review of EIA frameworks for livestock and agriculture and identified 50 frameworks. From these, it filtered nine frameworks on the basis that they enabled the measurement of nine key environmental impact dimensions: 1) GHG emissions; 2) energy use; 3) water usage and pollution; 4) biodiversity loss; 5) nutrient cycling, mainly of nitrogen and phosphorus; 6) land use; 7) land cover changes; 8) waste products and emissions; 9) eco-toxicity.

Furthermore, out of the 50 frameworks, 28 are categorized as general frameworks, 10 as dimension-specific (i.e. covering a single environmental impact dimension) and 12 as modelling frameworks. Just over half of the identified frameworks (26) are applied to case studies in developing countries.

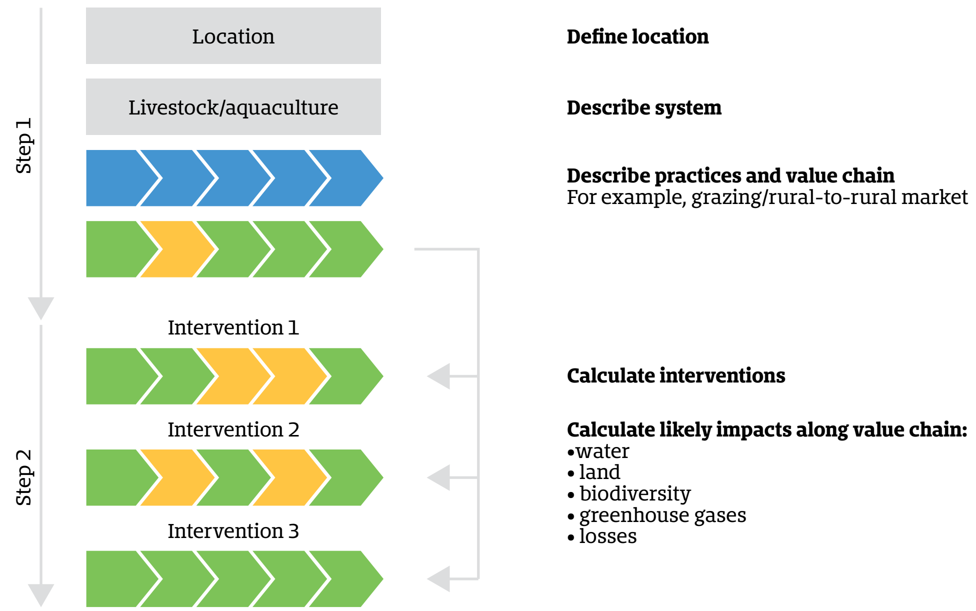
The authors have identified three big gaps in research: first, there is a need for effective methods of assessment that focus on livestock VCs and their environmental impact, since there is often a lack of consensus on how to address certain impacts. For example, there is no consensus on how to address the impact dimension of water. A distinction should be made between assessments of water quality and water quantity because they use different indicators and methods. In the case of the LCA, for instance, water use is measured by indicators related to local water stress, using a local-specific water stress indicator to spatially connect the calculations to the local importance of water use. Water quality is then usually assessed in terms of pesticide use, fertilizer use and the nutrient balance associated with production. Secondly, there is a need for ex-ante assessments that can be used to identify desirable outcomes and trade-offs, and that can indicate a benchmark for livestock projection systems under development, thus helping policymakers and decision makers, as well as investment agents, to determine impacts, trade-offs and co-benefits of proposed development. TEEB is, however, trying to bridge this gap in research. Thirdly, none of the 50 frameworks can capture the entirety of the impacts caused by livestock production. Therefore, there needs to be an increased understanding of the links between livestock VCs and local, regional and global landscapes for there to be a realistic chance that the projected increases in livestock production can be sustainable.

The way forward is to create environmental and sustainability assessments of livestock and agricultural VCs that are holistic (i.e. the systems approach, mentioned in section 2.1): they need to capture all environmental impacts and measure such impacts at multiple temporal and spatial scales. The challenge will be to match different methods with different input and output data, to generate results that are both easy to analyse and comparable. In addition, for a framework to be successful in assessing the environmental impacts of livestock VCs, it should include: 1) a clear aim and purpose; 2) a set of measurable objectives that cover multiple spatial and temporal scales; 3) indicators to measure the concrete objectives; 4) a clear and visible presentation of the outputs that is comparable with other assessments (e.g. visuals, infographics), easy to understand for the target audience and other targeted parties; and 5) a provision of clear information on the chosen focus of the assessment method, why the EIAs have been chosen, the methods and indicators that will be used to measure them and why these indicators and methods have been selected. Finally, two promising frameworks often referred to in the

study are the Driving forces, Pressures, State, Impacts, Response (DPSIR) analysis framework and the LCA methodology. The latter is discussed in more detail further on.

The SEI study was conducted as part of the CLEANED–LVC project (Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along Livestock and aquaculture VCs). This project was set up to provide a rapid assessment tool that can indicate the likely impacts of planned interventions in livestock and fish production systems (e.g. the pressure of livestock production on water and land). Such a tool can support informed decision-making and have a positive impact on nutrition and food security, while sustaining the natural resources base for the future. Moreover, this rapid assessment framework encompasses the entire VC. In the calculation of impact, more emphasis is placed on the earlier stages, as most of the environmental impact of livestock VCs can be observed inside the farm gate. An estimate of total food loss in the later stages will be used to increase ecosystems' efficiencies and thereby influence the extent of the environmental impact.
The CLEANED–LVC framework could be used in several ways, including to identify the likely impacts of implementing specific technologies, to quickly evaluate the impacts of a wide range of interventions or to link these interventions to global and regional change models.

FIGURE 7 CLEANED–LVC project (Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along Livestock and aquaculture VCs)



Source: https://www.ilri.org/cleaned

TABLE 2

The nine frameworks that were reviewed in-depth (SEI, 2015)

FRAMEWORK	ORGANIZATION AND/OR DATE ESTABLISHED	AIM OR PURPOSE	APPLICATION
Vital Signs – African monitoring systems (Scholes, Palm and Andelman, 2013; Vital-Signs, 2014)	Conservation International (CI), the Council for scientific and Industrial Research (CSIR) in South Africa, and the Earth Institute (EI) at Columbia University.	To ensure that improvements in food production also support livelihoods that are resilient, and healthy natural ecosystems.	Initially launched in five African countries – Tanzania, Ethiopian, Ghana, Uganda and Mozambique.
Response-Inducing Sustainability Evaluation (RISE) (Grenz et al., 2009; Häni et al., 2003; Häni et al., 2006; Häni, Stämpfli, Tello, et al., undated)	Barn University of Applied sciences. Partnered with Nestle, the research Institute of organic Agriculture, the Danone Fonds pour l'Ecosysteme, the Swiss Federal Office for Agriculture and Energy and Capacity Building International (GIZ)	Indicator – and interview – based method for assessing the sustainability of farm operations.	RISE has been used in 40 countries on more than 1400 farms, both agriculture and dairy.
AgBalance (AgBalance, 2012; Schoeneboom, Saling and Gipmans, 2012)	BASF	AgBalance is a tool designed to assess the sustainability of agricultural products processes.	Unknown amount of applications but built on several hundreds of previous case studies.
Life-Cycle Assessment (LCA) (Bauman and Tillman, 2004; Cederberg, Flygsjö and Ericson, 2007; Cederberg, Henriksson and Berglund, 2013; De Boer, 2003; De Boer et al., 2011; De boer et al., 2012; De bries and De Boer, 2010; Flygsjö, Cederberg, Henriksson and Ledgard, 2012; Frava;, 2014; Thomassen, Dalgaard, Heijungs and De Boer, 2008; Vellinga et al., 2013)	Ian bousted published the first book on LCA work in 1979.	A holistic method for evaluating environmental impact during the entire life cycle of a product, considering two types of environmental impacts: (1) use of resources; and (2) emission of pollutants.	Unknown. Standardized method. 70 articles on livestock-related LCSs have been identified (Fraval, 2014)
World Agricultural Watch (WAW) (CIRAD, 2011 ; FAO, 2012b; George, Bosc, Even, Belieres and Bessou, 2012)	FAO, Agricultural research for development (CIRAD), and the French Government, with the participation of the International fund for agricultural development (IFAD)	The main goal is to bring the dynamics and relative performances of different types of agriculture into the policy debate in terms of production and economic, social and environmental sustainability at the local and global levels, while taking anticipated changes into account.	Farms in Vietnam, Marley and Madagascar
Environmental sustainability index (ESI) (Esty, Levy, Srebotnjak and de Sherbinin, 2005, 2005a, 2005b, 2005c)	Yale Centre of environmental law and policy, Center for International Earth Science Information Network (CIESIN)	The environmental sustainability index capital (ESI) is a measure of overall progress towards the environmental sustainability of the national environmental stewardship based on a compilation of indicators derived from underlying datasets.	Global assessments, applied to all nations
Sustainable performance assessment (SPA) (Elferink et al., 2012; Kuneman et al., 2014; SAI, 2010)	Sustainable Agriculture Initiative, 2010	A blueprint for a set of indicators on chosen sustainability issues, aims to indicate to finalise the impact of the farming practices to help them improve the sustainability of their funding.	Not applied yet
MESMIS (López-Ridaura, van Keulen, van Ittersum and Leffelaar, 2005a, 2005b; López-Ridaura, Colomer, Astier and Masera, 2007)	Interdisciplinary group for rural technology	A systemic, participatory, interdisciplinary and flexible framework for evaluating sustainability, offering guidelines on the selection of specific environmental, social and economic indicators focused on the important characteristics that steer systems performance.	More than 20 case studies in Mexico and Latin America.
GAIA (CLM, 2012, 2014)	CLM, 2012	A yardstick to make biodiversity measurable and comparable.	Unknown. Free online access web tool

TABLE 3 Checklist of how value chain interventions might produce climate-resilient outcomes (IFAD, 2015)

VALUE CHAIN INTERVENTIONS/ OUTCOMES	CLIMATE RISK ISSUES	CLIMATE RISK MANAGEMENT OPPORTUNITIES
INPUT SUPPLIES		
Seeds	High-yield varieties may perform poorly under higher temperatures, humidity salinity; certain hybrid seed varieties degrades soils over the long term	Provide access to specific climate-adapted varieties where available (e.g. heat-tolerant, submergence-tolerant); maintain diversity through seed banks, including wild relatives (CGIAR, 2013); test different seeds under different conditions
Fertilizers	Generally positive and low-input systems, but may increase inter-annual variability in yields; trade-offs with emissions	Integrate fertilizer advice and supply with wider soil management (FAO, 2013, Module 4); precision farming
Animal feed and breed	Feed quality helps emissions reductions, but larger better-fed animals maybe more exposed to climate-related water stress	Evaluate heat tolerance, housing and feed requirements of proposed livestock (FAO, 2013, module 8)
Pest management	Possible increases in pests and diseases for crops (e.g. maize stem borer, tomato flies, cassava mealy bug) and livestock (e.g. cattle ticks)	Promote integrated pest management (e.g. push-pull methods [Minja 2006]); develop monitoring, knowledge and applied research systems for pests and diseases of crops, livestock and fisheries
Information services	Advance climate information enables better decisions about the timing of planting, input application and harvesting, and the choice of varieties, labour inputs and planting or grazing locations	Enable provision of seasonal and near-term forecast in formats usable and accessible by farmers (Tall, 2013); strengthen early warning systems; invest in country-level capacity in scaled down climate impact modelling (WCRP, 2013; CCAFS, 2013) and scenario planning
Financial services	Lack of upfront capital may be a major drawback for farmers to adopt climate-resilient practices	Investigate financial channels to reduce risks associated with innovation (e.g. microfinance, small grants programmes, index-based weather insurance (WFP and IFAD, 2011)
Tools and equipment	Possible damage of tools and equipment (e.g. water tanks, irrigation canals, pumps, generators, vehicles, seed storage) from extreme weather events	Substitute low-cost high-efficiency systems wherever possible (e.g. rainwater harvesting plus surface water irrigation); provide access to early warning systems; introduce protective features to the siting and storage of seeds, tools, vehicles, fuels and energy infrastructure
AGRICULTURAL PRODUCTION		
Soil management	Rising temperatures, greater soil moisture evaporation and more destructive interplay between dry spells and intensive rainfall events increase soil erosion and reduce soil organic content	Introduce measures to counter soil erosion (e.g. terracing, contour bunds, drainage, agroforestry, perennial crops); increase soil carbon and improve management of soil organic matter; rehabilitate degraded lands (FAO, 2013, module 4)
Water management	Greater crop evapotranspiration; loss of soil water; changes in amount and timing of rainfall; more variable river run-off; reduced groundwater recharge; changes in sea level; salinity intrusions into soil and groundwater	Adopt water conservation and efficiency measures such as water harvesting, efficient irrigation infrastructure, check dams, flood management and drainage; support riparian habitat restoration; undertake hydraulic hydrological and salinity monitoring; introduce water allocation systems (FAO, 2013, Module 3)
On fire and energy	Mechanization using fossil fuels causes emissions increases; use a fuelwood can cause deforestation and erosion	Undertake trade-offs analysis (FAO, 2011; FAO, 2013, Module 5); introduce renewable energy sources (e.g. solar energy for heating, cooling, drying and pumping, small wind turbines, biogas digesters)

VALUE CHAIN INTERVENTIONS/ OUTCOMES	CLIMATE RISK ISSUES	CLIMATE RISK MANAGEMENT OPPORTUNITIES
INPUT SUPPLIES		
AGRICULTURAL PRODUCTION *cotinued*		
Diversification	Monoculture crops are more prone to catastrophic losses from climate extremes than diversified systems	Investigate potential for sustainable intensification and diversified cropping systems through crop rotations (e.g. staple/horticulture), intercropping, agroforestry, mixed crop/livestock systems (FAO, 2013, Module 6)
Livestock	Declining pasture productivity; increasing livestock mortality from heat stress; loss of productive pasture from erosion; damage to livestock infrastructure; declining fodder quality	Introduce mixed crop/livestock farming systems; support pasture restoration; diversify livestock breeds; improve rangeland management; make livestock infrastructure more climate resilient; increase production efficiency (FAO, 2013, Module 8)
Fisheries and aquaculture	Changing salinity conditions in natural reservoirs; shifting fish stocks due to higher water temperatures; migratory shifts of biodiversity	Improve production efficiency and feed management (FAO, 2013, Module 10); diversify aquaculture; introduce mixed crop/aquaculture or aquaculture/livestock systems; introduced mixed fish/crop/forest systems
Production infrastructure	Value chain-related production facilities in certain locations (including fields, greenhouses, livestock facilities) face greater exposure to floods, wildfires, high wind speeds	Include physical risk management structures at farm-level (e.g. windbreaks, flood control dykes, firebreaks); retrofit or relocate sensitive infrastructure; create buffer zones (e.g. wetlands, greenbelts, flood recession schemes)
Landscape-level management	Positive value chain outcomes (e.g. higher incomes) may incentivise greater land clearance and unsustainable water use, affecting local microclimate and hydrology and compounding climate hazards	Undertake participatory mapping and land-use planning; remote sensing-based landscape monitoring; exploit all available incentives (financial, regulatory, etc.) for sustainable environmental management in the project area (FAO, 2013, Module 9)
Skills base of farmers and local institutions	Local knowledge and capacity is central to managing production under conditions of rapid change	Invest in local capacity for planning, monitoring, decision-making and financial management; transfer control to local institutions; provide training on climate issues and support to farmer-based research and knowledge systems; include smallholders in policy dialogue and scenario-building exercises
POST-PRODUCTION: STORAGE, PROCESSING, TRANSPORT AND RETAIL		
Post-harvest management	Rising losses in harvest volume; declining safety, market quality and nutritional value due to increasing temperatures, humidity, pests and diseases	Incentivize waste reduction measures and value addition for by-products (FAO, 2013, Module 11); provide renewable energy sources to cover changing requirements for cooling, drying, milling and threshing
Siting of processing facilities	Extreme climate events (such as floods, heatwaves, storms) may damage processing facilities; shifting climatic conditions may render some sites redundant or increase transport costs	Use hazard exposure and crop suitability maps to inform siting of processing facilities; retrofit processing facilities with protective features; insure processing facilities against extreme climate events

TABLE 4

The three pillars of CSA (WorldFish, 2015, adapted by Knaepen et al., 2015

	FOOD SECURITY (SUSTAINABLE PRODUCTIVITY IMPROVEMENT)	ADAPTATION (BUILDING RESILIENCE)	MITIGATION (REDUCING GHG EMISSIONS AND ENHANCING GHD REMOVAL)
Farm issues	Sustainable intensification Integrated farming Improved nutrients and water management	Conservation agriculture Adjust crop calendars Use different crop cultivators and animal species and strains Integrated pest, disease and weed management	Precision agriculture Improve soil-carbon storage/ Develop carbon sequestration options (conservation tillage, covered cropping, crop rotation)
Landscapes and regional issues	Landscape approach Restoration of degraded farm lands, wetlands and forests	Ecosystem-based agriculture (to improve ecosystem services) Agro-forestry (enhance the role of forests	Agro-ecology
Institutional and policy issues	Strengthening science-policy linkages CSA mainstreaming in agricultural development policy frameworks Trade-offs between diversification vs. specialization Gender, youth involvement & reduction inequalities	Enhanced whether information systems and advisory services Empower women and the poor Pro-poor financing, insurance mechanisms and safety nets	Incentives for pro-poor mitigation

BOX 4

By the numbers: GHG emissions from livestock (FAO, 2016c)

Total emissions from global livestock: 7.1 gigatonnes of CO_2-equivalents per year, representing 14.5 percent of all anthropogenic GHG emissions. This figure is in line with FAO's previous assessment, Livestock's Long Shadow, published in 2006, although it is based on a much more detailed analysis and improved data sets. The two figures cannot be accurately compared, as reference periods and sources differ.

Cattle (raised for both beef and milk, as well as for inedible outputs such as manure and draught power) are the animal species responsible for the most emissions, representing about 65 percent of the livestock sector's emissions.

In terms of activities, feed production and processing (this includes land-use change) and enteric fermentation from ruminants are the two main sources of emissions, representing 45 and 39 percent of total emissions, respectively. Manure storage and processing represent 10 percent. The remainder is attributable to the processing and transportation of animal products.

Cutting across all activities and all species, the consumption of fossil fuel along supply chains accounts for about 20 percent of the livestock sector's emissions.

On a commodity basis, beef and cattle milk are responsible for the most emissions, contributing 41 percent and 20 percent respectively of the sector's overall GHG outputs. (This figure excludes emissions from cow manure and cattle used as draught power).

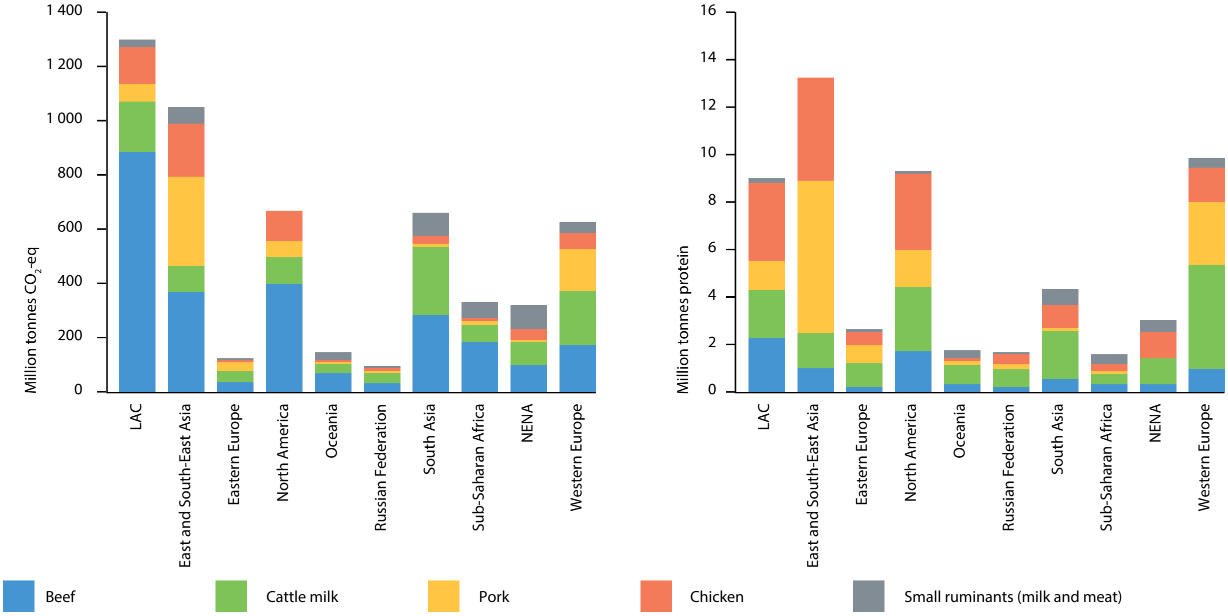
They are followed by pig meat, (9 percent of emissions), buffalo milk and meat (8 percent), chicken meat and eggs (8 percent), and small ruminant milk and meat (6 percent). The remaining emissions are sourced to other poultry species and non-edible products.

Emission intensities (i.e. emissions per unit of product) vary from commodity to commodity. They are highest for beef (almost 300 kg CO_2-equivalents per kilogram of protein produced), followed by meat and milk from small ruminants (165 and 112 kg CO_2-equivalents per kilogram respectively). Cattle milk, chicken products and pork have lower global average emission intensities (below 100 CO_2-equivalents per kilogram). At the subglobal level, within each commodity type there is very high variability in emission intensities, due to the different practices and inputs to production used around the world.

Enteric emissions and feed production (including manure deposition on pasture) dominate emissions from ruminant production. In pig supply chains, the bulk of emissions is related to the feed supply and manure storage in processing, while feed supply represents the bulk of emissions in poultry production, followed by energy consumption.

About 44 percent of livestock emissions are in the form of methane (CH_4). The remaining part is almost equally shared between nitrous dioxide (N_2O, 29 percent) and carbon dioxide (CO_2, 27 percent).

FIGURE 8 Global livestock production and GHG emissions from livestock, by commodity and regions



Source: GLEAM, cited by Gerber et al., 2013.

BOX 5

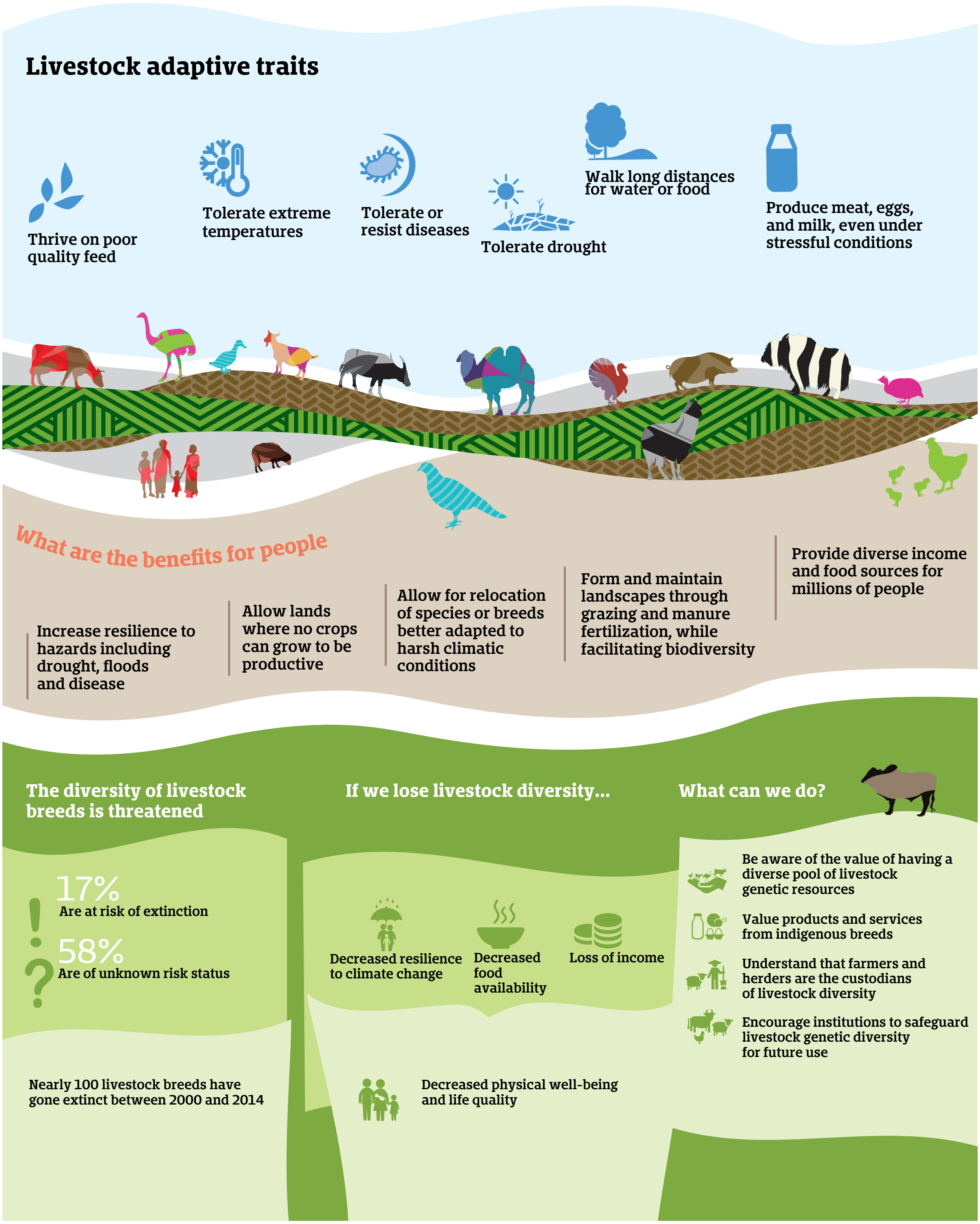
Practices under SRI

SRI works best when the following seven rice agronomic practices are combined:

1. Use young seedlings, i.e. 8–12 days old, maximum 15 days – to enhance the plants' growth potential.
2. Avoid trauma (or shock) to the roots – transplant quickly, at shallow depth (1–2 cm). Avoid inversion of seedling's root tips as this could delay the plant's growth after transplanting.
3. Transplant one plant per hill instead of the usual three to five seedlings (ngundi). Plant in lines and in a square pattern.
4. Give plants optimally wider spacing – about 25 cm × 25 cm. With wider spacing and a single plant per hill, plants get more sunlight, air and nutrients, enabling faster growth of roots and canopies, and producing stronger stalks and more tillers.
5. Do not continuously flood the soil. You can just keep the soil sufficiently moist or practise AWD. This enables the soil to hold air. This has been scientifically proven to enable plant roots to grow more profusely due to presence of oxygen in the soil, leading to effective nutrient uptake, healthier plants and better grain.
6. Weed control is preferably done using a simple mechanical (rotary) weeder. This kind of weeding actively aerates the soil, while mixing weeds with the soil to form green manure.
7. Enhance soil organic matter as much as possible by applying compost, mulch, manure. Chemical fertilizers can be used with SRI, but the better results are obtained wit.

FIGURE 9

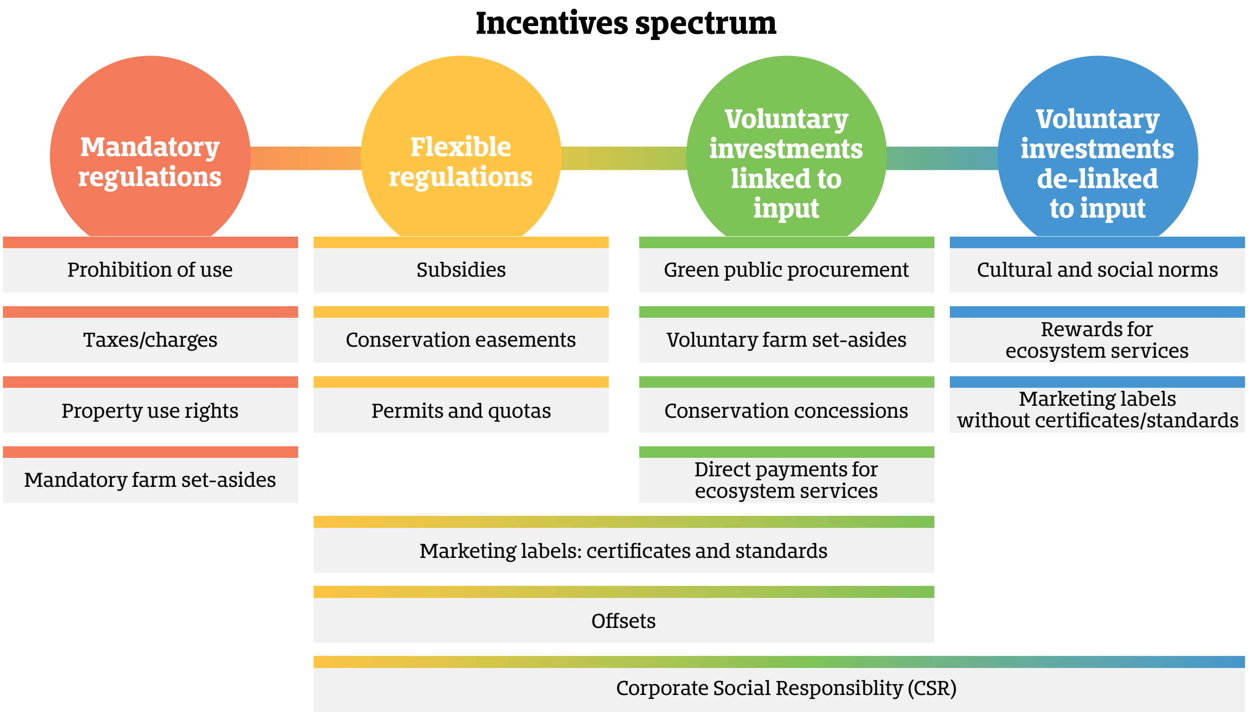
Livestock diversity helps cope with climate change



Source: FAO, 2016c.

FIGURE 10

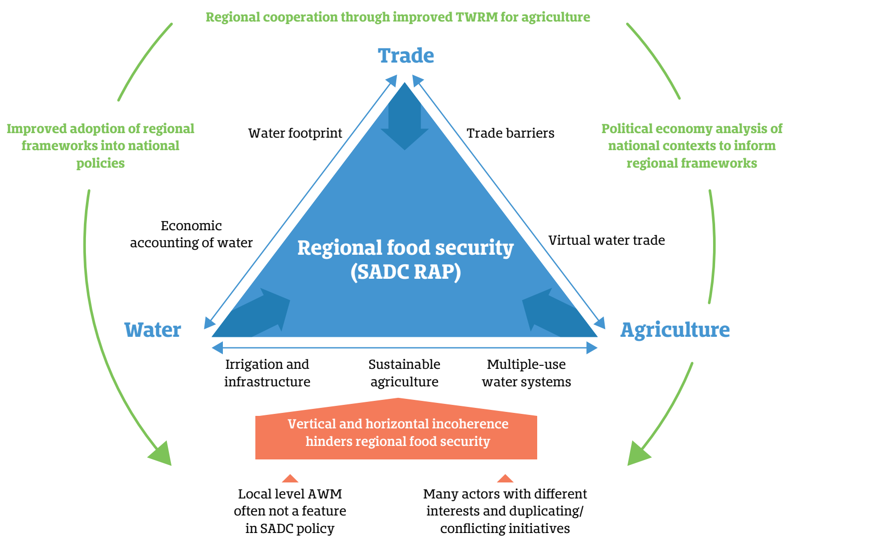
Overview of incentives for ecosystem services



Source: Garrett, 2016.

FIGURE 11

Water, agriculture and trade: a potential three-sided sectoral synergy for regional food security in SADC



Potential synergies/what CAADP can do
Bottlenecks to achieve regional food security
Bridging actors and sectors

SADC Souther African Development Community
RAP Regional Agricultural Policy
AWM Agricultural Water Management
TWRM Transboundary Water Resources Management

Source: Rampa & Van Wyk, 2014.

This study was conceptualized, technically implemented and commissioned by the **United Nations Development Programme (UNDP)**, Regional Service Centre for Africa (RSCA), Inclusive Growth and Sustainable Development Cluster (IGSD) and the **Global Environment Facility (GEF)**.

The **UNDP team**, led by Tomas Sales, includes Pascale Bonzom, Phemo Karen Kgomotso, David Müller and Gemechu Berhanu.

The **GEF team**, led by Mohamed Imam Bakarr, includes Asha Bobb-Semple.

The teams were supported by the independent 'think and do tank' **European Centre for Development Policy Management (ECDPM)**. We would like to thank Hanne Knaepen and Francesco Rampa as co-authors as well as Carmen Torres and Paulina Bizzotto Molina.

We would also like to thank various subject-matter experts from different backgrounds who provided valuable contributions for this study through interviews as well as through their participation in the expert validation workshop of this study, which was held in Debre Zeyit, Ethiopia in May 2017.

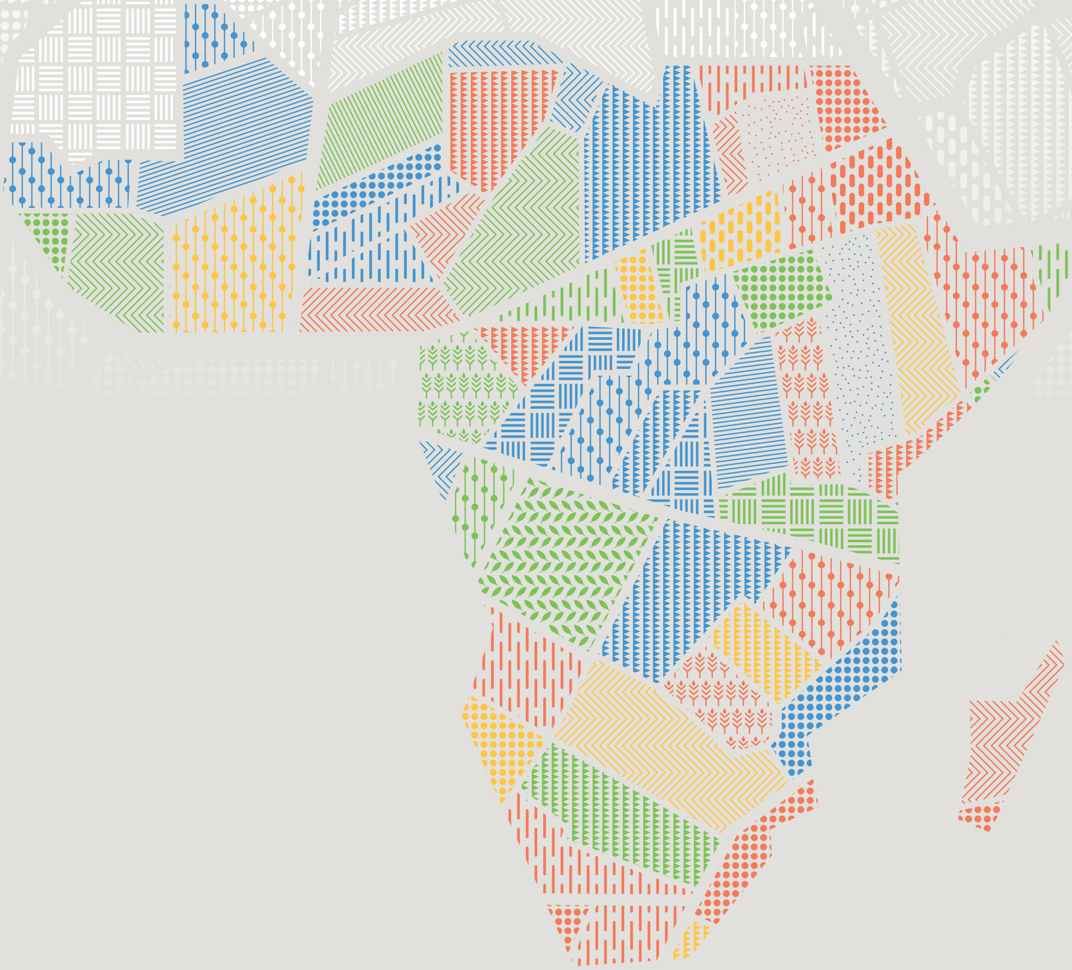
Options and Opportunities to Make Food Value Chains More Environmentally Sustainable and Resilient in Sub-Saharan Africa

August 2017

For more information, see:
www.undp.org/africa/privatesector

United Nations Development Programme
One United Nations Plaza, New York, NY 10017, USA

Design: Strategic Agenda UK LTD



Empowered lives.
Resilient nations.

GLOBAL ENVIRONMENT FACILITY
INVESTING IN OUR PLANET

United Nations Development Programme
One United Nations Plaza
New York, NY 10017, USA

www.undp.org/africa/privatesector

The World Bank
1818 H Street NW
Washington, DC 20433, USA

www.thegef.org