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Cross-cutting capacity building,
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Food Security Integrated Approach

Pilot Program

(Ethiopia, Uganda, Ghana, Burundi, Swaziland, Kenya, Senegal, Burkina, Niger, Malawi, Tanzania and Nigeria)

Best Practices and Guidelines for Policy Action

A Progress report submitted by UNEP (2020)

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Sustainable Land Management for Food Security in Africa

Best Practices and Guidelines for Policy Action

Peter Lowe/ CIMMYT

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Executive Summary

Food insecurity in Sub-Saharan Africa has been a reality for many years as droughts and social crises have brought loss of life and livelihood. With the growing threat of climate change and environmental degradation, African leaders must mitigate and adapt to these new realities if they want to guide their countries on a path to the prosperous economic development that is their destiny.

To assist them, the international community assembles the best of agricultural and social science and provides the means for its application and dissemination into small holder farming communities. To this end, the International Fund for Agricultural Development (IFAD) developed its Integrated Approach Programme (IFAD IAP) on Food Security (IAP-FS) in sub-Saharan Africa with funding from the Global Environment Facility (GEF). The IAP-FS targets agro-ecological systems in the drylands of Sub-Saharan Africa (SSA) where the need to enhance food security is directly linked to opportunities for generating local and global environmental benefits.

Under IFAD's leadership, this report is UNEP's contribution to the IAP-FS. The document presents best practices under the aegis of Sustainable Land Management (SLM) for SSA agriculture. SLM not only protects the valuable land resource, but it provides for the economic well-being of the small holder farmers. The best SLM practices identified here include Integrated Soil Fertility Management (ISFM), Conservation Agriculture (CA), Rain Water Harvesting (RWH), Agroforestry (AF), Ecosystem-based Adaptation for small holder farmers, and Reduction of post-harvest losses. Evidence of application of these best practices in SLM from countries across SSA is documented and demonstrates positive impacts both for the environment and the livelihoods of communities. A key message is that, in the face of climate change, land degradation, environmental or social crises, agriculture in SSA needs to ramp up the use of SLM to minimize food insecurity.

Some of the main findings from the application of these best practices in SSA include:

- **Integrated Soil Fertility Management (ISFM)** embodies the principles of Inclusive CE in SSA and is based on 3 principles: (1) maximising the use of organic sources of fertilizer; (2) minimising the loss of nutrients; (3) judiciously using inorganic fertilizer according to needs and economic availability. ISFM was applied in Meru South district, Kenya where low soil fertility was a systemic problem. Using maize as a test crop, experimental treatments were conducted with different combinations of leguminous trees, herbaceous legumes, cattle manure, and chemical fertilizer. Results showed that farmers participated actively in the experiments, formed farmer groups, and practiced various technologies on their farms. Findings confirmed that adoption of new agricultural technologies, such as ISFM, has generally lagged behind scientific and technological advances, and their impact on agricultural production has been low. Future work must address the lack of adequate understanding of farmers' adoption behavior towards the new technologies.
- **Conservation Agriculture (CA)** was tested in Ghana and Tanzania and is based on minimum soil disturbance, permanent soil cover, and crop rotation. In Ghana, a reduction in labor costs was reported, whereas in Tanzania, small holder farmers were able to harvest at a reduced level during a drought period when other farmers had very little to show. The implication was that CA is a viable option for obtaining at least a survival harvest, even during times of crop stress.
- **Rain Water Harvesting (RWH)** refers to all technologies where rainwater is collected to make it available for agricultural production or domestic purposes. RWH minimises effects of seasonal variations in water availability due to dry periods thereby enhancing the reliability of agricultural production.
- **Agroforestry** is a practice in which woody perennials are deliberately integrated with agricultural crops and/or livestock in some form of spatial arrangement or temporal sequence for a variety of benefits and services. For example, fodder shrubs are very attractive to farmers because they require little or no cash input, nor do they require farmers to take land out of production for food or other crops. In one regional project in East Africa, farmers planting Calliandra shrubs increased their net income by between US$ 62 to 122/year depending on whether they used shrubs as a substitute, a supplement, or where they are located.
- **Ecosystem-based Adaptation (EbA)** uses biodiversity and ecosystem services to help people adapt to climate change. Benefits include the continued provision of key ecosystem services (water, food, nutrient regulation, pest control, pollination) on which farming depends. Ecosystem-based Adaptation for food security in Africa Assembly (EBAFOSA) is a UNEP-led initiative that convenes partnerships to bridge policy and operational gaps to climate proof Africa food systems. For example, the Sierra Leone EBAFOSA task force is harmonizing finance, industry, energy,

agriculture sectorial policies to establish tax concession incentives for agro-based industries in rural areas.

- **Reducing post-harvest losses** builds incentives to minimise losses across value chains. Recent estimates indicate about one-third of all food produced in the world is either lost or wasted, while in sub-Saharan Africa post-harvest grain losses total $4 billion per year. To minimize post-harvest losses, Hermetic Storage (HS) is gaining popularity as a storage method for cereal, pulses, coffee, and cocoa beans in developing countries due to its effectiveness and avoidance of the use of chemicals and pesticides. Ease of installation, elimination of pesticide use, favorable costs, and modest infrastructure requirements are some of the additional advantages that make the hermetic storage options attractive.

These SLM best practices embody the principles of an Inclusive Circular Economy by keeping resources such as water, soil organic matter, fertilizer, etc. within the system as long as possible. The best practices are not mutually exclusive, so the reader should see them as integrated toolkits from which users can explore the best solutions for their needs. Selection from available best practices should be informed by the science of environmental sustainability and driven by an assessment of the target communities' social and economic needs.

Acronyms

AF	Agroforestry
AGRA	Alliance for a Green Revolution in Africa
C	Carbon
CO_2	Carbon Dioxide
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo
CE	Circular Economy
CA	Conservation Agriculture
CI	Conservation International
EbA	Ecosystem –based Adaptation
EBAFOSA	Ecosystem-based Adaptation for Food Security in Africa Assembly
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FIES	Food Insecurity Experience Scale
FS	Food Security
GEF	Global Environment Facility
HS	Hermetic Storage
IAP	Integrated Approach Programme
ISFM	Integrated Soil Fertility Management
IPCC	Intergovernmental Panel on Climate Change
IFAD	International Fund for Agricultural Development
NDC	Nationally Determined Contribution
N	Nitrogen
NDVI	Normalized Difference Vegetation Index
n.a.	Not available
OM	Organic Matter
RoU	Republic of Uganda
RWH	Rain Water Harvesting
SOM	Soil Organic Matter
SSA	Sub-Sharan Africa
SAP	Sustainable Agricultural Practices
SDG	Sustainable Development Goal
SLM	Sustainable Land Management
UN	United Nations
UNICEF	United Nations Children's Fund
UNCCD	United Nations Convention to Combat Desertification
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
US$	United States Dollar
WB	World Bank
WFP	World Food Program
WOCAT	World Overview of Conservation Approaches and Technologies
WRI	World Resources Institute

Introduction

Land constitutes a key component of all facets of human development and environmental sustainability. It is the foundation, ingredient, and catalyst in the quest for socio-economic progress on Planet Earth. However, its quality, which largely influences the outcomes of these gainful opportunities, precariously hangs on balance due to biophysical and anthropogenic pressures (Shukla et al., 2019). A continued strain on the limits of production results in a phenomenon termed as land degradation (Akhtar-Schuster et al., 2017), which perpetuates a downward spiral in the land quality as well as its biological and economic productivity.

The key biophysical culprits of land degradation (Bongaarts, 2019) include climate change, biodiversity loss, overexploitation, pollution, invasive species, and other current environmental emergencies with direct impacts on land resources. These factors, jointly or singly, affect the health and productivity of land-based natural capital, with loss of its ability to support gainful utilization (FAO, IFAD, UNICEF, WFP, 2019).

A burgeoning human population paired with its demand for resources to sustain it is among the land's adverse anthropogenic burdens. Current reports project an increase of 2 billion people on Earth by 2050 to about 9.7 billion, with most of the surge being in Sub-Saharan Africa (UNDESA, 2019). The population of Sub-Saharan Africa is projected to double by 2050 (99% increase) (EU, 2020), These demographic shifts are expected to generate a more than 50 per cent rise in land-dependent food needs, which is in addition to the existing food security gaps affecting millions of its people (AGRA, 2019). In the frontline of these challenges are Africa's rural smallholder farming communities, who are responsible for producing more than 80 per cent of the region's annual food output.

Reports in 2019 placed sub-Saharan Africa as one of the most food-deficient regions of the world with nearly a quarter of its population affected (AGRA, 2019; FAO, IFAD, UNICEF, WFP, 2019). The region's food-deficient populations constitute more than 30 per cent of the global population clustered as "*chronically hungry people*", despite being home to only 16 per cent of the earth's population.

Imperatively, and in line with the changing demographics, decision-makers and other stakeholders must explore innovative avenues for improving how these needs will be met while ensuring natural capital is sustainably managed. Sustainable Land Management (SLM), through its application to agriculture in SSA, provides these actors with such a roadmap to improve food security for the future. SLM embodies the main principle of an Inclusive Circular Economy (Inclusive CE) (Preston el al. 2019) which is based on a simple concept: to keep resources and materials in use within the production cycle for as long as possible while using a minimal amount of external inputs. SLM in SSA agriculture builds on existing interventions to curtail the agents of adverse shifts in land resources while enhancing productivity in the face of snowballing environmental emergencies.

SLM encompasses ongoing, best practices for sustainable land management. These include integrated food systems approaches that would not only guarantee food security and livelihood needs but also ensure societies remain on course for achieving the Agenda 2030 for Sustainable Development. Such best practices will be pivotal in the attainment of Sustainable Development Goal (SDG) 2 on the need to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. Success in SDG 2 will also contribute to other SDGs, including on poverty, gender equality, economic growth, management of terrestrial ecosystems, and building partnerships.

Entitled, *Sustainable Land Management for Food Security in Africa: Best Practices and Guidelines for Policy Action,* the current compendium highlights trends, challenges, and opportunities for action in sub-Saharan Africa. It presents SLM practices that countries and communities can incorporate in their design of agricultural systems to boost the productivity of land resources. These options can be applied either at the national or community levels, or both. These technologies fall under the *IFAD Integrated Approach Programme* (IFAD IAP) on Food Security in sub-Saharan Africa. The IFAD IAP offers a customizable approach for users to build land management programs, either within investment operations or as standalone technical assistance. Its advantages include building upon the existing volume of evidence and knowledge derived from sub-Saharan Africa, while accessing UNEP's expertise in applying Inclusive CE at science and policy interfaces and its global and regional assessments and advisory services.

In addition, this anthology features case studies and other documentation from twelve African countries (Burkina Faso, Burundi, Eswatini, Ethiopia, Ghana, Kenya, Malawi, Niger, Nigeria, Senegal, Tanzania, Uganda) taking part in the GEF-funded Food Security IFAD IAP, and jointly coordinated with other GEF agencies (United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), the World Bank (WB), Conservation International (CI) and the United Nations Industrial Development Organization (UNIDO). It thus highlights and recommends the principles and best practices for

SLM in sub-Saharan Africa. These include embedding of partnerships, innovation, skills development, knowledge management and harmonized, aligned and scaled-up investments at regional, country, sub-national, and community levels.

SLM and Agenda 2030 for Sustainable Development

Sustainable Land Management (SLM) is the overall Best Practice and is defined as *"the stewardship and use of land resources, including soils, water, animals and plants, to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions"* (WOCAT, n.a.). Achieving the objective of ensuring that productive potential is maintained in the long term will require the implementation of adaptive management and 'triple loop learning', that seeks to monitor outcomes, learn from experience and emerging new knowledge, and modify management accordingly. SLM is the antidote to poor land management by helping to increase average productivity, reducing seasonal fluctuations in yields, and underpinning diversified production and improved incomes. As such, SLM is simply about people looking after the land to safeguard its productivity and that of its connected systems, while preserving inter-generational equity.

SLM seeks to enable people's coexistence with nature over the long-term, while ensuring the perpetuity of provisioning, regulating, cultural and supporting services of ecosystems. Accordingly, in SSA, SLM increases the productivity of agroecosystems while adapting to its socio-economic context. SLM improves the resilience to environmental variability while preventing the degradation of natural resources.

Adopted by the global community in 2015, Agenda 2030 for Sustainable Development constitutes a universal call to action on ending poverty, protecting the planet and ensuring that all people enjoy peace and prosperity by 2030. The call includes a requirement for measures that promote sustainable land management which is the focus of this report. For food security, SDG 2 advocates sustainable solutions to end hunger in all its forms by 2030. The aim is to ensure that all populations have enough quality food to lead a healthy and productive life. Achieving this Goal will require better access to food and the widespread promotion of sustainable agriculture. This entails improving the productivity and incomes of small-scale farmers by promoting equitable access to land, technology and markets, sustainable food production systems and resilient agricultural practices. It also demands increased investments through international cooperation to strengthen the productive capacity of agriculture (Akhtar-Schuster et al., 2017) among developing countries in Africa and other parts of the world. Figure 1 presents indicators

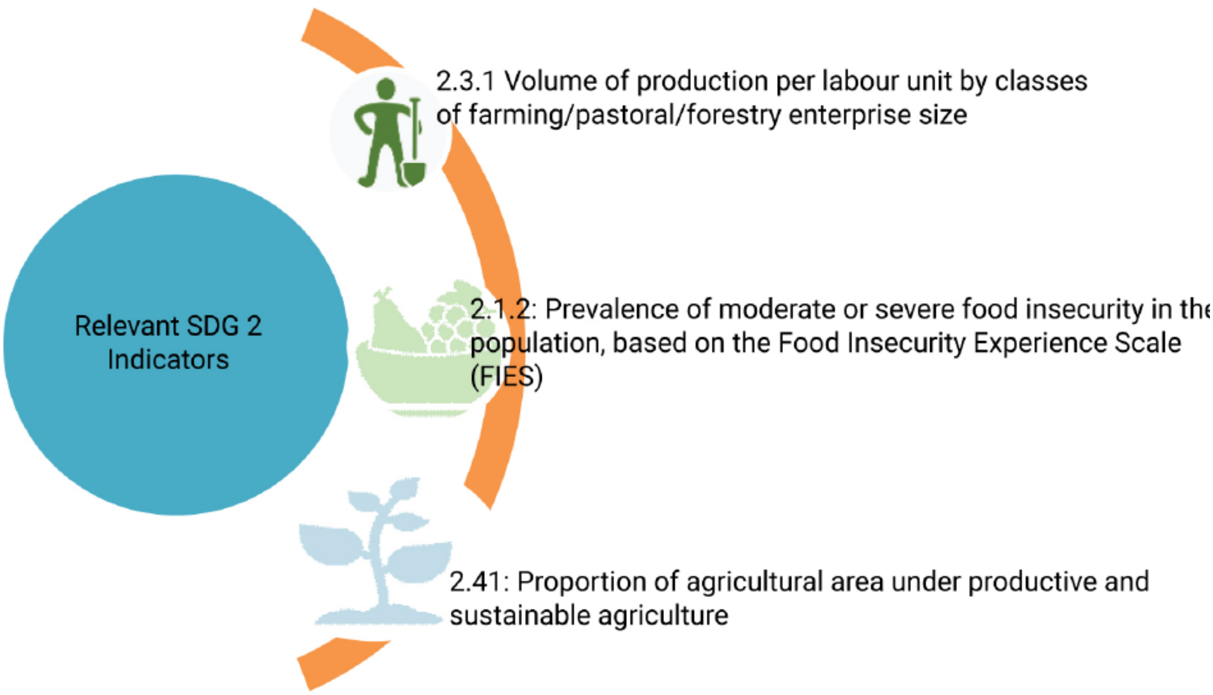


Figure 1: SDG 2 indicators relevant to the nexus between SLM and Food security (UN, 2019a)

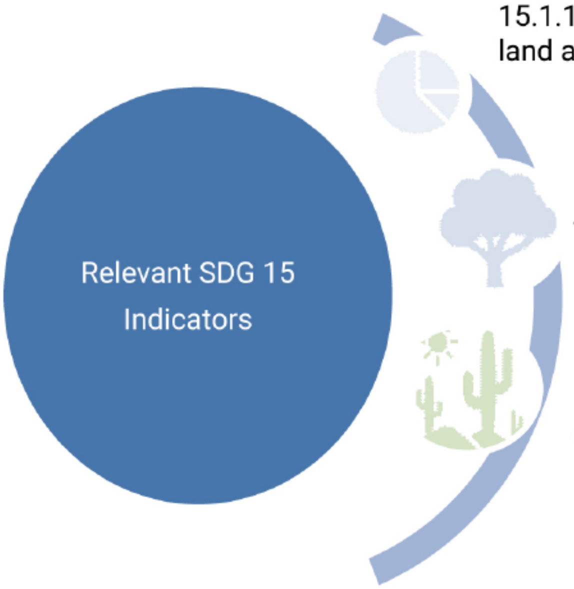


Figure 2: SDG 15 indicators relevant to the nexus between SLM and Food security (UN, 2019b)

used for monitoring progress toward implementing SDG 2.

Goal 15 – *Life on Land* – seeks to enhance the protection, restoration, and promotion of sustainable use of terrestrial ecosystems, paired with sustainable management of forests, and actions to combat desertification. Goal 15 includes twin targets for halting and reversing land degradation, and curbing biodiversity loss. Figure 2 presents indicators used for monitoring progress toward Goal 15.

SLM and Growing Concerns in Sub-Saharan Africa

Sub-Sharan Africa's growing **population**, which is expected to double from its current 1.1 billion to 2.4 billion, constitutes one of the major environmental and socio-economic drivers of change. Its consequences are evident, with ensuing pressure on agricultural land to produce food.

Accordingly, countries in the region will need to meet the food needs of these expanding populations. The need for growth in productivity presents a herculean task for the countries in this region as only 1 per cent of its land is useful for long-term cultivation, despite representing more than 50 per cent of the world's agricultural land. Key among the challenges facing these limited arable lands include declining productivity (Harper & Meado, 2018); (Pflaanz, 2013).

Up to 20 per cent of the world's arable land recorded a decline in productivity in the last two decades with losses per year estimated to USD 6-10 trillion. These declines are both a factor and result of increasing levels of rural poverty. Areas with a high poverty rate comprise 40 per cent of the world's degraded land, while 80 per cent of the world's poor live in rural areas and 64 per cent work in agriculture. At the core of these dynamics are soil nutrient deficiencies due to sub-optimal land management practices and the increasing prevalence of pests and agricultural diseases (GreenFacts, 2019).

Sub-Saharan Africa's land degradation is a major SLM and wider development concern. Resulting from unsustainable land management practices, land degradation (Figure 3) constitutes a significant threat to environmental sustainability and livelihood options in the region. It manifests itself through loss of soil health, vegetation degradation, biodiversity loss, and climatic instabilities. A majority of SSA's growing population directly relies on rain-fed agriculture which puts it at risk to droughts exacerbated by climate change. Hence, SSA is at serious risk of being left behind in the Agenda 2030 development trajectory as shown in Figure 3 below.

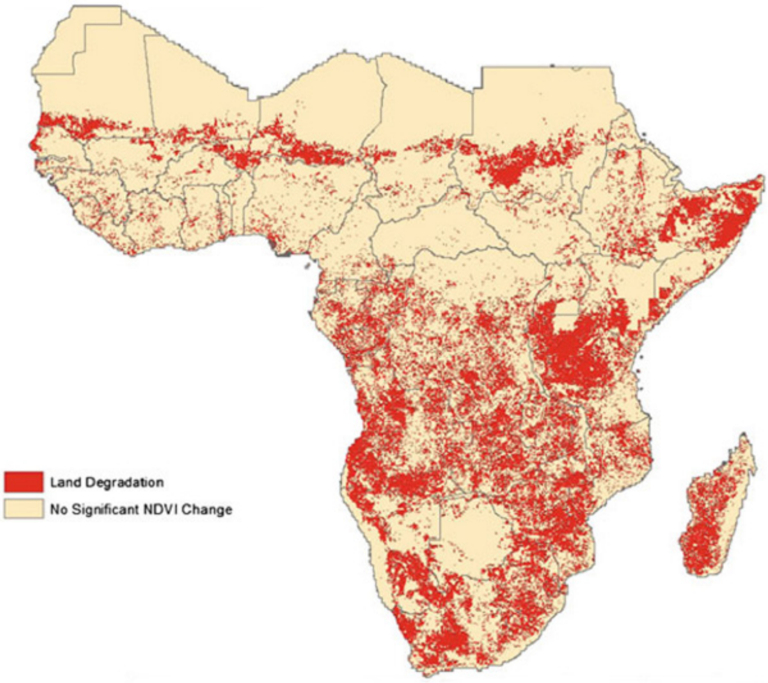


Figure 3: Extent of land degradation in SSA. Note: Red color indicates degradation after correction for rainfall variability and carbon fertilization. Gray color indicates areas that did not experience degradation after correction for rainfall variability and carbon fertilization:
(Nkonya, Mirzabaev, & von Braun, 2015)

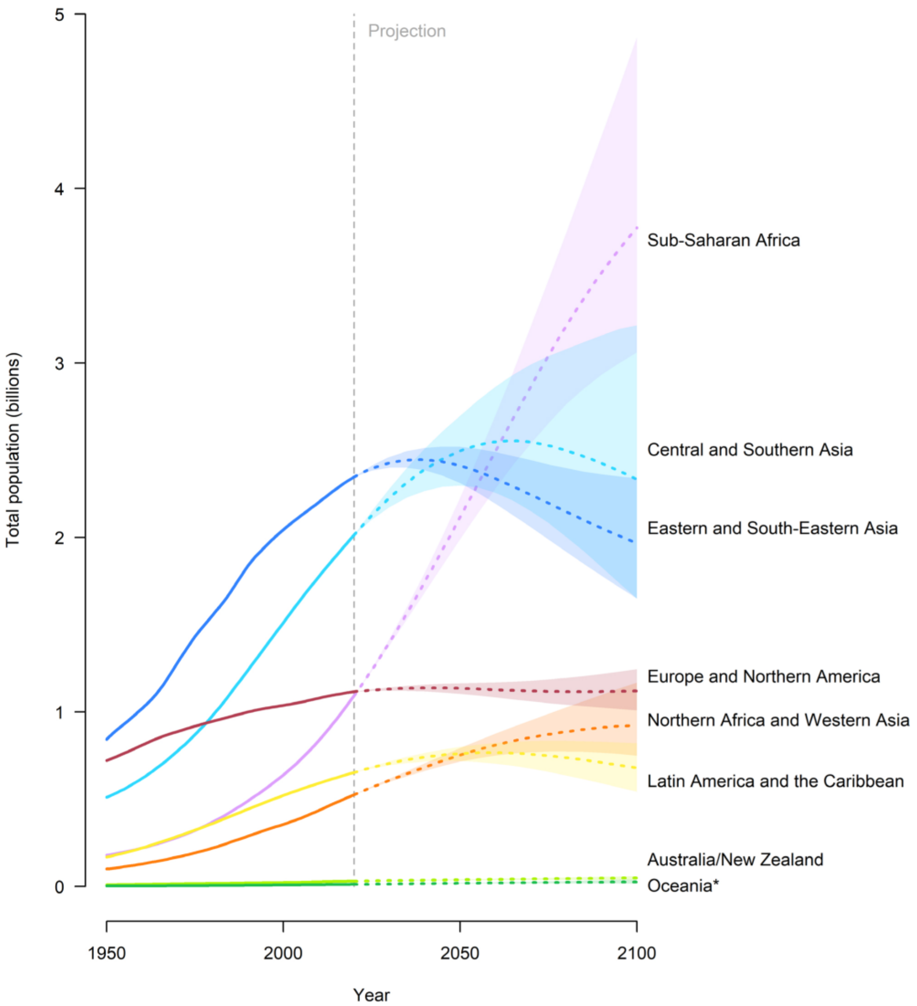


Figure 4: Sub-Saharan Africa is projected to sustain rapid population growth through the end of the century according to the medium-variant projection, compared to other SDG regions (UNDESA, 2019).

Moreover, land degradation lowers resilience to environmental stress while increasing competition for scarce natural resources which results in instability, conflict, and migration. Current estimates show about 1.3 billion people are trapped on degrading agricultural land, with most of them being farmers on marginal lands, including drylands (GreenFacts, 2019). Despite the adverse impacts of land degradation on the poor and the crucial role that land plays in human wellbeing and overall development, investments in sustainable land management (SLM) remain inadequate, especially in developing countries. In response to the climate change challenge, SLM has good potential for mitigation and adaptation at the regional and local levels.

Land degradation occurs in different forms on various land-use types (Nkonya et al., 2015):

- **On cropland:** soil erosion by water and wind; chemical degradation - mainly loss of soil organic matter and fertility decline - due to nutrient mining and salinization; physical soil degradation due to compaction, sealing and crusting; biological degradation due to insufficient vegetation cover, the decline of local crop varieties and mixed cropping systems; and water degradation mainly caused by increased surface runoff (polluting surface water) and changing water availability as well as high evaporation leading to aridification.
- **On grazing land:** biological degradation with loss of vegetation cover and valuable species; the increase of invasive and 'undesirable' species. The consequences in terms of soil physical degradation, water runoff, and erosion are widespread and severe. Low productivity and reduced ecosystem services from degraded grazing lands are widespread and a major challenge to SLM.
- **On forest land:** biological degradation with deforestation; removal of valuable species through selective logging; replacement of natural forests with mono-cropped plantations or other land uses (which do not protect the land) triggering biodiversity loss and soil and water degradation.

Global **climate change** also presents a fundamental concern for SLM in SSA. Climate change exacerbates land degradation, in addition to triggering a downward spiral of overexploitation and collapse of vital natural resources. This, in turn, leads to reduced availability of natural resources and diminishing production, with long-term consequences on food security and poverty. For example, Figure 5 presents a scenario for changes in cereal production by year 2050 in SSA, with predicted impacts in the Sudano-Sahel region being most severe. Climate-change induced degradation carries with it an estimated annual cost of up to US$ 65 billion, which amounts to about 4 per cent of the total GDP of the region. This share varies considerably among countries (UNCCD, 2018). The main drivers are listed in table 1.

The increasing rates of deforestation in Africa are another key concern for SLM. Prevalent in the region is poor forest management policies manifested through unrestricted logging, unsustainable harvesting of firewood and medicinal plants, and uncontrolled infrastructure development in sensitive conservation areas. Loss of vegetation cover has been documented as a main driver for land degradation. Deforestation predisposes people and ecosystems to flooding, forest fires, and other natural disasters. In particular, the removal of standing trees to provide wood for heating and cooking and for making charcoal is a systemic problem in sub-Saharan Africa. Over 70 per cent of domestic energy needs in the region come from woodfuel supplies (UNEP, 2019), a level that is significantly higher than in many other parts of the world (see Figure 6).

Table 1: Main drivers of land degradation (GreenFacts, 2019); (UNCCD, 2018)

Driver	Per cent
Overgrazing	35%
Deforestation	30%
Agricultural activities	28%
Overexploitation for biofuels	7%

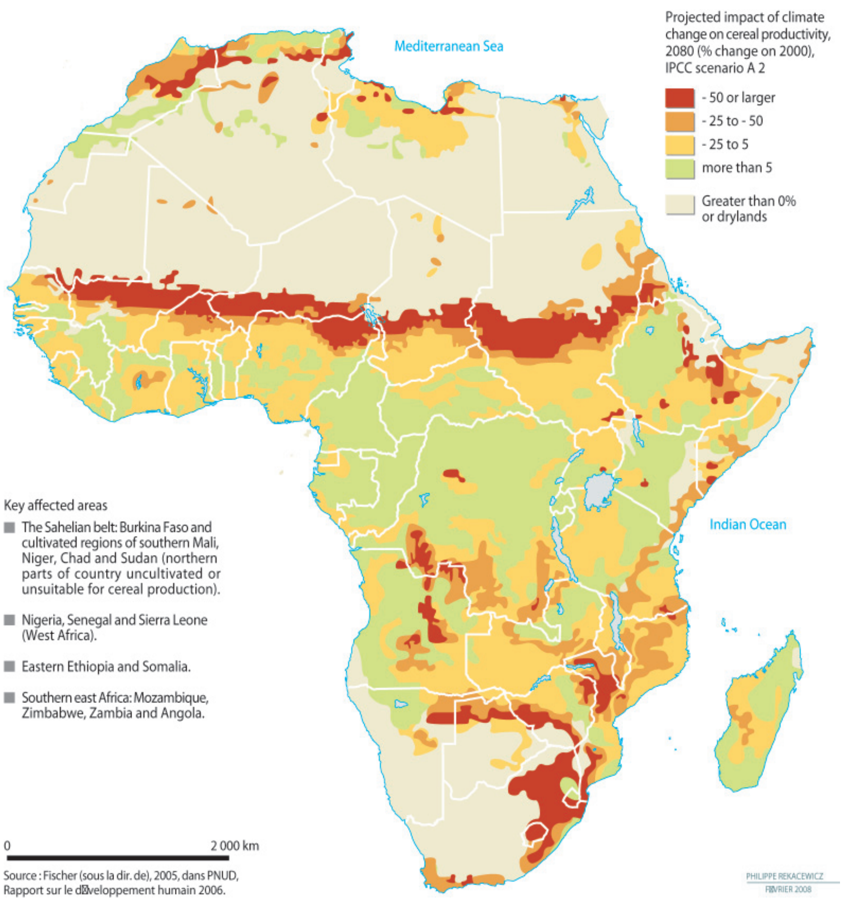


Figure 5: Cereal productivity in SSA under a scenario of IPCC that shows CO_2 atmospheric concentration a level at 520-640 ppm by 2050 (UNEP, 2009)

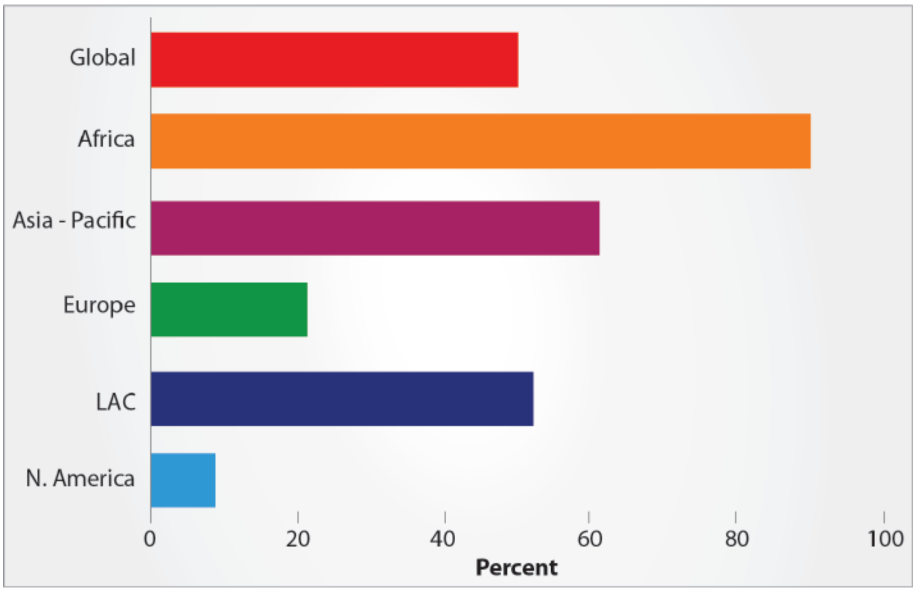


Figure 6: Global and region dependency on woodfuel for domestic needs by percentage in 2016 (UNEP, 2019)

Aims and Audience

These best practices seek to identify, describe, analyse, and present SLM practices for dissemination in sub-Saharan Africa. They focus on innovative solutions and landscape approaches that are appropriate for the region, drawing from the large body of evidence within and outside the region. Materials are drawn from experience and selected case studies that largely focus on those practices with rapid paybacks and profitability, as well as high likelihood for adoption and scaling up. Specifically, the objectives include:

- Knowledge synthesis and dissemination of SLM'S Best Practices;
- Alignment of stakeholders for improved decision support in SSA;
- Promotion of standardised documentation, evaluation, sharing and use of SLM knowledge for decision-making.

Among others, these documentation targets include key stakeholders in SLM programmes and projects, with various roles in the design and implementation stages. These encompass policymakers, planners, programme managers together with practitioners, international financial and technical institutions, and other donors. The highlighted best practices seek to raise further awareness and understanding among the wider public on matters that are linked to SLM and livelihoods, including poverty, environmental sustainability, climate change, and land degradation.

Axel Fassio/CIFOR

Principles of SLM

Africa's major land-use systems, including cropland, grazing land, forest and mixed land, have their main SLM focus as increased land productivity and improved livelihoods and ecosystems. Permanent pasture lands constitute the main land use in Africa (Nkonya et al., 2015), (Figure 7 below):

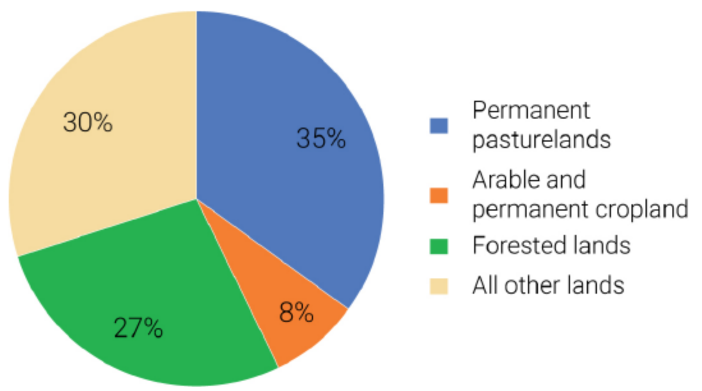


Figure 7: Major land-use systems in Africa (Nkonya et al., 2015)

Guiding these land-use systems are several principles that are aimed at optimizing output with a minimal level of inputs, investment cost, and impact on the environment. These principles include the need to: (a) increase land productivity; (b) improve livelihoods; (c) promote environmental sustainability.

Increased Land Productivity

Africa ranks low in the production of cereal yields despite the prevalent demand, poverty, and nutrition-related challenges. In response, the region's key SLM's aspirations and targets include enhancing the productivity of arable lands and expansion of other food security measures. Principally, there exist three options to attain increased land productivity: (1) expansion, (2) intensification and (3) diversification of land use, although without SLM, each option alone may introduce new risks to land health. For example, agricultural expansion into arid and semi-arid lands is often uncertain, while intensification with increased use of fertilizers and pesticides alone is not sustainable (Figure 8). However, harnessing these three solutions in an integrated and more sustainable manner harbors multiple ecological benefits which can be tapped by focusing on the following land productivity principles:

- Enhanced water productivity and water-use efficiency, including availability for plant growth.
- Improved soil organic matter and soil fertility.
- Ensuring greater diversity of species and varieties.
- Optimum modification of micro-climates, including through shading and wind-breaking.

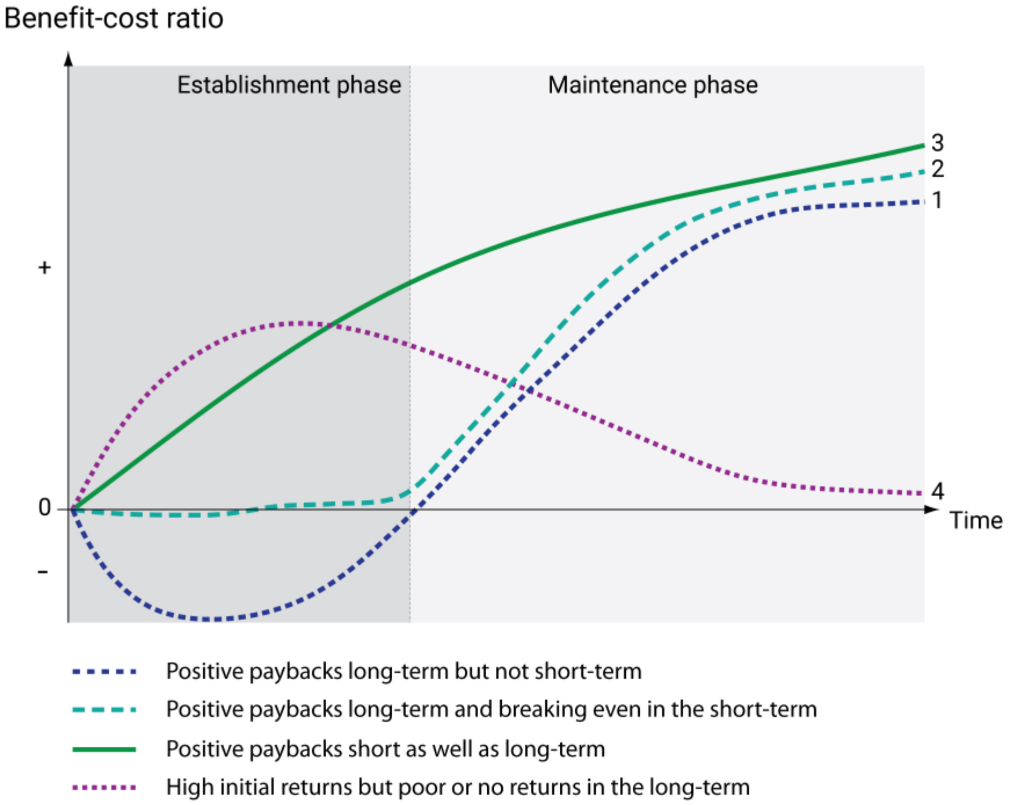


Figure 8: Benefits and costs of SLM over time, short-term establishment phase and long-term maintenance phase (Grainger, 2015)

Improve Livelihoods

The quest for livelihood improvement constitutes a focus of SLM. Livelihoods are tied to agricultural production and food security and clean water, as well as healthy and productive ecosystems, which in turn depend on the prevailing quality of land management practices under implementation. Constraints to these benefits are lowered by adopting SLM, whose livelihood dividends include higher net returns, lower risks or a combination of both (Figure 8).

Environmental Sustainability

Environmental sustainability is at the core of SLM. As a matter of principle, any given best practice should be environmentally responsive, aimed at curtailing any current land degradation, increasing biodiversity, and building resilience to any climatic shifts. An integrated ecosystem approach that includes a combination of various land management interventions would be vital. This could, for instance, inculcate traditional SLM practices as an entry point for action at the micro-level, paired with transdisciplinary technical interventions, including in monitoring and assessment of macro-level impacts.

Triple-Win Solutions

Best land management practices enable win-win-win solutions for people and the environment by improving productivity, livelihood and ecosystems (Figure 9). As soil fertility, efficiency of water use, quality of planting material, and microclimate improve, possibilities for diversification, intensification, and expansion increase.

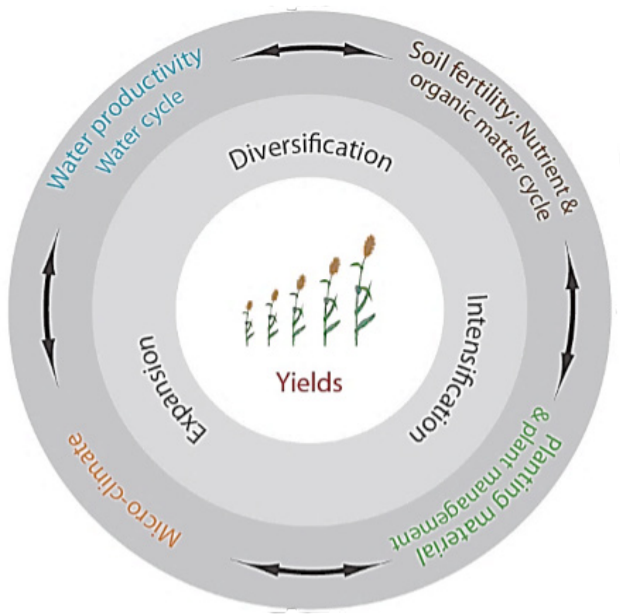


Figure 9: Key to improved land productivity and food security (Liniger et al., 2011)

Best SLM Practices in Focus Countries

Cognizant of the fact that there exists no "one-size-fits-all" solution in addressing land degradation in Africa, the present documentation posits that any suitable SLM practice will best be adapted by local stakeholders to the local geographic, environmental and socio-economic conditions. The following SLM groups have been drawn from the need to align with the principle of best practices, particularly on raising productivity, improving livelihoods and ecosystems resilience. These groups of SLM practices generally fit within the Inclusive CE and are not mutually exclusive. Indeed, synergies across all best practices exist and should be targeted for optimum impact. For example, innovation possibilities arise where Inclusive CE initiatives such as reusing agricultural waste for energy production may be co-located with SLM projects for soil and water conservation, thereby leveraging additional resources. Other examples include using household wastewater for home gardens, growing fruit trees, among others.

As such, various groups of SLM technologies taken from country case studies from IFAD IAP project countries are presented here (see map in Figure 10 below), with a need to:

- Encompass major land-use systems;
- Represent degradation types and agro-ecological zones;
- Cover a broad variety of technologies;
- Have potential for upscaling, in terms of both production and conservation;
- Capture local innovation and recent developments as well as long-term project experience;
- Strike a balance between prevention, mitigation and rehabilitation of land degradation.

The highlighted groups of SLM technologies and case studies draw from existing standards of the World Overview of Conservation Approaches and Technologies (WOCAT) and FAO.

Integrated Soil Fertility Management (ISFM)

What Does It Entail?

Integrated Soil Fertility Management (ISFM) seeks to enhance the quality of soil by combining different methods of soil fertility amendment together with soil and water conservation. It takes into account all farm resources and is based on 3 principles: (1) maximising the use of organic sources of fertilizer; (2) minimising the loss of nutrients; (3) judiciously using inorganic fertilizer according to needs and economic availability. In Sub-Saharan Africa, soil fertility depletion is reaching a critical level, especially under small-scale land use. ISFM techniques can regenerate degraded soils and maintain soil fertility by using available nutrient resources in an efficient and sustainable way. ISFM aims at making use of techniques such as organic fertilizer, crop residues and nitrogen-fixing crops, in combination with seed priming and water harvesting.

Applicability: ISFM is required in areas with low or rapidly declining soil fertility. Due to the wide variety of ISFM techniques, there is no specific climatic restriction for application apart from arid or hyper-arid zones where water is constantly a limiting factor. ISFM is particularly applicable in mixed crop-livestock systems.

Resilience to climate variability: ISFM leads to an increase in soil organic matter (SOM) and biomass, and thus builds soils with better water holding capacity that can support more drought tolerant cropping systems.

Main benefits: Increased nutrient replenishment and soil fertility maintenance will enhance crop yields and thus increase food security, improve household income and hence improved livelihoods and well-being.

Adoption and upscaling: Land users' attitudes and rationale behind the adoption of ISFM are influenced by the availability and access to inputs such as organic fertilizers (compost, manure), the affordability of inorganic fertilizers, and cost of labour. Access to financial services and micro-credit must be provided to land users to enable investment in fertility management. Awareness raising and capacity building on suitable options of ISFM techniques and appropriate application are needed.

Principles and Types

For optimized soil fertility, an integrated nutrient management system including both organic and inorganic inputs must be envisaged.

Organic inputs: Manuring and composting encompasses nutrient sources derived from plant or animal origin. Very often the availability of material is the main restriction, since it competes with feeding of animals and/or burning as fuel. The application of crop residues for mulching can also enhance soil fertility. Furthermore, seed priming can be used to reduce germination time. It ensures a more uniform plant establishment and increases resistance to insects and fungi.

Integration of nitrogen-fixing crops: Green manure or cover crops are leguminous plants that are intercropped or planted in rotation with other crops and fix nitrogen. Very often green manure is incorporated into the soil, which is not the most effective way, due to the fast decomposition and release of nutrients: it is often better to slash and directly drill into the residue (Liniger, et al, 2011). The natural incorporation of cover crop and weed residues from the soil surface to deeper layers by soil micro- and macro-fauna is a slow process. Nutrients are released slowly and can provide the crop with nutrients over a longer period. Additionally, the soil is covered by the residues, protecting it against the impact of rain and sun.

Inorganic fertilizer: Crop yields can be improved through the application of inorganic fertilizers at planting or as a top dressing after crop emergence. However, the application must be well targeted to reduce costs, to minimize GHG emissions and to avoid unhealthy plant growth, as well as an accelerated decomposition of soil organic matter. Application of inorganic fertilizer should be used as a complement, not a replacement, for soil organic matter.

Socio-Ecological Impact Scores

Table 2: Socio-ecological impacts of Integrated Soil Fertility Management (Liniger et al., 2011)

Attribute	Impact*
Development issues addressed	
Preventing/reversing land degradation	++
Maintaining and improving food security	+++
Reducing rural poverty	++
Creating rural employment	+
Supporting gender equity/marginalised groups	++
Improving crop production	+++
Improving fodder production	+
Improving wood/fibre production	+
Improving non wood forest production	n.a.
Preserving biodiversity	+
Improving soil resources (OM, nutrients)	+++
Improving of water resources	+
Improving water productivity	++
Natural disaster prevention/mitigation	+
Climate change mitigation/adaptation	++
Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year)	no data
C Sequestration: above ground	+
C Sequestration: below ground	+
Climate change adaptation	
Resilience to extreme dry conditions	++
Resilience to variable rainfall	++
Resilience to extreme rain and wind storms	+
Resilience to rising temperatures and evaporation rates	+
Reducing risk of production failure	++

* For the classification of impacts, the following categories are used in the presentation of SLM groups and case studies: +++ = high impact; ++ = moderate impact; + = low impact; n.a. = not applicable

Figure 10: IFAD IAP project focus countries in Africa (GEF-IFAD, 2019)

Country Cases

Case 1.1: Kenya

A project on ISFM was initiated in 2000 in Meru South district in the central highlands of Kenya. Figure 11 presents the main elements of the project design. The project sought to address the problem of low soil fertility among smallholder farmers through promotion of integrated methods of soil fertility management combining organic resources and mineral fertilizers. A demonstration for farmers was established in a primary school and served as a mother trial for the mother-baby trial model (CIMMYT, 1993) adopted in this study to disseminate the ISFM technologies. The experimental treatments in the mother trial consisted of two leguminous trees (Calliandra calothyrsus, Leucaena trichandra), two herbaceous legumes (Mucuna pruriens, Crotalaria ochroleuca), Tithonia diversifolia and cattle manure applied solely or combined with chemical fertilizer, chemical fertilizer alone at 60 kg N ha−1 and a control treatment (Table 3).

Maize was used as the test crop. The leguminous trees were planted in nearby plots and biomass was cut and carried to the experimental plots. The herbaceous legumes were intercropped with the maize, with seeds sown two weeks after planting the maize. To introduce the ISFM technologies and practices to farmers and promote their adoption, participatory methods/ approaches were used. The main method used was the mother-baby approach (Snapp, 1999), which was designed to improve the flow of information between farmers and researchers about technology performance and appropriateness. This approach, in addition to generating data to assess the technology performance under realistic farmer conditions (through the baby trials), encouraged farmers to participate actively in the trials and was therefore expected to stimulate farmer

Table 3: Treatments showing organic resources and the amount of inorganic N applied in the demonstration trial at Kirege School, Chuka, Meru South district, Kenya (Mugwe, et al. 2009)

Treatment	Amount of N supplied (kg ha−1)		Cropping system
	Organic	Inorganic	
Mucuna pruriens alone	*	0	Intercropping
Mucuna + 30 kg N ha−1	*	30	Intercropping
Crotalaria ochroleuca alone	*	0	Intercropping
Crotalaria + 30 kg N ha−1	*	30	Intercropping
Cattle manure alone	60	0	Biomass transfer
Cattle manure + 30 kg N ha−1	30	30	Biomass transfer
Tithonia diversifolia	60	0	Biomass transfer
Tithonia + 30 kg N ha−1	30	30	Biomass transfer
Calliandra calothrysus	60	0	Biomass transfer
Calliandra + 30 kg N ha−1	30	30	Biomass transfer
Leucaena trichandra	60	0	Biomass transfer
Leucaena + 30 kg N ha−1	30	30	Biomass transfer
Recommended rate of fertilizer	0	60	Monocrop
Control (no inputs)	0	0	Monocrop

*Total N applied varied among seasons and depended on amount of biomass produced during the previous season. Mean applied per season ranged from 34 to 40 kg N ha−1 for Mucuna pruriens and 36 to 43 kg N ha−1 for Crotalaria ochroleuca.

adoption of the new technologies and practices. All the farmers within the vicinity of the 'mother' sites were given opportunity to participate in the study through participation in field days, demonstrations, training and evaluation of treatment performance in the field, conducted every season during the grain filling stage.

Farmers were allowed to discuss their observations freely and also encouraged to choose technologies they preferred and practice on their farms. Farmer groups were also formed in order to develop an effective working relationship and synergy. After the technologies had been disseminated for almost four years, it was realised that no reliable information existed on how farmers were taking up the technologies. Past research in Kenya shows that adoption of new agricultural technologies, including soil management practices, among the smallholder farmers in the region has generally lagged behind scientific and technological advances, and hence their impact on agricultural production has been low. One of the main reasons for low adoption was the lack of adequate knowledge of farmers' adoption behavior towards the new technologies.

As such, an analysis of factors that condition the uptake of technologies by farmers would be an important link in the process of technology generation and dissemination. This way, practitioners and other key stakeholders would be able to answer several questions regarding adoption of technologies, such as what categories of farmers adopt/do not adopt, and what factors drive adoption of technologies.

Case 1.2: Burkina Faso

The relation between technology adoption and farmers' socio-economic characteristics has increasingly been given attention in developing countries. However, most of the studies conducted by economists dealt with the adoption of external technologies.

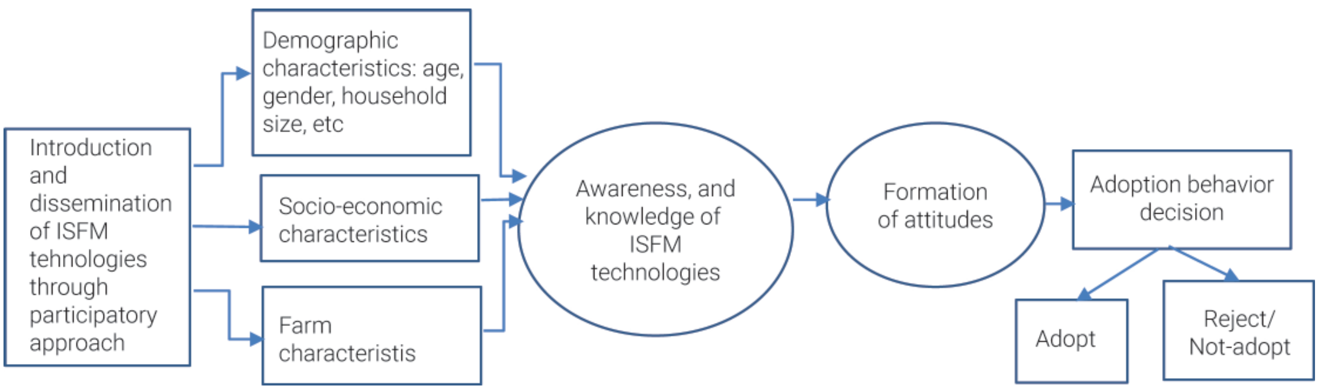


Figure 11: Schematic framework of farmers' adoption behavior in Meru County, Kenya (Mugwe et al., 2009)

The Burkina Faso-based study (Somda et al., 2002) tested the determinants of compost adoption, which is an alternative indigenous technology for soil fertility management. The results of their data analysis using a Logit model point to two main conclusions. First, the agro-ecological location of farmers influences their decision to widely adopt compost technology. Second, among farmers' characteristics affecting compost adoption, three groups can be distinguished. The most important socio-economic characteristics are farmers' age, their comparative perception on the yield effect of compost with regards to other fertilizers and their annual agricultural income. A second group of characteristics include the institutional factors, which are represented by the farmers' participation in extension workshops. A third group of factors comprises the farmer's labor force participating rate, the number of ruminants owned and farmers' gender.

Case 1.3: Ethiopia

The adoption and diffusion of sustainable agricultural practices (SAPs) has become an important issue in the development policy agenda for Sub-Saharan Africa, especially as a way to tackle land degradation, low agricultural productivity and poverty. However, the adoption rates of SAPs remain below expected levels. A study in Ethiopia (Teklewold et al, 2013) analyzed the factors that facilitate or impede the probability and level of adoption of interrelated SAPs, using recent data from multiple plot-level observations in rural Ethiopia. Multivariate and ordered probit models were applied to the modelling of adoption decisions by farm households facing multiple SAPs, which can be adopted in various combinations.

Their results show a significant correlation between SAPs, suggesting that adoptions of SAPs are interrelated. The analysis further shows that both the probability and the extent of adoption of SAPs are influenced by many factors including a household's trust in government support, credit constraints, spouse education, rainfall and plot-level disturbances, household wealth, social capital and networks, labour availability, plot and market access.

The results of this study imply that policymakers and development practitioners should seek to strengthen local institutions and service providers, maintain or increase household assets and establish and strengthen social protection schemes in order to improve the adoption of SAPs.

Conservation Agriculture (CA)

What Does It Entail?

Conservation Agriculture (CA) is a farming system that conserves, improves, and makes more efficient use of natural resources through integrated management of soil, water and biological resources (FAO 2017). It is a way to combine profitable agricultural production with environmental concerns and sustainability. The three fundamental principles behind the CA concept are: *minimum soil disturbance, permanent soil cover, and crop rotation.* Each of the principles can serve as an entry point to the technology; however, only the simultaneous application of all three results in full benefits. CA covers a wide range of agricultural practices based on no-till (also known as zero tillage) or reduced tillage (minimum tillage). These require direct drilling of crop seeds into cover crops or mulch. Weeds are suppressed by mulch and/or cover crops and need to be further controlled either through herbicide application or pulling by hand.

Applicability: CA has been proven to work in a variety of agro-ecological zones and farming systems: high or low rainfall areas; in degraded soils; multiple cropping systems; and in systems with labour shortages or low external-input agriculture. CA has good potential for dry environments due to its water-saving ability, though the major challenge here is to grow sufficient vegetation to provide soil cover.

Resilience to climate variability: CA increases tolerance to changes in temperature and rainfall including incidences of drought and flooding.

Main benefits: CA is considered a major component of a 'new green revolution' in SSA which will:

- Help to make intensive farming sustainable through increased crop yields/yield reliability and reduced labour requirements;
- Cut fossil fuel needs through reduced machine use;
- Decrease agrochemical contamination of the environment through reduced reliance on mineral fertilizers;
- Reduce greenhouse gas emissions, minimise run-off and soil erosion, and improve fresh water supplies.

CA can thus increase food security, reduce off-site damage, reduce foreign exchange required to purchase fuel and agrochemicals, and create employment by producing CA equipment locally. The potential to mitigate and to adapt to climate change is high.

Adoption and upscaling: Change of land user's mind-set, support for specific material inputs and good technical know-how increase the potential for adoption. A main aim is to phase out or minimise herbicide use because of the potential risk to the environment. Alternative methods of weed control with minimum soil disturbance are needed. Pioneer farmers in regions of new adoption require support for access to no-till tools/equipment, cover crop seed and technical guidance. Critical constraints to adoption appear to be competing uses for crop residues (as mulch), increased labour demand for weeding, and lack of access to and use of external inputs.

Principles and Types

Minimal soil disturbance: The main principle of conservation agriculture is minimal soil disturbance through reduced or no-tillage. This favours soil life and buildup of soil organic matter (less exposure to oxygen and thus less soil organic matter mineralization). Compared to conventional tillage, CA increases the organic matter content of soils, increasing their porosity and hence improving their ability to absorb and retain water. This has two positive effects: first, there is more water to support crop growth and the biological activity crucial for productivity, and second, less water accumulates and thus does not flow across the surface, causing floods and erosion.

Seeding is done directly through the mulch (usual residues of previous crops), or cover crop (grown legumes in particular). Although small-scale farmers can apply CA using a standard hoe or planting stick to open planting holes, appropriate machinery such as direct seed drills (large- or small-scale motorised or animal drawn) or jab-planters (hand tools) are normally required to penetrate the soil cover and to place the seed in a slot. Prior sub-soiling is often required to break up existing hardpans resulting from ploughing or hoeing to a constant depth. Compacted soils may require initial ripping and sub-soiling to loosen the soil.

Permanent soil cover: Permanent soil cover with cover crops or mulch has multiple positive effects: increased availability of organic matter for incorporation by soil fauna, protection from raindrop splash, reduced soil crusting and surface evaporation, better micro-climate for plant germination and growth, reduced runoff and soil erosion, and suppression of weeds. In the initial years of CA, a large weed seed population requires management through use of herbicides or hand weeding to reduce the seed bank. Use of herbicides and weeding then falls to a minimum level after a few years, as the number of seeds is reduced and their growth hindered by crop cover.

Crop rotation: In order to reduce the risk of pests, diseases and weed infestation, a system of rotational cropping is beneficial. Typical systems of rotation are cereals followed by legumes and cover/fodder crops. However, for small-scale farmers, it is often difficult to become accustomed to growing crops in rotation, when this practice goes against tradition and dietary preference. One solution is intercropping which allows permanent cover and also replenishment of nutrients – when nitrogen-fixing legumes are included in the mixture. For successful adaptation in SSA, CA needs to evolve to suit the biophysical and socio-economic conditions which implies being flexible regarding soil cover and crop rotation and emphasizing the role of water harvesting in dry regions.

Socio-Ecological Impacts

Table 4: Socio-ecological impacts of Integrated Soil Fertility Management (Liniger et al., 2011)

Attribute	Impact*
Development issues addressed	
Preventing/reversing land degradation	++
Maintaining and improving food security	+++
Reducing rural poverty	++
Creating rural employment	+
Supporting gender equity/marginalised groups	++
Improving crop production	+++
Improving fodder production	+
Improving wood/fibre production	+
Improving non wood forest production	n.a.
Preserving biodiversity	+
Improving soil resources (OM, nutrients)	+++
Improving of water resources	+
Improving water productivity	++
Natural disaster prevention/mitigation	+
Climate change mitigation/adaptation	++
Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year)	no data
C Sequestration: above ground	+
C Sequestration: below ground	+
Climate change adaptation	
Resilience to extreme dry conditions	++
Resilience to variable rainfall	++
Resilience to extreme rain and wind storms	+
Resilience to rising temperatures and evaporation rates	+
Reducing risk of production failure	++

* For the classification of impacts, the following categories are used in the presentation of SLM groups and case studies: +++ = high impact; ++ = moderate impact; + = low impact; n.a. = not applicable

Country Cases

Case 2.1: Ghana

A study conducted on the impact of no-till in Ghana in the context of conservation agriculture showed a significant reduction of labour for land preparation and planting by 22 percent. Labour for weed control fell by 51 per cent, from an average of 8.8 person days/ha to 4.3 person days/ha. There was, however, a slight increase in labour for harvest from 7.6 person days/ha to 8.6 person days/ha. This was largely a consequence of higher yields obtained. Ninety-nine per cent of no-till users reported that it was less physically demanding than the traditional technology and that labour requirements at critical moments were reduced, thus simplifying labour management (Ekboir et al., 2002).

Case 2.2: Tanzania

Likamba, Tanzania suffered from a severe drought in 2004. Even though adequate soil cover was not attained, farmers who had ripped their land and planted lablab bean (Lablab purpureus) with maize were able to harvest at least 2-3 bags (90 kg) of maize per hectare, while conventional farmers harvested nothing, or less than half a bag, per hectare. This experience showed conservation agriculture was able to ensure an adequate harvest even under drought conditions (Shetto & Owenya, 2007)

Rainwater Harvesting (RWH)

What Does It Entail?

Rainwater Harvesting (RWH) refers to all technologies where rainwater is collected to make it available for agricultural production or domestic purposes. RWH aims to minimise effects of seasonal variations in water availability due to droughts and dry periods and to enhance the reliability of agricultural production. A RWH system usually consists of three components: (1) a catchment/collection area which produces runoff because the surface is impermeable or infiltration is low; (2) a conveyance system through which the runoff is directed e.g. by bunds, ditches, channels (though not always necessary); and (3) a storage system (target area) where water is accumulated or held for use - in the soil, in pits, ponds, tanks or dams. When water is stored in the soil and used for plant production, RWH often needs additional measures to increase infiltration and to reduce evaporation loss, for example by mulching. Furthermore, soil fertility needs to be improved by composting/manuring, or micro-dosing with inorganic fertilizers. Commonly used RWH techniques can be divided into micro-catchments collecting water within the field and macro-catchments collecting water from larger catchments further away.

Applicability: RWH is applicable in semi-arid areas with common seasonal droughts. It is mainly used for supplementary watering of cereals, vegetables, fodder crops and trees but also to provide water for domestic and stock use, and sometimes for fish ponds. RWH can be applied on highly degraded soils. RWH reduces risks of production failure due to water shortage associated with rainfall variability in semi-arid regions and helps cope with more extreme events. RWH enhances aquifer recharge and enables crop growth (including trees) in areas where rainfall is normally not reliable.

Main benefits: RWH is beneficial due to increased water availability, reduced risk of production failure, enhanced crop and livestock productivity, improved water use efficiency, access to water (for drinking and irrigation), improved off-site effects including reduced flooding, reduced erosion, and improved surface and groundwater recharge. Improved rainwater management contributes to food security and health through households having access to sufficient, safe supplies of water for domestic use.

Adoption and upscaling: The RWH techniques recommended must be profitable for land users and local communities, and techniques must be simple, inexpensive and easily manageable. Incentives for the construction of macro-catchments, small dams and roof catchments might be needed, since they often require high investment costs. High maintenance costs may discourage land users and/or the local community from adopting the technique.

Principles and Types

In-situ rainwater conservation (sometimes not classified as RWH) is the practice where rainfall water is captured and stored where it falls. Runoff is not allowed and evaporation loss is minimised. This is achieved through mulching, cover crops, contour tillage, etc. Those technologies are further described under conservation agriculture.

Micro-catchments (for farming) are normally within-field systems consisting of small structures such as holes, pits, basins, bunds constructed for the collection of surface runoff within the vicinity of the cropped area. The water-holding structures are associated with specific agronomic measures for annual crops or tree establishment, especially fertility management using compost, manure and/or mineral fertilizers.

Macro-catchments (for farming) are designed to provide more water for crop or pasture land through the diversion of storm floods from gullies and ephemeral streams or roads directly onto the agricultural field. Huge volumes of water can be controlled through large earth canals often built over many years. In the cultivated area, through different practices and by manipulating the soil surface structure and vegetation cover, evaporation from the soil surface and surface runoff can be potentially reduced, infiltration is enhanced and thereby the availability of water in the root zone increased. Small dams/ponds are structural intervention measures for the collection and storage of runoff from different external land surfaces including hillsides, roads, rocky areas and open rangelands. Sometimes runoff is collected in furrows/channels below terraces banks. Small dams/ponds act as reservoirs of surface and floodwater to be used for different purposes e.g. for irrigation, livestock and/or domestic use during dry periods.

Roof catchments: Rainwater harvesting from rooftops is a popular method to secure water supplies for domestic use. Tiled roofs or roofs covered with corrugated iron sheets are preferable, since they are the easiest to use and provide the cleanest water. Thatched or palm leafed surfaces are also feasible, but are difficult to clean and often taint the runoff.

Water is collected and stored in plastic, metal or cement tanks. Roof catchments provide water at home, are affordable, easy to practice, can be shared by several houses or used on public infrastructure (schools, clinics, etc.).

Socio-Ecological Impacts

Table 5: Socio-ecological impacts of Integrated Rainwater Harvesting (Liniger et al., 2011)

Attribute	Impact
Development issues addressed	
Preventing/reversing land degradation	++
Maintaining and improving food security	++
Reducing rural poverty	+
Creating rural employment	+
Supporting gender equity/marginalised groups	+
Improving crop production	+++
Improving fodder production	++
Improving wood/fibre production	++
Improving non wood forest production	n.a.
Preserving biodiversity	+
Improving soil resources (OM, nutrients)	+
Improving of water resources	+++
Improving water productivity	+++
Natural disaster prevention/mitigation	+
Climate change mitigation/adaptation	+++
Climate change mitigation	
Potential for C Sequestration(tonnes/ha/year)	0.26-0.46 (+/-0.35)*
C Sequestration: above ground	+
C Sequestration: below ground	+
Climate change adaptation	
Resilience to extreme dry conditions	+++
Resilience to variable rainfall	+++
Resilience to extreme rain and wind storms	+
Resilience to rising temperatures and evaporation rates	++
Reducing risk of production failure	+

* For a duration of the first 10-20 years of changed land use anagement (Pretty et al., 2006)

Country Cases

Case 3.1: Tanzania

In Tanzania a study was conducted on the productivity of RWH techniques. The results showed that farmers using RWH for maize and paddy could increase crop yields. However, the yield achieved can be depressed through higher labour requirements as well as low market prices. Other factors in production, such as fertility management, are essential for higher crop yields. Micro-catchments led to higher benefits than the use of storage ponds and macro-catchments, even though the increase in crop yield was higher with the latter, but the return to labour for storage ponds and macro-catchments is lower than for micro-catchments. The study also showed that using RWH techniques like storage ponds and macro-catchments is very beneficial to produce vegetables with returns to labour of between 10 US$ and 200 US$ per person day, whereas for maize and paddies it rarely exceeds 10 US$ per person day. One reason for the better return under vegetables is the higher market price (Hatibu, et al., 2004).

Case 3.2: Niger

Common in Niger are Tassa planting pits, used for the rehabilitation of degraded, crusted land. This technology is mainly applied in semi-arid areas on sandy/loamy plains, often covered with a hard pan, and with slopes below 5 per cent. Planting pits are holes of 20-30 cm diameter and 20-25 cm depth, spaced about 1 m apart in each direction, and are dug by hand. The excavated earth is formed into a small ridge downslope of the pit for maximum back capture of rainfall and runoff. Manure is added to each pit, though its availability is sometimes a problem. The improved infiltration and increased nutrient availability bring degraded land into cultivation. Common crops produced in this water harvesting system are millet and sorghum. At the start of the rainy season, seeds are sown directly into the pits. Silt and sand are removed annually. Normally the highest plant production is during the second year after manure application. The technology does not require external inputs or heavy machinery and is therefore favourable to spontaneous adoption. Tassa pits are often combined with stone lines along the contour to enhance water infiltration, reduce soil erosion and siltation of the pits. Growing grass between the stones helps increase infiltration further and accelerates the accumulation of fertile sediment.

Agroforestry (AF)

What Does It Entail?

Agroforestry (AF) is a collective name for land use systems and practices in which woody perennials are deliberately integrated with agricultural crops and/or livestock for a variety of benefits and services (Branca et al., 2013; Vignola et al., 2015). The integration can be either in a spatial mixture (e.g. crops with trees) or in a temporal sequence (e.g. improved fallows, rotation). AF ranges from very simple and sparse to very complex and dense systems. It embraces a wide range of practices: alley cropping, farming with trees on contours, or perimeter fencing with trees, multi-story cropping, relay cropping, intercropping, multiple cropping, bush and tree fallows, parkland systems, home gardens etc.; many of these are traditional land-use systems.

AF is thus not a single technology but covers the broad concept of trees being integrated into cropping and livestock systems in order to achieve multifunctionality. There is no clear boundary between AF and forestry, or between AF and agriculture.

Applicability: On sub-humid mountain slopes, AF can be practiced on a whole farm as around Mt. Kilimanjaro (Chagga system) and Mt. Kenya (Grevillea system). In the drylands, AF is rarely practiced on whole farms (except under parkland systems in the Sahel). It is more common for trees to be used in various productive niches within a farm. AF is mainly applicable to small-scale land users and in small-to large-scale tea/coffee/cocoa plantations.

Resilience to climate variability: AF is tolerant to climate variability. AF systems are characterised by creating their own micro-climates, and buffering extremes (excessive storms or dry and hot periods). AF is recognised as a greenhouse gas mitigation strategy through its ability to sequester carbon. The adaptation and mitigation potential depends on the AF system applied.

Main benefits: Agroforestry systems have great potential to diversify food and income sources, improve land productivity and to stop and reverse land degradation via their ability to provide a favourable micro-climate, provide permanent cover, improve organic carbon content, improve soil structure, increase infiltration, and to enhance fertility and biological activity of soils.

Adoption and upscaling: There is a lack of quantitative and predictive understanding about traditional and innovative agroforestry practices and their importance in order to make them more adoptable. Long term field research/monitoring are needed because of the complex nature of tree/crop systems.

Principles and Types

The factors influencing the performance of AF are crop, livestock and tree types and mixtures, germplasm, number and distribution of trees, age of trees, management of crops, livestock and trees, and the climate.

Agroforestry parkland systems are mainly cropland areas with dispersed trees (often indigenous). Among the characteristics of traditional agroforestry parklands are the diversity of tree species they contain and the variety of products and uses (including fruits, fodder, etc.). They generate and provide favourable micro-climates (through shade especially) and buffer extreme conditions by acting as windbreaks. Parklands are found primarily in the semi-arid and sub-humid zones of West Africa. Faidherbia albida/cereal systems are common throughout the Sahelian zone (e.g. 5 million ha in Niger) (Pye-Smith, 2013) and in some parts of East Africa. For many local populations, these systems are very important for food security, income generation and environmental protection.

Multistory systems are defined as existing or planted stands of trees or shrubs that are managed as an upper story of woody plants and one to several understories of woody and non-woody plants that are grown for a variety of products. The purpose is (a) to use different layers and improve crop diversity by growing mixed but compatible crops of different heights in the same area; (b) to protect soil and provide a favourable micro-climate; (c) to improve soil quality by increasing utilization and cycling of nutrients and maintaining or increasing soil organic matter and (d) to increase carbon storage in plant biomass and soil. The Chagga home gardens of Tanzania, which integrate more than 100 plant species, provide a classic example of a multistory AF system.

Fodder banks: Trees and shrubs with palatable leaves and/or pods are attractive to farmers as fodder for their livestock because they require little or no cash for inputs, and they can be grown on plot boundaries as trees (often pollarded to reduce competition) or as hedges. They do not compete for land as they are grown along plot boundaries, pathways - and along contours to curb soil erosion. Managing fodder shrubs requires multiple skills including raising seedlings in a nursery, pruning trees, and feeding the leaves to livestock. This is a constraint to rapid spread of the technology. Nevertheless, over the past 10 years, about 200,000 farmers in Kenya, Uganda, Rwanda, and northern Tanzania have planted fodder shrubs, mostly to feed dairy cows. Improved fallows consist of planted woody species in order to restore fertility within a short time. Traditionally fallows take several years. Natural vegetation is slow in restoring soil productivity. By contrast, fast growing leguminous trees and bushes - if correctly identified and selected - can enhance soil fertility by bringing up nutrients from lower soil layers, litterfall, and nitrogen fixation. Improved fallows are one of the most promising agroforestry technologies in the sub-humid and humid tropics and have shown great potential for adoption in southern and eastern Africa in recent years (Franzel & Wambugu, 2007).

Windbreaks/shelterbelts are barriers of trees and shrubs that protect against damaging wind. They are used to reduce wind velocity, protect growing plants (crops and forage), improve micro-environments to enhance plant growth, delineate field boundaries, and increase carbon storage.

Socio-Ecological Impacts

Table 6: Socio-ecological impacts of Agroforestry (Liniger et al., 2011)

Attribute	Impact
Development issues addressed	
Preventing/reversing land degradation	+++
Maintaining and improving food security	+++
Reducing rural poverty	+++
Creating rural employment	+
Supporting gender equity/marginalised groups	++
Improving crop production	++
Improving fodder production	++
Improving wood/fibre production	++
Improving non wood forest production	+
Preserving biodiversity	+++
Improving soil resources (OM, nutrients)	+++
Improving of water resources	++
Improving water productivity	+++
Natural disaster prevention/mitigation	+++
Climate change mitigation/adaptation	+++
Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year)	0.3 - 6.5*
C Sequestration: above ground	++
C Sequestration: below ground	++
Climate change adaptation	
Resilience to extreme dry conditions	++
Resilience to variable rainfall	+++
Resilience to extreme rain and wind storms	++
Resilience to rising temperatures and evaporation rates	++
Reducing risk of production failure	++

Country Cases

Case 4.1: Kenya

Within a study conducted in Kitui County in the eastern part of Kenya, the cost effectiveness of growing Melia volkensii trees on croplands was determined. The value of timber products gained versus crop value lost due to competition over an 11-year rotation were compared. Costs for seed, cultivation, tree planting stock or labour were not taken into account, which would increase the surplus of cash from the tree products because in recent years, crop failure occurred at a 50 per cent rate. It was shown that at the end of the rotation, the accumulated income from tree products exceeded the accumulated value of crop yield lost through competition by US$ 10 or 42 per cent during average years and US$ 22 or 180 per cent with the assumption of 50 per cent crop failure due to drought. (In Kitui County, six of the 16 cropping seasons failed during the trial period (Verchot, et al. 2006)).

Case 4.2: Kenya, Uganda, Rwanda, and northern Tanzania

In the highlands of East Africa, farmers with 500 Calliandra shrubs increased their net income by between US$ 62 to 122/year depending on whether they used shrubs as a substitute, or as a supplement, and depending on where they are located (Figure 13). Fodder shrubs are very attractive to farmers because they require little or no cash, nor do they require farmers to take land out of production for food or other crops (Franzel and Wambugu, 2007).

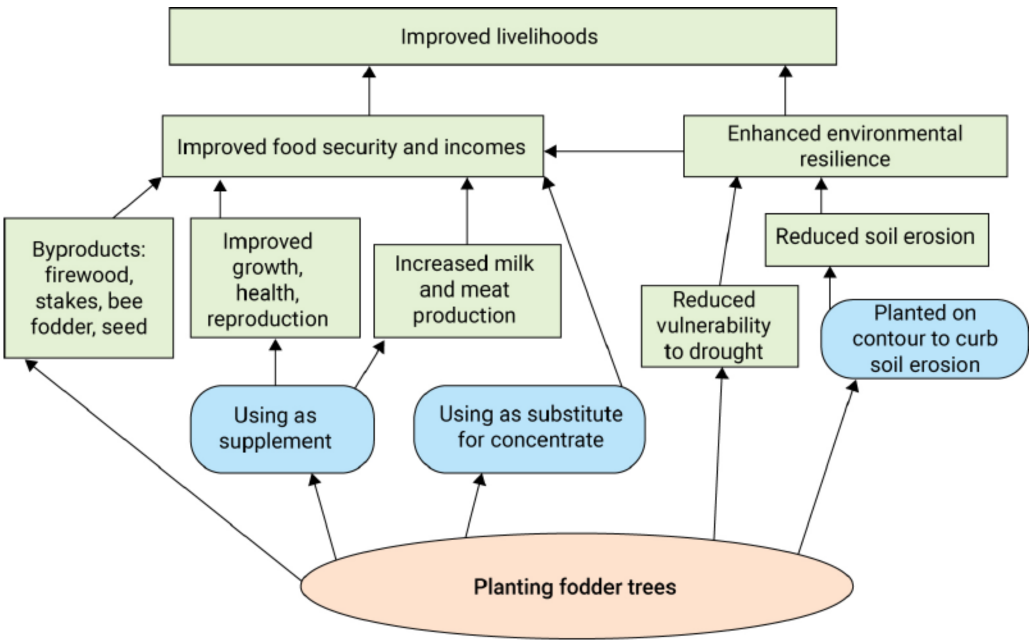


Figure 12: Schematic depicting how fodder trees play a vital role in SLM measures for improving livestock productivity and smallholder livelihoods in Africa (Source: Franzel et al., 2014).

Harnessing Ecosystem-Based Adaptation Options for Smallholders (EbA)

What Does It Entail?

Ecosystem-based Adaptation (EbA) refers to the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change (Vignola et al., 2015). In the context of SLM and agricultural systems, EbA entails an implementation multifaceted agricultural management practices harnessing biodiversity, ecosystem services and/or ecological processes to help boost adaptability of crop and livestock enterprises to climate variability. In this respect, adaptation is a process to promote the maintenance or further adoption of ecologically based management practices that can provide adaptation benefits.

Context: More than 1.3 billion smallholders depend on farming for their food and livelihood needs across the globe (Vignola et al., 2015). However, their farming practices, especially in the sub-Saharan Africa, are highly susceptible to the changing climate (Dougill et al., 2017; Nkonya et al., 2015) due to impacts on crop and livestock productivity. They thus represent a significant group of stakeholders in the quest to promote best practices that benefit people and the environment.

In Africa, key crops such as maize, rice, sorghum, and cassava, as well as various types of livestock, have been projected to face major climatic constraints in the coming years. This is compounded by their limited capacity to adapt to the changing climate and complicated by other socioeconomic, biophysical and infrastructural pressures (Simotwo et al., 2018; Vignola et al., 2015; WRI, 2019).

Applicability: Many smallholder farmers are already implementing EbA practices that maintain complex agro-biodiversity and increase capacity to resist, cope with, and/or recover from extreme climatic events, without putting additional pressure on land resources. These farmers make use of ecological processes and biological diversity to provide adaptation benefits to agricultural producers. Given climate change projections and associated impacts, various stakeholders, including state and non-state actors are currently at the forefront of exploring opportunities for intervention. Many of these interventions seek to strengthen and/or broaden four main types of activities deemed to be essential in enhancing the capacity of smallholders to manage climate risks. These include: (a) developing new technologies, such as satellite-based, early warning systems; (b) facilitating government support (subsidies, insurance, technical assistance, etc.); (c) assisting farmers in accessing credit, capital and risk-insurance, and/or; (d) adapting farm management practices. However, the first three are often difficult to implement in the short-term due to time required to put in place the necessary enabling conditions such as appropriate policies, governance structures, economic incentives and infrastructure (Vignola et al. 2015),

Resilience to climate variability: An immediate and direct way to help smallholder farmers ensure their farm-based livelihoods in the face of the increasing stresses posed by climate variability is to help use farm management practices based on agro-biodiversity and ecosystem services that provide adaptation benefits. A wide range of agricultural practices enable farmers to improve their farming systems and increase the resiliency of their systems to climate change.

Main benefits: EbA practices offer multiple benefits to smallholders and land sustainability, and not only on the climate change front. Benefits include ensuring continued provision of key ecosystem services (water, food, nutrient regulation, pest control, pollination) on which farming depends. EbA practices contrast with other (non-EbA) adaptation measures, such as the construction of dams for water irrigation or the increased use of agrochemicals, which also confer adaptation benefits but may negatively impact the provision of ecosystem services. Furthermore, EbA practices diversify production systems and sources of income generation, thus availing more stability to smallholder farmers.

Many EbA practices mitigate climate change by either reducing the amount of Greenhouse Gases (GHG) emitted from agricultural systems (e.g., by reducing the use of inorganic fertilizers, agrochemicals, machinery and associated emissions), or by increasing the overall farm biomass (e.g., by increasing soil carbon stocks or above-ground biomass). Overall, the co-benefits of EbA practices in terms of climate regulation, water purification, habitat creation, biodiversity conservation and landscape amenities are often significantly greater than those of engineering alternatives e.g., flood control infrastructure, water treatment plants.

Principles and Types

Table 7: Dimension and benefits of Ecosystem-based Adaptation (EbA) (Bongaarts, 2019; Vignola et al., 2015; WRI, 2019)

Dimension 1: Ecosystem-Based	Dimension 2: Adaptation Benefits	Dimension 3: Livelihood Security
EbA is based on the need to revitalize ecosystem functioning through: • Conservation, restoration and sustainable management of biodiversity (e.g., genetic, species and ecosystem diversity); • Conservation, restoration and sustainable management of ecological functions and processes (such as nutrient cycling, soil formation, water infiltration, carbon sequestration, etc.)	EbA seeks to boost adaptation benefits through: • Sustaining and improving crop, animal or farm productivity in face of increased climate variability and climate change; • Reducing the biophysical impacts of extreme weather events (heavy rainfall, extremely high temperatures, strong winds, etc.) and high temperatures on crops, livestock or farming systems; • Reducing crop pest and disease hazards due to climate change	EbA is at the core of livelihood security, as characterized by its: • Increasing food security of smallholder household; • Enhancing or diversifying income generation of smallholder households; • Leveraging local or traditional knowledge of smallholder farmers; • Utilizing local, available and renewable inputs (e.g., using local materials within the farm or landscape, rather than external inputs such as pesticides, inorganic fertilizers, etc.; • Requiring implementation costs and labour affordable to smallholder farmers

Socio-Ecological Impacts

Table 8: Socio-ecological impacts of Ecosystem-based Adaptation (EbA) (Liniger et al., 2011)

Attribute	Impact
Development issues addressed	
Preventing/reversing land degradation	++
Maintaining and improving food security	++
Reducing rural poverty	++
Creating rural employment	++
Supporting gender equity/marginalised groups	++
Improving crop production	++
Improving fodder production	+
Improving wood/fibre production	n.a
Improving non wood forest production	n.a.
Preserving biodiversity	+
Improving soil resources (OM, nutrients)	++
Improving of water resources	++
Improving water productivity	+++
Natural disaster prevention/mitigation	++
Climate change mitigation/adaptation	++
Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year)	0.57 ± 0.14*
C Sequestration: above ground	++
C Sequestration: below ground	++
Climate change adaptation	
Resilience to extreme dry conditions	++
Resilience to variable rainfall	++
Resilience to extreme rain and wind storm	s +
Resilience to rising temperatures and evaporation rates	++
Reducing risk of production failure	+

* Change from conventional tillage to no tillage

Country Cases

Case 5.1: Kenya

Pastoralism and ecosystem-based adaptation in Kenyan Masailand. A study was run in Kenya's Masailand to assess the potential for pastoral communities to adapt to climate change using conservation and payment for ecosystem services. The study entailed the triangulation of socioeconomic and climatic factors associated with EbA to assess drought frequency and intensity. A framework of the interactions between pastoralists' drought coping and risk mitigation strategies and the conservation effects was developed and used to qualitatively assess the study area. Payment for ecosystem services was found to buffer households from fluctuating livestock income, in addition to generating synergies and/or trade-offs depending on land use restrictions. This demonstrated a contribution of EbA through the integration of conservation with drought coping and risk mitigation strategies of pastoral communities in rangeland ecosystems.

Case 5.2: EBAFOSA in Africa.

Ecosystem-based Adaptation for food security in Africa Assembly (EBAFOSA) is a UNEP-led concept for building adaptation to climate change. Its main approach entails convening and forging the necessary multi-sectorial partnerships needed to bridge policy and operational gaps to maximize productivity and climate proof Africa food systems. EBAFOSA also promotes sustainable EbA-driven agriculture and clean energy powered industrialization. For example, at the policy level, EBAFOSA is convening policy makers from line ministries of agriculture, energy, infrastructure/ roads, lands, trade and industry, planning, environment to form inter-agency policy task forces. Their task is to

Caption - Solar driers have been used since early 2018 in Ngoulemakong commune in Cameroon's Sud Province to dry cassava and store it for longer
(Source; UNEP-Africa Office)

bridge ministerial silos and foster collaborative policy processes to harmonize respective sectorial policies towards complementing the shared aim of maximizing productivity and climate-proofing Africa's food systems. For example, the Sierra Leone EBAFOSA task force is harmonizing finance, industry, energy, agriculture sectorial policies to establish tax concession incentives for agro-based industries in rural areas.

Ecosystems-based adaptation is crucial for meeting African countries' Nationally Determined Contributions (NDCs) under the 2015 Paris Climate Agreement. Clean energy and sustainable agriculture informed by ecosystems-based adaptation are prioritized in over 60 per cent of NDCs across the continent.

The EBAFOSA promotes renewable energy investments, including the expansion of electricity access in rural areas. It is targeting off-grid and mini-grid solutions to complement the main power grids to catalyse rural agro-industries. EBAFOSA promotes job creation to target youth who comprise sixty per cent of Africa's unemployed.

Reducing Post-Harvest Losses

What Does It Entail?

Addressing the challenges associated with worrisome levels of post-harvest losses in sub-Saharan Africa is a key item in the menu of options for SLM (Figure 14). Applicable measures include shared commitments for monitoring and responsive actions and incentives to minimise the post-harvest losses across the value chain. Recent estimates (FAO, IFAD, UNICEF, WFP, 2019; WRI, 2019) indicate about one-third of all food produced in the world, measured by weight, is either lost or wasted. *Technically speaking, food loss and waste refer to the decrease in mass (quantitative) or nutritional value (qualitative) of food - edible parts - throughout the supply chain that was intended for human consumption. Food that was originally meant for human consumption but for various reasons is removed from the human food chain is considered as food loss or waste, even if it is then directed to a non-food use (feed, bio-energy)* (UNEP, n.a.). At the global level, post-harvest processes incur losses of about $1 trillion per year.

In Sub-Saharan Africa, post-harvest grain losses total up to $4 billion per year. Most losses are concentrated during harvesting and storage which results in constraints to the famers, such as low levels of food security and income opportunities. Most of the losses occur at field-to-market stages, with the lowest share occurring at the consumer level. Among the key factors implicated include premature harvesting, poor storage facilities, lack of infrastructure, limited processing facilities, and inadequate market facilities. These losses drive up food prices, increase food insecurity and limit livelihood opportunities along the entire food supply chain.

Reducing post-harvest losses, especially in developing countries, could be a sustainable solution to increase food availability, reduce pressure on natural resources, eliminate hunger and improve farmers' livelihoods. Cereal grains are the basis of staple food in most developing nations and account for most post-harvest losses on a calorific basis among all agricultural commodities. As much as 50-60 per cent of cereal grains can be lost during the storage stage due only to the lack of technical inefficiency. Use of scientific

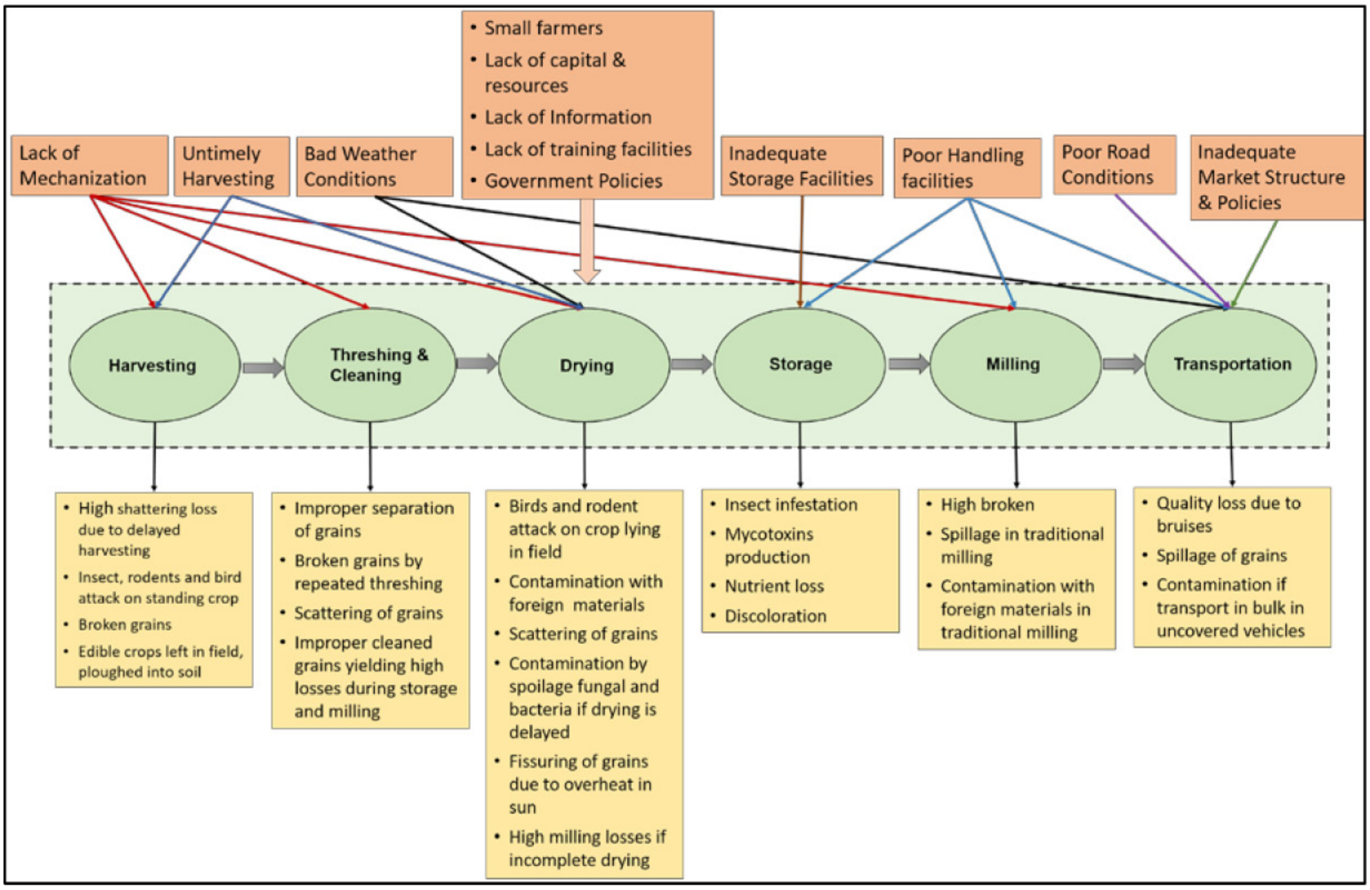


Figure 13: Conceptual model for post-harvest losses in developing countries (source: Kumar & Kalita, 2017).

storage methods can reduce these losses to as low as 1-2 per cent.

Principles and Types

Storage

Storage is the practice of protecting the quality of agricultural crops and preventing them from deterioration for a specific period beyond their normal shelf life. Different crops are harvested and stored by various means depending on the end use. Whether the seed will be used for new plantings the following year, for forage being processed into livestock feed, or even for crops to be developed for a special use, the grower must be aware of harvesting and storage requirements toward a quality product. After determining the prescribed use for the crop, timing for harvest and storage is an important consideration. Along with an assessment of when to harvest, the farmer needs to determine the method of harvesting. There is a wide range of storage structures used throughout the world to successfully store horticultural produce. In general, the structure needs to be kept cool (refrigerated, or at least ventilated and shaded), and the produce put into storage must be of high initial quality.

Storage is essential for the following reasons:

- Perishable nature of agriculture and biomaterials
- Provision of food materials all year round
- Provision for large scale processing
- Preservation of nutritional quality
- Price control and regulation
- Optimization of farmers gain/financial empowerment of farmers
- Opportunity for export market

Processing

Excessive hulling or threshing can also result in grain losses, particularly in the case of rice (hulling) which can suffer cracks and lesions. The grain is then not only worthless, but also becomes vulnerable to insects such as the rice moth (Corcyra cephalonica).

Marketing

Marketing is the crucial element in the post-harvest system, although it can occur at various points in the agro-food chain, in particular during processing. Moreover, it cannot be separated from transport, which is an essential link in the system.

Socio-Ecological Impacts

Table 9: Socio-ecological impacts reducing post-harvest losses (Liniger et al., 2011)

Attribute	Impact
Development issues addressed	
Preventing/reversing land degradation	+
Maintaining and improving food security	++
Reducing rural poverty	++
Creating rural employment	++
Supporting gender equity/marginalised groups	++
Improving crop production	++
Improving fodder production	++
Improving wood/fibre production	++
Improving non wood forest production	n.a.
Preserving biodiversity	++
Improving soil resources (OM, nutrients)	+
Improving of water resources	+
Improving water productivity	+
Natural disaster prevention/mitigation	+
Climate change mitigation/adaptation	+++
Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year)	limited data
C Sequestration: above ground	+
C Sequestration: below ground	+
Climate change adaptation	
Resilience to extreme dry conditions	+++
Resilience to variable rainfall	+++
Resilience to extreme rain and windstorms	+
Resilience to rising temperatures and evaporation rate	s++
Reducing risk of production failure	++

Country Cases

Case 6.1: UNEP's integrated interventions to curb post-harvest losses in Africa

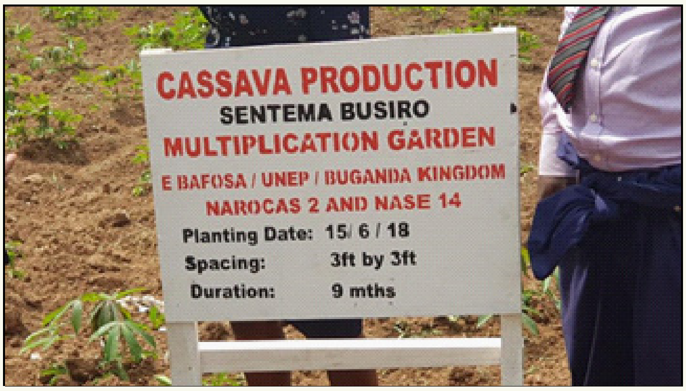
UNEP and partners are working in Africa to boost agricultural production, create jobs, and counter climate unpredictability. In Ngoulemakong commune in Cameroon's South Province, solar driers have been used since early 2018 to dry cassava and store it for longer, allowing farmers to get better prices. Previously, farmers were forced to sell their crop quickly at rock-bottom prices, and often ended up making a loss. So far, over 500 cassava farmers have reduced their post-harvest losses and obtained higher prices while at the same time creating a market opportunity for solar drier suppliers.

In Uganda's Kingdom of Buganda, the local government won a US$141 million contract for its farmers to supply cassava to Uganda Breweries. Previously, a major challenge was to provide a regular supply of quality cassava. Now, solar-powered micro-irrigation is being used to enhance yields and solar driers are helping to preserve surplus crops for later use. Several hectares have been set aside in Busiro County to produce cuttings for use in all 18 of the Kingdom's counties.

These are two examples of smart agriculture achieved thanks to innovative partnerships, fostered by UNEP and others under the Ecosystem-Based Adaptation for Food Security Assembly (EBAFOSA) initiative set up in 2015. The initiative supports the implementation of SDG 17 (Partnerships for the goals).

The Assembly also promotes food security and socioeconomic development by reducing post-harvest losses estimated at around US$48 billion in Africa. "Lost yields due to declining ecosystem services like water, healthy soils and pollinators can be avoided by upscaling the use of ecosystem-based adaptation approaches which are known to increase yields by up to 128 per cent," says Munang (De Pinto, & Ulimwengu, 2017).

UN Environment's role has been to provide the vision on climate action and support its implementation through technical advice and capacity enhancement. UN Environment has also provided a convening space and platform for innovative partnerships so people can come together to bring about change. The simultaneous realization of environmental and socioeconomic benefits is the essence of the Innovative Environmental Solutions adopted by the 3rd UN Environment Assembly in 2017.



Caption; Cassava production that inculcates interventions to reduce post-harvest losses in Uganda
Photo credit: UNEP-Africa Office

Caption: Solar powered irrigation being inaugurated in Busiro County in Uganda's Kingdom of Buganda.
Photo credit: UNEP-Africa Office

Case 6.2: Countries - Benin, Kenya

Hermetic Storage to reduce post-harvest losses in grain storage

Hermetic Storage (HS), also known called as "sealed storage" or "airtight storage", is gaining popularity as a storage method for cereal, pulses, coffee, and cocoa beans in developing countries due to its effectiveness and avoidance of the use of chemicals and pesticides (Kumar & Kalita, 2017). The method creates a modified atmosphere of high carbon dioxide concentration using sealed waterproof bags or structures. As the structures are airtight, the biotic portion of the grains (insects and aerobic microorganisms) creates a self-inhibitory atmosphere over time by increasing carbon dioxide concentration (oxygen decreases) due to its respiration metabolism. Some studies have reported that the aflatoxin production ability of Aspergillus flavus is also reduced at high concentrations of CO2. Hermetic storage also has been observed to be very effective in avoiding losses (storage losses less than 1 per cent) during long distance (international) shipments. Ease of installation, elimination of pesticide use, favorable costs, and modest infrastructure requirements are some additional advantages that make the hermetic storage options attractive.

Table 10: Comparison of maize storage in metal silos and hermetic bags in Kenya and Benin

Country	Duration of storage	Assessments	Findings
Kenya (De Groote et al., 2013)	6 months	Evaluated performance of hermetic storage (metal silos and super grain bags) and polypropylene bags to control infestation of pests.	• Metal silo was the most effective option in controlling pest infestation. • Metal silo was equally effective in controlling pest infestation even without any insecticide use. • Supergrain bags were effective in controlling the infestation; however the insect mortality was not complete as bags were perforated by a large grain borer.
Benin (Ognakossan et al., 2013)	150 days	Compared performance of hermetic bags and woven polypropylene bags for storage of maize infested with Prostephanus truncatus (Horn) and Sitophilus zeamaiswas (Motschulsky).	• Moisture levels remained unchanged in hermetic bags. • Growth of insects (Prostephanus truncatus and Sitophilus zeamaiswas) was significantly less in hermetic bags. • There were 0.5%–6% losses at end of storage compared to 19.2%–27.1% losses in woven bags.

Summary

This document provides a succinct summary of the best practices for SLM in SSA agriculture. A key message is that, in the face of climate change, land degradation, environmental or social crises, agriculture in SSA needs to ramp up the use of these best practices to minimize risk to food security. Evidence of application of these best practices from countries across SSA is documented and demonstrates positive impacts both for the environment and the livelihoods of communities.

These SLM best practices embody the principles of Inclusive CE. The best practices are not mutually exclusive, so the reader should see them as integrated toolkits from which users can explore the best solutions for their needs. Selection from available best practices should be informed by the science of environmental sustainability and driven by an assessment of the target communities' social and economic needs.

Michael Major/Crop Trust

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Annex 1 – Mount Elgon Case Study

Background

Mount Elgon is an extinct African volcanic mountain on the border of eastern Uganda and western Kenya. The mountain serves as a water tower for Uganda and Kenya, and is a catchment area for the drainage systems lakes Victoria, Turkana and Kyoga.

On the upper slopes of the mountain lies the Mount Elgon National Park. The park covers an area of 1,279km² of the mountain's 4,000 km² area. It is one of the most important areas of biodiversity. The Afromontane forests provide foods, fuel, fibres and fodder for the people living around the mountain. Protected areas (PAs) conserve and manage biodiversity and forest resources on the mountain.

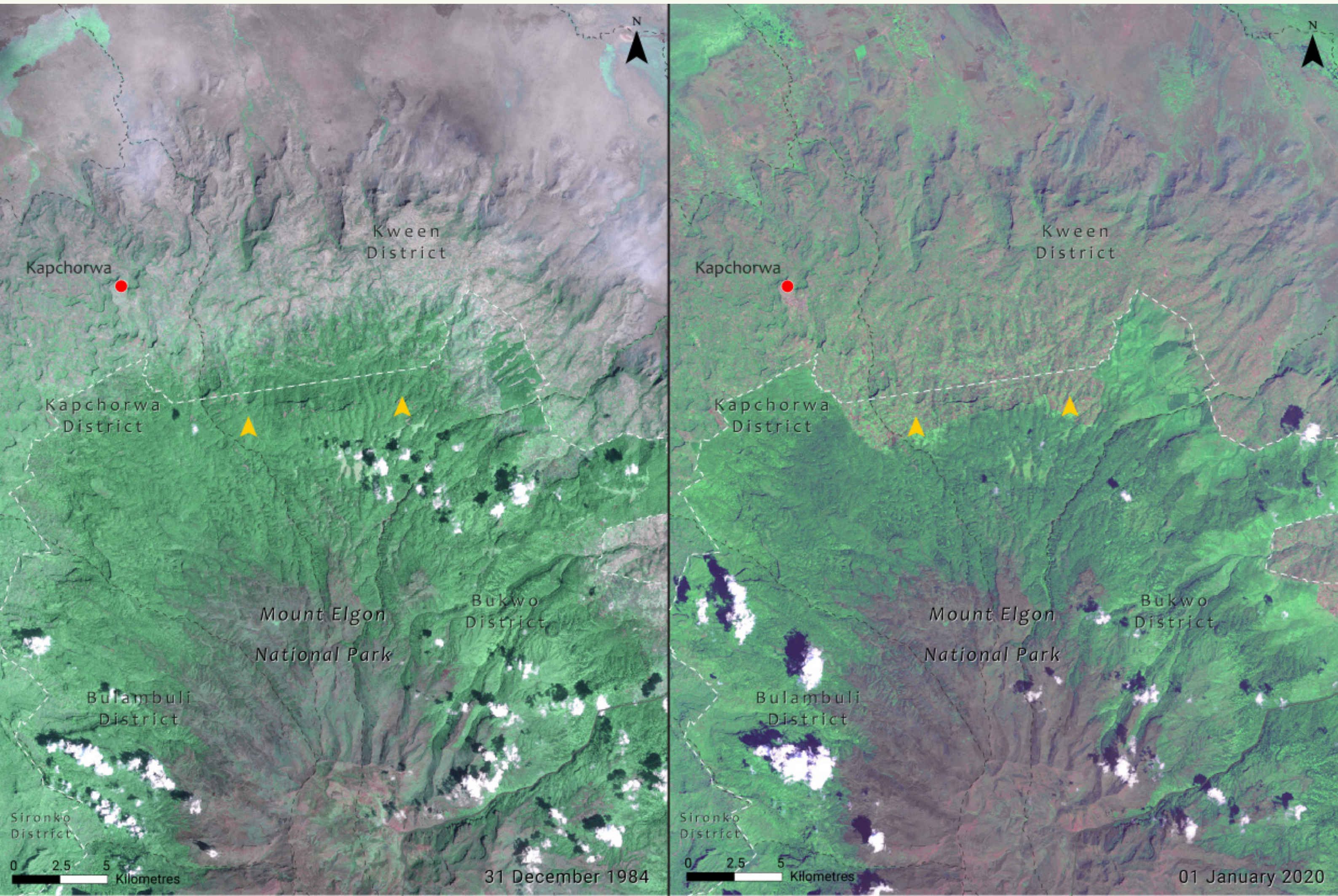
Issues

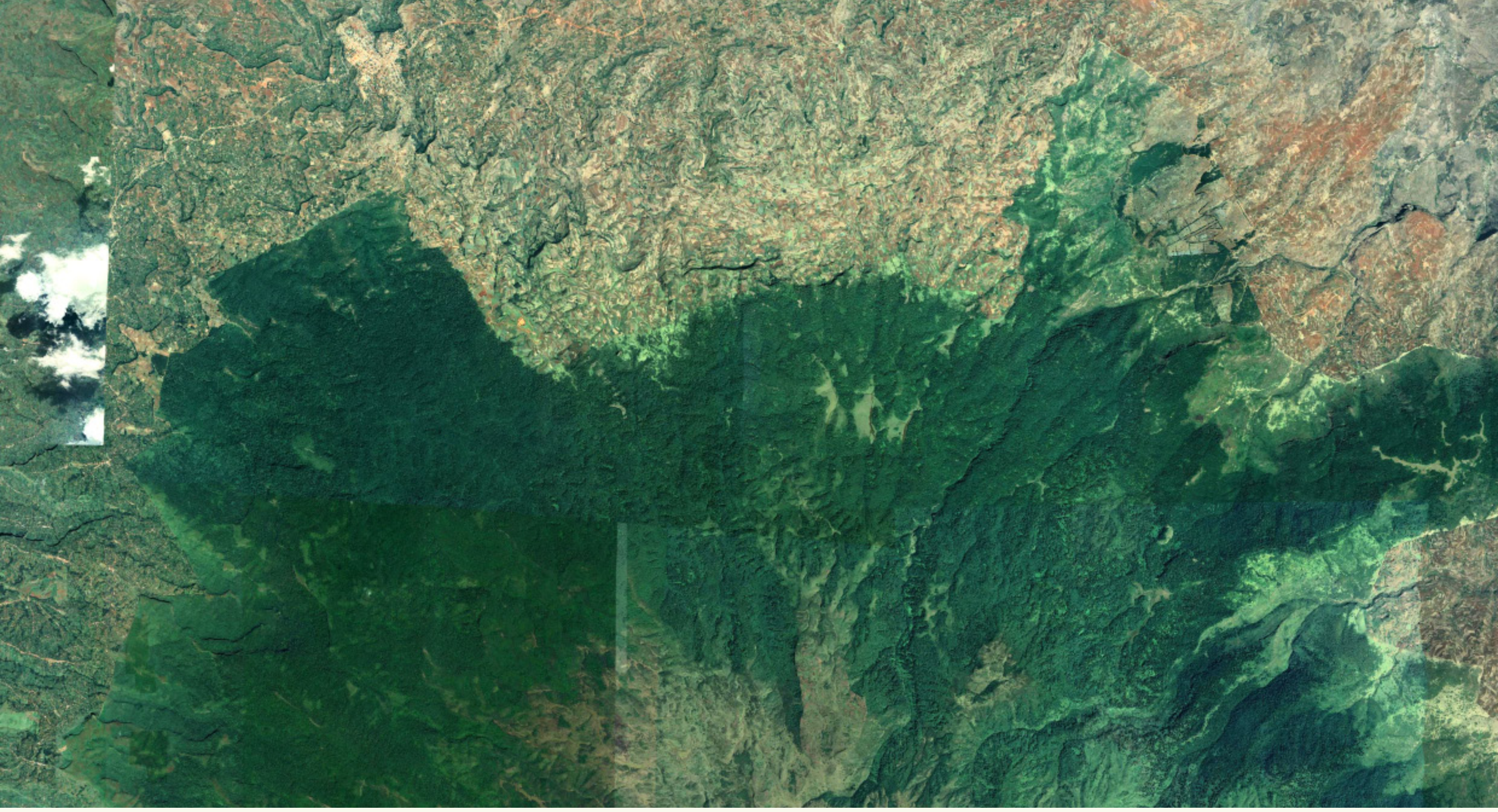
Farmlands in the region have continuously increased in spatial coverage; partly due to the conversion of other land uses to agriculture; There is increased encroachment on natural forests leading to significant loss of tree cover as a result of the high increase in human population.

Mount Elgon has a high and increasing population density (900 people per km² on the Uganda side, with a population growth rate of 3.4 per cent per annum). This It is one of the most densely populated mountain areas in Africa. The mountain's high population density is putting pressure on the mountain ecosystem. As agriculture is the main source of income, the hilly areas are being cleared for livestock grazing, farming and settlements. As a result deforestation has occurred and the area is vulnerable to climate change.

Because of the steep slopes and the loss of vegetative cover, the Mt. Elgon region is very susceptible to landslides. Soil erosion also occurs in this region posing severe limitations on sustainable agriculture. Given the terrain, land cover types, intense rainfall and nature of soils, erosion in most parts of the region will likely with continued loss of vegetative cover and climate change.

Landsat satellite imagery taken in 1984 and 2020 show the extent of forests clearance within Mount Elgon National Park (cleared areas marked wirth yellow arrows).





High resolution image of the main forest clearance area within the Mount Elgon National Park.
Image source: Google Earth

Ecosystem-based Adaptation (EbA) is one of the measures that can be used to minimize the effect of climate change and vegetation loss. EbA is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people adapt to the adverse effects of climate change

What's being done?

There are 6 broad actions for managing climate change risks and enduring sustainable crop production: in Uganda.

- Water, soil and land management. Promote small-scale irrigation, conservation agriculture and a watershed-scale approach.
- Agronomic practices. Disseminate culturally acceptable and affordable, stress-resistant crop varieties; support optimum crop diversification and intercropping techniques; support optimum use of agroforestry and multipurpose shade trees; and support farmers in replacing old, unproductive coffee plantations.
- Infrastructure and financing. Promote appropriate storage for maize and coffee, improve road infrastructure and flood control structures, and support or expand rural microfinance.
- Information and communication technologies. Enhance the role of technology for providing accurate, reliable and timely climate information, and combine local and scientific knowledge for improved local weather forecasts and early warning systems.
- Local governance and social organization. Support strong farmers' institutions and organizations, especially for women.
- Capacity development. Build capacity in application of new stress-resistant seeds conservation agriculture, intercropping and agroforestry, and in access to weather information.

Specific interventions to combat the climate related hazards and expected impacts in the Mt. Elgon region have been suggested including relocation of people, soil stabilization (through tree planting, grass bunds, avoided deforestation), farm/land use planning, awareness raising and capacity building, establishment of early warning systems, irrigation, water conservation (water harvesting), sinking of boreholes, gravity flow schemes, protected springs, drought resistant crop varieties, post-harvest management (e.g. food storage), de-silting of rivers, riverbank protection (e.g. planting grass, trees), enhancing enforcement and governance systems through use of bylaws, demarcation, mapping and gazettement of wetlands, agroforestry (hedgerows, alley cropping), tree planting, reforestation/ afforestation, conservation tillage, organic manuring, contour banding, mulching and use of cover crop (RoU; UNDP, 2013).

Uganda has embarked on a Global Environment Facility (GEF) Project Plan "Integrated Landscape Management for Improved Livelihoods and Ecosystem Resilience in Mount Elgon".

Table 11: Overview of Ecosystem-based Adaptation (EbA) land rehabilitation, alternative livelihoods and ecosystem restoration measures implemented in Sanzara, Uganda, with observed and expected benefits (UNEP, 2018)

EbA measure	Climate change adaptation function (observed and expected)	Environmental benefits (observed and expected)	Social benefits (observed and expected)	Economic benefits (observed and expected)
Land rehabilitation: Fuel-efficient cooking stoves	Landslides, soil erosion, drought and flooding reduced from decreased deforestation and improved forest and tree cover from reduction in fuel wood collection	Enhanced ecosystem restoration as a result of reduced tree cutting Increased indigenous tree species	Reduction in time spent in collecting firewood especially for women Improved human health from decrease in less soot/smoke There is less time spent in cooking which gives women more time to tend to their spouses and children	Increased savings that would have otherwise been used for charcoal or firewood. Farmers shift the incomes to health and education of their children
Alternative livelihoods: Unbaked bricks		**Reduction of deforestation** **Clean indoor air**		
Ecosystem restoration: Catchment restoration: Gravity flow scheme, soil and water conservation, river bank management, agroforestry, tree planting	Decreased soil erosion from enhanced vegetation Enhanced provision of water year round, including during drought, for agriculture, livestock, domestic use, hydropower and tourism (where relevant) Restored ecosystem services in surrounding catchment ecosystem to sustain water flow	Reduce siltation Stabilise slopes Enhance water recharge capacity Enhance vegetation growth downstream Water regulation and storage: regulate runoff, flooding and aquifer recharge Erosion regulation Enhanced carbon storage in grasslands Biodiversity conservation	Increased cohesion social capital among parish actors from establishing water groups and jointly planning and implementing activities Improved health from stable water supply, enough food and better nutrition Decrease in risk to human well-being from prevention of flooding Decrease in time spent in search for water	Improved agricultural livelihoods and increased income from increased commercial sale of more varied and healthier crops at local market

Table 11 lists observed and expected outcomes regarding climate change and environmental, social and economic benefits of Ecosystem-based Adaptation (EbA) measures.

The anticipated outputs include:

• Individual Farm plans and Sustainable Forest Management (SFM) activities implemented in 4 districts. The plans will be developed with each landowner or community in line with the community resource maps. (Details to be further clarified during the Project Preparation Grant (PPG) phase).

• 20,500 ha of land put under conservation agricultural practices including minimum tillage soil cover maintenance to reduce soil erosion and less frequency of opening land for cultivation (GEF/RoU/UNDP, 2014).

• Soil erosion monitored at select sites in Manafwa District (sites to be selected in collaboration with National Agricultural Research Organization (NARO) during Project Preparation Grant (PPG)

• A Monitoring system and established and used to estimate emission reduced from further encroachment of forests, clearing and increase in storage from reforestation.

• A Site specific monitoring system for carbon monitoring established-in line with country agriculture Nationally Appropriate Mitigation Actions (NAMAs)

• 1,000 ha reforested and managed for sustainable fuelwood harvesting (GEF/RoU/UNDP, 2014).

• Communities collectively engaged and capacitated to implement SLM to reverse land degradation and to access and utilize energy efficient technologies to conserve biomass and reduce GHG emissions

• Best Practice guidelines developed, disseminated and training conducted in 3 Districts. [These may include criteria for assessing the state of land and natural resources for the purposes of land use decision making].

What Next?

Uganda's leadership should continue to:

• Implement existing key policies and strategies.

• Mainstream climate risk into key policy documents, such as the draft coffee policy.

• Mainstream climate risk at all levels of crop value chains, from production to consumption.

• Promote continuous improvement of coordination functions among government agencies, as well as between national institutions, local governments and communities.

• Involve local communities in detailed regional climate risk assessments and the design and implementation of adaptation options.

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