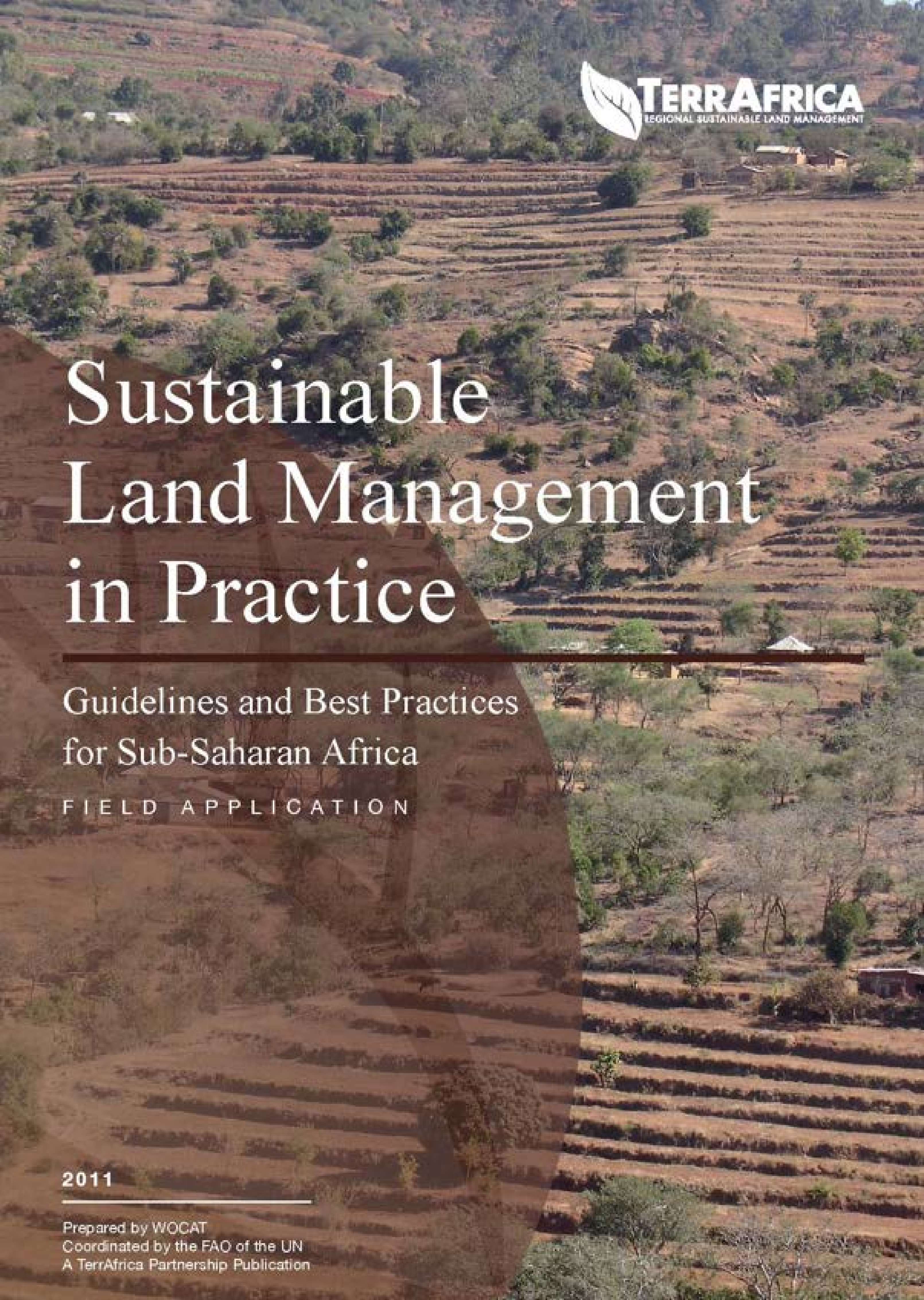

TERRAFRICA
REGIONAL SUSTAINABLE LAND MANAGEMENT

Sustainable Land Management in Practice

Guidelines and Best Practices for Sub-Saharan Africa

FIELD APPLICATION

2011

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Sustainable Land Management in Practice

Guidelines and Best Practices for Sub-Saharan Africa

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Cover photo:	Sustainable Land Management practiced on small-scale farms in Machakos, Kenya: Protection of erosion-prone slopes through hand-dug terraces in combination with agroforestry (Hanspeter Liniger)

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FOREWORD

Land is the true of wealth of Sub-Saharan Africa (SSA). The region is characterized by a very rich diversity of natural ecosystem resources, including soils, vegetation, water and genetic diversity. Together, these constitute the region's main natural capital. It is from these assets that the provision of food, water, wood, fibre and industrial products, and essential ecosystem services and functions are derived. And they must be maintained in order to support African populations into the future. Simultaneously, it is from the land that 60 percent of the people directly derive their livelihoods - from agriculture, freshwater fisheries, forestry and other natural resources (FAO 2004).

However, African land and water resources in some areas are seriously threatened through overuse although per capita availability is one of the highest in the world. This is a direct result of the increasing needs of a growing population, combined, often, with inappropriate land management practices. Thus, on the one hand, the African population is growing at over two percent a year (FAO 2008), requiring a doubling of food production by 2030 to keep pace with demand; on the other hand, productivity of natural resources is in general in decline. Additionally, the number of natural disasters has increased and climate change is already taking its toll.

A new system of management and governance of land resources is urgently needed; one that is able to respond in a systematic and integrated manner to this key development challenge. Sustainable land management (SLM) is a comprehensive approach, with the potential of making very significant and lasting differences in the near future, and over the long-term. But what is sustainable land management exactly? What are the principles, and above all, the practices that people can use? How can it make a real difference and provide concrete solutions for Africa? These are the key questions that this book wishes to address - and answers are provided through the case studies and analyses.

These guidelines have been developed based on FAO's and WOCAT's extensive experience. The book draws, in particular, on WOCAT's network and its database of SLM knowledge - as well as on WOCAT's first overview book entitled 'Where the land is greener'. These guidelines were implemented in the framework of the TerrAfrica partnership, whose main objective is to mainstream and upscale SLM in SSA, through the leveraging and harmonising of multisectoral investments at the local, country, subregional and regional levels.

This book is aimed at giving a strong boost to the adoption of SLM on the African continent. It is based on scientific and technical as well as practical and operational knowledge. It was written to provide clear guidance to countries, regional institutions and programmes, development partners and land users organizations that are ready and eager to change present investments towards a more sustainable direction.

The book presents 13 major groups of SLM technologies and approaches in a user-friendly manner, exemplified by 47 case studies from all over the region. It should be emphasized that, although comprehensive, these practices are not intended to be prescriptive or top-down, and in most cases can be improved and tailored to different situations. Users are therefore encouraged to adapt and modify them, based on specific conditions, integrating local knowledge and ingenuity.

Furthermore, the book addresses environmental issues that are the most pressing for SSA: thus not just combating land degradation, but also preserving ecosystem functions, ensuring food security, securing water resources within the land and confronting the climate change issues of adaptation and mitigation. Typical situations in SSA are addressed, and the potential for major contributions to improved livelihoods is emphasized.

It is expected that on-going major initiatives, such as country programmes and investment operations supported by TerrAfrica, national action plans and sector investment strategies, the Comprehensive Africa Agriculture Development Programme (CAADP) planning, as well as forest, water resources and climate change initiatives will facilitate operationalization and upscaling of these practices through multi-stakeholder partnerships. It is hoped that all stakeholders will benefit from the invaluable information contained in this guide and participate in the TerrAfrica partnership to expand and document the state of the knowledge.

Jacques Diouf
FAO Director-General

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This volume is a core knowledge product for the TerrAfrica platform, prepared under the Food and Agriculture Organisation's (FAO) leadership, and financed by the multi-donor TerrAfrica Leveraging Fund, the World Bank, FAO, Swiss Development Cooperation (SDC) and World Overview of Conservation Approaches and Technologies (WOCAT). These guidelines were prepared by Hanspeter Liniger, Rima Mekdaschi Studer, Christine Hauert and Mats Gurtner, initiated and coordinated by Dominique Lantieri of FAO, edited by William Critchley, CIS, VU-University Amsterdam and received support, technical contributions and reviews from Steve Danyo of the World Bank and Sally Bunning of FAO. The guidelines are based largely on an iterative process that tapped into the collected experiences of people and institutions both inside and outside Africa and could only be realised through the guidance, cooperation, and assistance of many contributors who champion SLM as a way to secure environmentally friendly and climate resilient livelihoods.

The SLM groups as they stand now could not have been realised without the review and technical inputs from the following resource persons: **Integrated Soil Fertility Management:** Jacqueline Gicheru, FAO; Stephen Twomlow, UNEP; Wairimu Mburathi, FAO; **Conservation Agriculture:** Amir Kassam, FAO; Josef Kienzle, FAO; Maimbo Malesu, ICRAF; Ric Coe, ICRAF; Theodor Friedrich, FAO; **Rainwater Harvesting:** Bancy Makanya Mati, ICRAF; Christoph Studer, Swiss College of Agriculture; Maimbo Malesu, ICRAF; Sally Bunning, FAO; **Smallholder Irrigation Management:** Bernard Keraita, IWMI; Chris Morger, Intercooperation; Pay Drechsel, IWMI; Sourakata Bangoura, FAO; Wairimu Mburathi, FAO; **Cross-Slope Barriers:** Hans Hurni, CDE; Jan De Graaff, WUR; Kithinji Mutunga, FAO; **Agroforestry:** Aichi Kityali, ICRAF; Chin Ong; Hubert de Foresta, Institute for Research and Development (IRD); Jeremias Mowo and Ric Coe, ICRAF; **Integrated Crop-Livestock Management:** Jonathan Davies, IUCN; **Pastoralism and Rangeland Management:** Eva Schlecht, University of Kassel; Jonathan Davies, IUCN; Pierre Hiernaux, CESBIO; **Sustainable Planted Forest Management:** Walter Kollert, FAO; **Sustainable Natural Forest Management in Drylands:** Anne Branthomme, FAO; Nora Berrahmouni, FAO; **Sustainable Rainforest Management:** Alain Billand, CIRAD; Carlos de Wasseige, projet FORAF, CIRAD; Nicolas Bayol, 'Forêt Ressources Management' (FRM); Richard Eba'a Atyi, projet FORAF; Robert Nasi, CIFOR; **Trends and new Opportunities:** William Critchley, CIS, VU-University Amsterdam; **SLM Approaches:** William Critchley, CIS, VU-University Amsterdam; Ernst Gabathuler, CDE

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ABBREVIATIONS AND ACRONYMS

AfDB	African Development Bank
AU-NEPAD	African Union - New Partnership of African Development
CABI	Commonwealth Agricultural Bureaux International
CC	Climate Change
CDE	Centre for Development and Environment
CEAS	Centre écologique Albert Schweizer
CESBIO	Centre d'Etudes Spatiales de la BIOsphère
CGIAR	Consultative Group on International Agricultural Research
CIFOR	Centre for International Forestry Research
CIRAD	La recherche agronomique pour le développement; Agricultural Research for Development
CIS	Centre for International Cooperation (VU University Amsterdam)
CTA	Technical Centre for Agricultural and Rural Cooperation
FAO	Food & Agricultural Organization of the United Nations
FFS	Farmer Field School
FORAF	African Forest Observatory
GHG	Greenhouse gases
GREAD	Groupe de Recherche d'Etude et d'Action pour le Développement, Niger
ICIPE	International Centre for Insect Physiology and Ecology – African Insect Science for Food and Health
ICRAF	World Agroforestry Centre
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
ILEIA	Centre for Learning on Sustainable Agriculture
INIDA	National Agrarian Development Institute, Cape Verde
ISRIC	World Soil Information
IUCN	International Union for Conservation of Nature
IWMI	International Water Management Institute
LADA	Land Degradation Assessment in drylands by FAO
M&A	Monitoring and Assessment
na	not applicable
NGO	Non Governmental Organisation
OECD	Organisation for Economic Co-operation and Development
PES	Payment for Ecosystem Services
PRA	Participatory Rural Appraisal
R&D	Research and Development
SDC	Swiss Development Cooperation
SLM	Sustainable Land Management
SOC	Soil Organic Carbon
SOM	Soil Organic Matter
SSA	Sub-Saharan Africa
SWC	Soil and Water Conservation
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN-REDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degardation
USDA	United States Department of Agriculture
WB	World Bank
WOCAT	World Overview of Conservation Approaches and Technologies
WUR	Wageningen University & Research Centre

EXECUTIVE SUMMARY

PART 1: GUIDING PRINCIPLES

Introduction

Aims and structure

Production of guidelines for best sustainable land management (SLM) technologies and approaches in Sub-Saharan Africa (SSA) has been part of TerrAfrica's programme during 2009-2010. These guidelines and case studies are intended to help create a framework for investment related to SLM in SSA. The particular aim of these guidelines is to identify, analyse, discuss and disseminate promising SLM practices - including both technologies and approaches - in the light of the latest trends and new opportunities. The focus is, in particular, on those practices with rapid payback and profitability and / or other factors that drive adoption.

This document is targeted at key stakeholders in SLM programmes and projects at the design and implementation stages, including practitioners, managers, policy-makers, planners, together with, financial and technical institutions, and donors. The guidelines are divided into two main parts. Part 1 highlights the main principles behind SLM, and what considerations are important for technologies and approaches to qualify as 'best practices' suitable for upscaling. Part 2 presents twelve groups of SLM technologies as well as a section on SLM approaches. These are supported by specific case studies. Key resource persons and experts on SLM in SSA were asked to assist in finalising the SLM groups and to describe specific case studies. This strives to be a 'state of the art' product.

Focus on Sustainable Land Management in Sub-Saharan Africa

Sub-Saharan Africa is particularly vulnerable to threats of natural resource degradation and poverty. This is due to various factors including a high population growth rate and increasing population pressure, reliance on agriculture that is vulnerable to environmental change, fragile natural resources and ecosystems, high rates of erosion and land degradation, and both low yields and high post-harvest yield losses. On top of this can be added sensitivity to climate variability and long-term climate change,

In SSA concerted efforts to deal with land degradation through SLM must address water scarcity, soil fertility, organic matter and biodiversity. SLM seeks to increase production through both traditional and innovative systems, and to improve resilience to the various environmental threats.

Principles for best SLM practices

Increased land productivity

In order to increase production from the land, water use efficiency and productivity need to be improved. This can be achieved by reducing high water loss through run-off and unperceived evaporation from unprotected soil, harvesting water, improving infiltration, maximising water storage - as well as by upgrading irrigation and managing surplus water. The first priority must be given to improving water use efficiency in rainfed agriculture; here lies the greatest potential for improved yields with all the associated benefits. For irrigated agriculture, conveyance and distribution efficiency are key water-saving strategies. Each of the best practices presented in Part 2 of these guidelines include improved water management and water use efficiency; some of them are particularly focused on coping with water scarcity - such as water harvesting in drylands or protection against evaporation loss and runoff, through conservation agriculture, agroforestry or improved grazing land management.

Soil fertility decline due to unproductive nutrient losses (through leaching, erosion, loss to the atmosphere) and 'nutrient mining' is a major problem in SSA. An improvement to the current imbalance between removal and supply of nutrients can be achieved through various means. These include cover improvement, crop rotation, fallow and intercropping, application of animal and green manure, and compost through integrated crop-livestock systems, appropriate supplementation with inorganic fertilizer and trapping sediments and nutrients e.g. through

Integrated land use system with maize-bean intercropping and grass strips for fodder production in a high potential area (Hanspeter Liniger).

bunds, vegetative or structural barriers / traps. All these are part of an integrated soil fertility management leading to an improvement in soil organic matter and soil structure. Improved agronomy is an essential supplement to good SLM practices. Strategic choice of planting materials that are adapted to drought, pests, diseases, salinity and other constraints, together with effective management is a further opportunity.

Major potential to improve land productivity also lies in improving micro-climatic conditions. A favourable microclimate in dry and warm areas can be created by reducing winds through windbreaks and shelterbelts, protecting against high temperature and radiation (using agroforestry and multistorey cropping) and by keeping conditions as moist as possible. Mulch and plant cover are important in this context. In humid areas the emphasis is on protecting soils against intensive rainfall.

Thus to increase land productivity it is essential to follow and combine the principles of improving water use efficiency and water productivity, increasing soil fertility, managing vegetation and attending to the micro-climate. These synergies can more than double productivity and yields in small-scale agriculture. Further increases in productivity can also be achieved by intensification and / or diversification of production.

Improved livelihoods

Despite the constraints and problems land users have, they are willing to adopt SLM practices if they provide higher net returns, lower risks or a combination of both. Cost efficiency, including short and longterm benefits, is the key issue for adoption of SLM. Land users are more willing to adopt practices that provide rapid and sustained pay-back in terms of food or income. Assistance for establishment of certain measures may be needed for small-scale subsistence land users if costs are beyond their means and if quick benefits are not guaranteed. Maintenance costs need to be covered by the land users to ensure self-initiative. This implies an accurate assessment of costs and benefits in monetary and non-monetary terms: herein lies a significant challenge.

Land users may require additional inputs to take up SLM practices. These are related to materials (machinery, seeds, fertilizers, equipment, etc.), labour, markets, and knowledge. Labour and inputs are of concern, especially in areas affected by, for example, outmigration. In these cases especially, SLM practices such as conservation agriculture, with the advantages of reduced labour and inputs, will stand a better chance of being adopted. Changes towards SLM should build on – and be sensitive to - values and norms, allow flexibility, adaptation and innovation to improve livelihoods. Most appropriate is the promotion of SLM practices that are easy to learn and thus require minimal training and capacity building.

Improved ecosystems: being environmentally friendly

Practices, to be truly sustainable, must be environmentally friendly, reduce current land degradation, improve biodiversity and increase resilience to climate variation and change. Given the current state of land in SSA, SLM interventions are vital to prevent, mitigate and rehabilitate land degradation. The main efforts should address the problems of water scarcity, low soil fertility, organic matter and reduced biodiversity. Priority should be given to low-input agronomic and vegetative measures, and only then consider the application of more demanding structural measures. Combinations of measures that lead to integrated soil and water, crop-livestock, fertility and pest management are promising. Spreading of local successes in combating degradation leads to compound impacts – the whole being greater than the sum of the parts - at the watershed, landscape and global levels.

A key concern in SLM and protecting ecosystem function in SSA is conservation of biodiversity. Plant and animal biodiversity are central to human well-being, most notably in supporting food production, but also as a source of fibre, wood, and medicines. They also have cultural, recreational and spiritual significance. Because African farming depends, still, very largely on local landraces of a wide variety of crops, the wealth of its agro-biodiversity must not be underestimated. In the protection of agro-biodiversity the precautionary principle needs to be applied: maintain as many varieties of plants and domestic animals as possible for their future potential.

Of immediate importance to people across SSA are the opportunities that SLM practices offer to help adapt to and mitigate climate change (CC). Adaptation to climate change can be achieved by adopting more versatile and CC-resilient technologies – but also through approaches which enhance flexibility and responsiveness to change. Some practices increase the amount of rainfall that infiltrates the soil (e.g. mulching, improved plant cover) as well as improving its capacity to store water (e.g. increased soil organic matter content) - while simultaneously helping protect the soil from extremes of temperature and more intense rainfall. Thus the most appropriate SLM practices for SSA are characterised by tolerance to increased temperatures, to climate variability, and to extreme events. If the SLM principles of improved water, soil fertility and plant management, and micro-climate are considered, the result will be better protection against natural disasters and increased resilience to climate variability and change. Diversification of production is an additional way to increase resilience.

Land users in SSA can also contribute to global efforts in mitigation of climate change primarily by adopting SLM that sequesters atmospheric carbon in the soil and in perennial vegetation. These technologies include afforestation, agroforestry, reduced tillage, improved grazing land management. Greenhouse gas emissions can also be reduced by limiting deforestation, reducing the use of fire, better livestock management, and better agronomic practices. In summary, the principles of improved water use efficiency, soil fertility, plant management and micro-climate underpin the best land management practices and they constitute win-win-win solutions for SSA. The SLM practices presented in Part 2 are based on these principles and contribute to the improvement of land productivity, livelihood and ecosystems.

Adoption and decision support for upscaling best practices

Despite continuous efforts to spread SLM practices adoption is still alarmingly low. Successful adoption of SLM depends on a combination of factors. All must be addressed.

Adoption - uptake and spread

Setting up institutional and policy frameworks to create an enabling environment for the adoption of SLM involves the strengthening of institutional capacities as well as collaboration and networking. Rules, regulations and by-laws need to be established, but must be relevant to be accepted and followed. Resource use rights and access are key entry points that give people individual and / or collective security and motivation for investment. Access to markets, where prices can change quickly, require flexible and adaptable SLM practices, open to innovation. These practices also need to be responsive to new trends and opportunities such as ecotourism or payment for ecosystem services.

A key aspect in adoption and spread of SLM is to ensure genuine participation of land users and professionals during all stages of implementation to incorporate their views and ensure commitment. At the same time off-site (e.g. downstream) interests may restrict freedom at the local level, such as the free use of water for irrigation. But it may equally provide an opportunity for collaboration, resulting in win-win solutions upstream and downstream.

Extension services need to be based on appropriate training and capacity building. These activities should involve individual land users (e.g. through farmer field schools, farmer–to-farmer exchange, support of local promoters) and communities, and not just depend on government agents. Access to credit and financing schemes can be of vital help for rural people starting new SLM initiatives - but may also create dependency if incentives are not used judiciously. Financial support needs to be enhanced for institutions providing advice, plans and decision support to land users.

Monitoring and assessment of SLM practices and their impacts is needed to learn from the wealth of knowledge available. This embraces traditional, innovative, project and research experiences and lessons learnt – both successes and failures. Major efforts are required to fill knowledge gaps and shed light on where and how to invest in the future. While donors request more and better quality data related to spread, impacts and benefit-cost ratios of SLM, there are still too few efforts in assessment and harmonised knowledge management.

Decision support – upscaling SLM

Given the challenge of finding best SLM practices for diverse local conditions, it is essential to provide decision support for local land users and the specialists who advise them - as well as for planners and decision-makers. This requires sound procedures, tapping into existing knowledge and weighing criteria that are important at all levels of scale. A first step is to raise awareness of the importance of, and the need for, investments in knowledge management and decision support mechanisms.

The building up of a common and standardised pool of knowledge related to SLM technologies and approaches for implementation and dissemination provides the basis for successful upscaling. Making this information available, and providing tools for comparing, selecting and fine-tuning SLM practices for different environments, ecological, economic, social and cultural conditions is a further requirement. Proper mapping of SLM practices and their impacts, and comparison of these with areas of land degradation, provides the foundation for deciding where to locate SLM investments that are cost-efficient and have the highest on-site and off-site impacts. Given the limited resources for SLM, decisions must be aimed at maximising impact with the least input.

Future interventions need to promote the development of joint or ‘hybrid’ innovation that ensures making the best of local and scientific knowledge. However all developments must take into consideration markets, policies and institutional factors that can stimulate widespread smallholder investment.

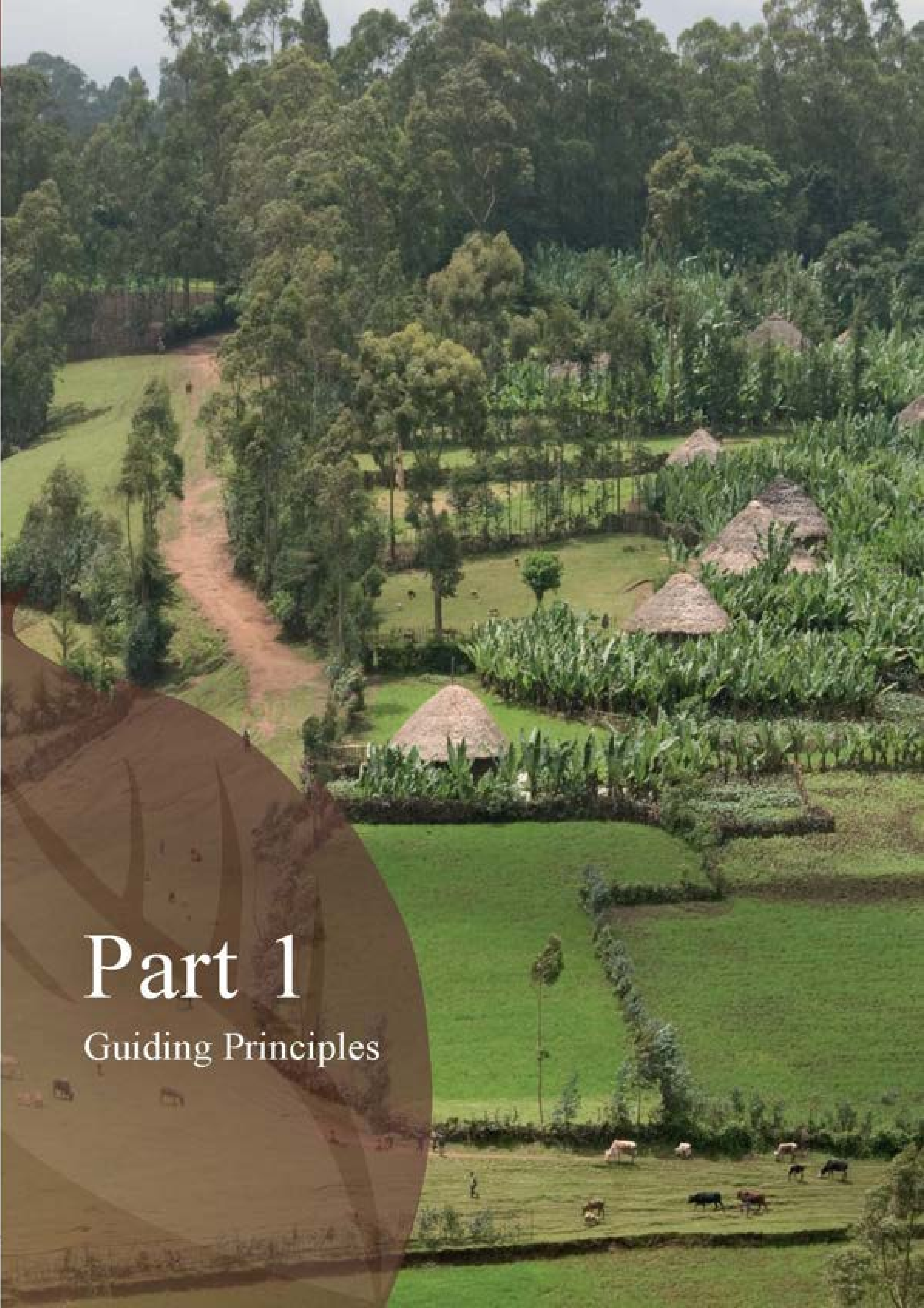
The way forward

Part 1 of the guidelines ends by acknowledging the complexity of sound natural resource management and clearly shows the need for major shifts in emphasis to overcome bottlenecks and barriers to the spread of SLM in SSA. These shifts concern various aspects, at different levels, including technologies and approaches, institutional, policy, governance, economy, knowledge management and capacity building.

Investments in spreading SLM practices in Sub-Saharan Africa have great scope and can provide multiple benefits not only locally, but also regionally nationally and globally. Consolidated action towards better use of valuable knowledge at all levels is needed and will be beneficial in the future, as it can be anticipated that change will be even more pronounced with respect to global markets, climate change, demands on ecosystem services, etc. In short, investment in SLM and a sound knowledge management pays now - and will continue to do in the future.

PART 2: BEST SLM PRACTICES FOR SUB-SAHARAN AFRICA

Twelve groups of SLM technologies backed up by 41 case studies and a section on SLM approaches, with 6 case studies, are presented in Part 2 of the guidelines. The SLM groups follow the principles of best practices: increasing productivity, improving livelihoods and improving ecosystems. The approaches illustrated were proven successful in implementing and spreading of SLM in SSA. All groups and case studies are presented according to the standardised WOCAT format for documenting and disseminating SLM. There is no one miracle solution (‘silver bullet’) to solve the problems which land users in SSA face. The choice of the most appropriate SLM practice will be determined by the local context and particular situation of local stakeholders.



Part 1

Guiding Principles


Hanspeter Liniger

INTRODUCTION

Setting the frame

Land degradation, resulting from unsustainable land management practices, is a threat to the environment in Sub-Saharan Africa (SSA), as well as to livelihoods, where the majority of people directly depend on agricultural production. There is a potentially devastating downward spiral of overexploitation and degradation, enhanced by the negative impacts of climate change - leading in turn to reduced availability of natural resources and declining productivity: this jeopardises food security and increases poverty. Sustainable land management (SLM) is the antidote, helping to increase average productivity, reducing seasonal fluctuations in yields, and underpinning diversified production and improved incomes.

Sustainable land management is simply about people looking after the land – for the present and for the future. The main objective of SLM is thus to integrate people's coexistence with nature over the long-term, so that the provisioning, regulating, cultural and supporting services of ecosystems are ensured. In SSA, this means SLM has to focus on increasing productivity of agro-ecosystems while adapting to the socio-economic context, improving resilience to environmental variability, including climate change and at the same time preventing degradation of natural resources.

These guidelines provide important guidance to assist countries to design and implement SLM technologies and approaches to scale up sustainable land and water management, at either the national program level or at the level of projects on the ground. The guidelines are one of a suite of products that falls under the TerrAfrica Country Support Tool, which offers a customisable approach for task teams and clients to build land management programs, either within investment operations or as standalone technical assistance. The guidelines build up on the experiences of the book 'where the land is greener' and have drawn from the expertise within the global WOCAT programme. They have been financed by the World Bank's Development Grant Facility 2008 as part of the 2009-2010 TerrAfrica Work Programs and co-funded by the Swiss Agency for Development and Cooperation (SDC).

TerrAfrica involves many Sub-Saharan countries and is led by the Planning and Coordination Agency (NPCA) of the African Union's New Partnership for Africa's Development (AU-NEPAD). TerrAfrica is a global partnership to mainstream and upscale sustainable land management (SLM) in SSA by strengthening enabling environments for mainstreaming and financing effective nationally-driven SLM strategies (www.terrafrica.org). Learning from past experiences, it endorses the principles of partnership, knowledge management and harmonised, aligned and scaled-up investment at the country level. The guidelines were developed in coordination with another TerrAfrica resource guide publication on 'Using sustainable land management practices to adapt to and mitigate climate change in Sub-Saharan Africa' (Woodfine, 2009).

These guidelines do not pretend to be exhaustive in terms of data and information collection, or to cover all aspects of SLM. A deliberate and strategic choice was made to show the potential of SLM in the context of SSA. A further function of these guidelines is to act as a prototype for national and regional compilations of SLM practices: thus showing how field knowledge can be made available in a way that can be followed by future publications covering other aspects of SLM. The focus here is on SLM practices in SSA which draw directly on WOCAT's extensive database, and take into account the experience of TerrAfrica's partners: in a rapidly changing environment every effort has been made to review and assimilate the latest trends, threats and opportunities (Crepin, et al., 2008; Woodfine, 2009).

Aims and audience

The overall aim of these guidelines is to identify, describe, analyse, discuss, and present for dissemination SLM practices, both technologies and approaches that are appropriate to Sub-Saharan Africa – and based in solid science. Materials are drawn from experience and representative case studies; these focus in particular on those practices with rapid paybacks and profitability and / or other factors likely to drive adoption. The direct objectives thus are:

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

The target group of this document constitutes key stakeholders in SLM programmes and projects, involved at the design and implementation stages. These thus include policy-makers, planners, programme managers together with practitioners, international financial and technical institutions, as well as other donors. The guidelines are intended also to raise further awareness and understanding among a broader public interested in poverty alleviation, protection of the environment and mitigation of land degradation.

Structure and sources

These guidelines build on WOCAT's book 'where the land is greener' (WOCAT, 2007), and are divided into two main parts.

Part 1 highlights the main principles behind SLM, and what considerations are important for technologies and approaches to qualify as 'best practices' suitable for upscaling. Information is based on literature and WOCAT's expertise.

Part 2 presents twelve groups of SLM technologies and a section on SLM approaches, supported by specific case studies. This section is based on the WOCAT global database, the TerrAfrica Knowledge Base, a literature review (publications, papers, project documents and manuals) and interactive contact with SLM specialists in SSA. The compilation of SLM groups and case studies focuses first on SLM interventions in order to identify factors of success / failure, good practices and lessons learnt. It determines the effectiveness and cost-efficiency of the various SLM interventions used to-date with the aim of identifying the best practices for scaling-up.

The best practices that are presented:

- cover major land use systems;
- represent solutions to various degradation types in different agro-ecological zones;
- cover a broad variety of technologies and approaches;
- 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.

All groups and case studies are presented according to the familiar and standardised WOCAT format for documenting and disseminating SLM.

Particular efforts were made to show impacts of SLM and their potential to address current global issues such as desertification, climate change, water scarcity, and food security. Key resource persons and experts on SLM in SSA were asked to review and assist in finalising the SLM groups on technologies and approaches, to provide figures on costs and benefits, and to describe specific case studies. This is thus a product that brings together all the available, important information about SLM in SSA: it strives to be a 'state of the art' product. Thus, the guidelines are founded on a body of solid practical experience - and underpin the benefits of investing in SLM and the potential for building on success.

Focus on Sub-Saharan Africa

Sub-Saharan Africa is particularly vulnerable to the twin threats of natural resource degradation and poverty owing to the following factors:

- High population growth and pressure;
- Dependency of livelihoods on agriculture, with 65-70% of the population depending directly on rainfed agriculture and natural resources. Industry and the service sector also depend heavily on land management (Eswaran et al., 1997);
- Agriculture is highly sensitive to variability and change in climate, and markets / prices;
- Multiple severe impacts are likely to result from climate change (IPCC, 2007; Stern, 2007): these include higher temperatures, water scarcity, unpredictable precipitation, higher rainfall intensities and environmental stresses;
- The phenomenon of El Niño Southern Oscillation (ENSO) exerting a strong influence on climate variability, particularly in Eastern and Southern Africa;
- Abundance of fragile natural resources and ecosystems including drylands, mountains, rainforests, and wetlands;
- High rates of land degradation (erosion and declining soil fertility, increasing water scarcity and loss of biodiversity) and sensitivity to climate variability and change;
- Low yields and high post-harvest losses due to poor land management and storage practices and limited availability of, and access to, inputs.

It is clear from the foregoing that Sustainable Land Management (SLM) is crucial for SSA, and that there are special circumstances that pose particular problems and challenges for the successful implementation of SLM.

Focus on Sustainable Land Management

Land degradation is simply defined, within the 'FAO-LADA Approach' as a decline in ecosystem goods and services from the land. Land degradation negatively affects the state and the management of the natural resources – water, soil, plants and animals - and hence reduces agricultural production. Assessments in SSA show the severity of land degradation and the urgency of improving natural resource use through sustainable land management (SLM). Land degradation occurs in different forms on various land use types:

- On cropland: soil erosion by water and wind; chemical degradation - mainly fertility decline - due to nutrient mining and salinisation; physical soil degradation due to compaction, sealing and crusting; biological degradation due to insufficient vegetation cover, 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 alien and 'undesirable' species. The consequences in terms of soil physical degradation, water runoff, erosion are widespread and severe. Low productivity and 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 logging; replacement of natural forests with monocrop plantations or other land uses (which do not protect the land) and consequences for biodiversity, and soil and water degradation.

Land uses addressed

Cropland: Land used for cultivation of crops (annual and perennial) e.g. field crops, vegetables, fodder crops, orchards, etc.

Grazing land: Land used for animal production e.g. natural or semi-natural grasslands, open woodlands, improved or planted pastures.

Forests / woodlands: land used mainly for wood production, other forest products, recreation, protection e.g. natural forests, plantations, afforestations, etc. *(WOCAT, 2008)*

Concerted efforts to deal with land degradation through SLM must address water scarcity, soil fertility, organic matter and biodiversity. Improving the water productivity and water cycle, soil fertility and plant management are important in raising land productivity.

Land degradation is exacerbated by climate change and climate variability. Africa's climate has long been recognised as both varied and varying: varied because it ranges from humid equatorial regimes, through seasonally-arid tropical and hyper-arid regimes, to sub-tropical Mediterranean-type climates; and varying because all these climates exhibit differing degrees of temporal variability, particularly with regard to precipitation (Nkomo et al., 2006). The complexities of African climates are attributable to a number of factors, many of which are unique to the continent, including the size of the tropical land mass, the expanse of arid and semi-arid lands, diverse vegetation, complex hydrology, incidence of dust exported from land surface to the atmosphere – and highly varied terrain including snow-capped mountains on the Equator, extensive low-lying swamp lands, huge inland lakes, rift valleys and two major deserts in the northern and southern sub-tropics (Crepin, et al., 2008; Woodfine, 2009).

Climate change is a major concern for SSA bringing new challenges. However, there is huge potential for SLM in climate change mitigation and adaption.

SLM best practices and their upscaling in Sub-Saharan Africa is essential for a variety of reasons – but the most basic is to sustain and improve livelihoods while protecting the land's resources and ecosystem functions. SLM thus seeks to increase production including traditional and innovative systems and to improve resilience to food insecurity, land degradation, loss of biodiversity, drought and climate change.

Sustainable Land Management has been defined by TerrAfrica as:
'the adoption of land use systems that, through appropriate management practices, enables land users to maximise the economic and social benefits from the land while maintaining or enhancing the ecological support functions of the land resources'[1].
SLM includes management of soil, water, vegetation and animal resources.

Degradation of vegetation, soils and water along river banks (Hanspeter Liniger).

SLM also includes ecological, economic and socio-cultural dimensions (Hurni, 1997). These three are not separate: in reality they are interconnected (Figure 1). They are also referred to as the '3 Es' of sustainable development - Equality, Economy, and Ecology (UNESCO, 2006).

Ecologically, SLM technologies – in all their diversity – effectively combat land degradation. But a majority of agricultural land is still not sufficiently protected, and SLM needs to spread further.

Socially, SLM helps secure sustainable livelihoods by maintaining or increasing soil productivity, thus improving food security and reducing poverty, both at household and national levels.

Economically, SLM pays back investments made by land users, communities or governments. Agricultural production is safeguarded and enhanced for small-scale subsistence and large-scale commercial farmers alike, as well as for livestock keepers. Furthermore, the considerable off-site benefits from SLM can often be an economic justification in themselves.

[1]In TerrAfrica's Background Note 1 SLM's definition is more complex, it is 'the combination of technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously maintain or enhance production, reduce the level of production risk, protect the potential of natural resources and prevent soil and water degradation, be economically viable and be sociable acceptable' which is drawn originally from Dirk Kloss, Michael Kirk and Max Kasparek. World Bank Africa Region SLM Portfolio Review, Draft 19 Jan 2004.

Best practices are basically the 'best' known to us at present: in the view of TerrAfrica 'best' implies those practices that increase production and are profitable, cost-efficient with primarily rapid, but also long-term payback, are easy to learn, socially and culturally accepted, effectively adopted and taken up, environmentally friendly and are appropriate for all stakeholders including socially marginalised groups (FAO, 2008a).

Scaling-up of SLM 'leads to more quality benefits to more people over a wider geographic area more quickly, more equitably and more lastingly' (ILEIA, 2001). Investments in scaling-up of best SLM practices in SSA are essential to have a significant impact. Too many best practices remain isolated in pockets. The challenge is to gain significant spread, not just to help an increased number of families, but to achieve ecosystem impacts that can only be realised on the large scale. In this context it is important to note that SLM covers all scales from the field to watersheds, landscapes and transboundary levels. Beyond field level, on-site and off-site as well as highland-lowland interactions need special attention. The simultaneous challenge and opportunity is to find best SLM practices which are win-win solutions leading to sustainability at the local, national and global scales.

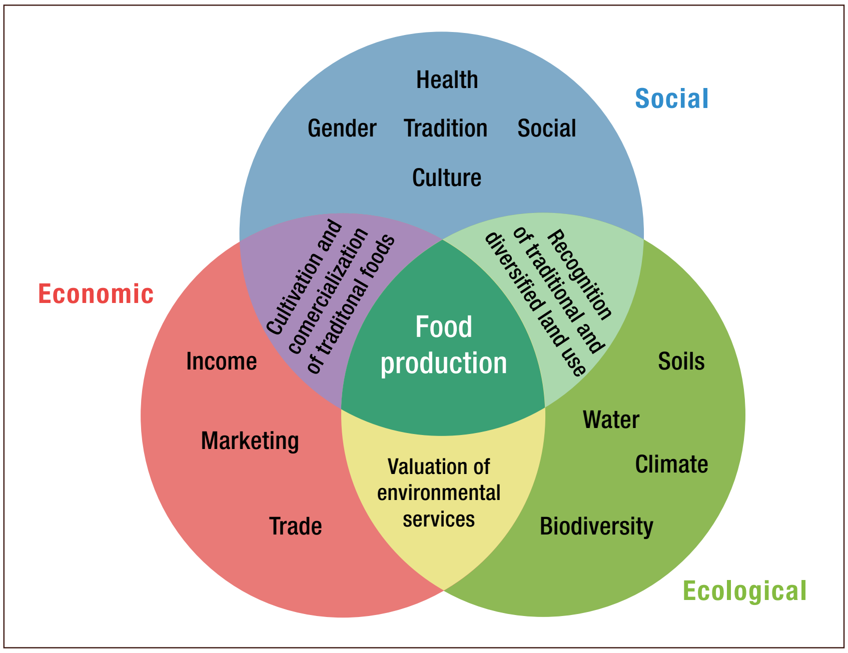


Figure 1: The 3 dimensions of sustainability. (Source: IAASTD, 2009a).


Hanspeter Liniger

PRINCIPLES FOR BEST SLM PRACTICES

For all major land use systems in Sub-Saharan Africa (SSA) including cropland, grazing land, forest and mixed land, the focus of SLM is on increased land productivity and improved livelihoods and ecosystems.

Table 1: Land use in SSA (2000)

Land use	Percentage cover
Permanent pasture	35
Arable and permanent cropland	8
Forested	27
All other land	30
Total	100

(Source: WRI, 2005 and FAO, 2004)

Increased land productivity

African cereal yields, particularly in the Sudano-Sahelian region, are the world's lowest. For SSA, increasing agricultural productivity for food, fodder, fibre and fuel remains a priority given the fast growing demand, widespread hunger, poverty, and malnutrition.

The primary target of SLM for SSA is thus to increase land productivity, improve food security and also provide for other goods and services. There are three ways to achieve this: (1) expansion, (2) intensification and (3) diversification of land use.

Expansion: Since 1960, agricultural production in Sub-Saharan Africa has been increased mainly by expanding the area of land under farming (Figure 2). Limited access and affordability of fertilizers and other inputs (e.g. improved planting material) has forced African farmers to cultivate less fertile soils on more marginal lands; these in turn are generally more susceptible to degradation and have poor potential for production. There is very limited scope for further expansion in SSA without highly detrimental impacts on natural resources (e.g. deforestation).

Intensification: The last 50 years have witnessed major successes in global agriculture, largely as a result of the 'Green Revolution' which was based on improved crop varieties, synthetic fertilizers, pesticides, irrigation, and mechanisation. However, this has not been the case for SSA (Figure 2).

Diversification: This implies an enrichment of the production system related to species and varieties, land use types, and management practices. It includes an adjustment in farm enterprises in order to increase farm income or reduce income variability. This is achieved by exploiting new market opportunities and existing market niches, diversifying not only production, but also on-farm processing and other farm-based, income-generating activities (Dixon et al., 2001). Diversified farming systems (such as crop–livestock integration, agroforestry, intercropping, crop rotation etc.) enable farmers to broaden the base of agriculture, to reduce the risk of production failure, to attain a better balanced diet, to use labour more efficiently, to procure cash for purchasing farm inputs, and to add value to produce.

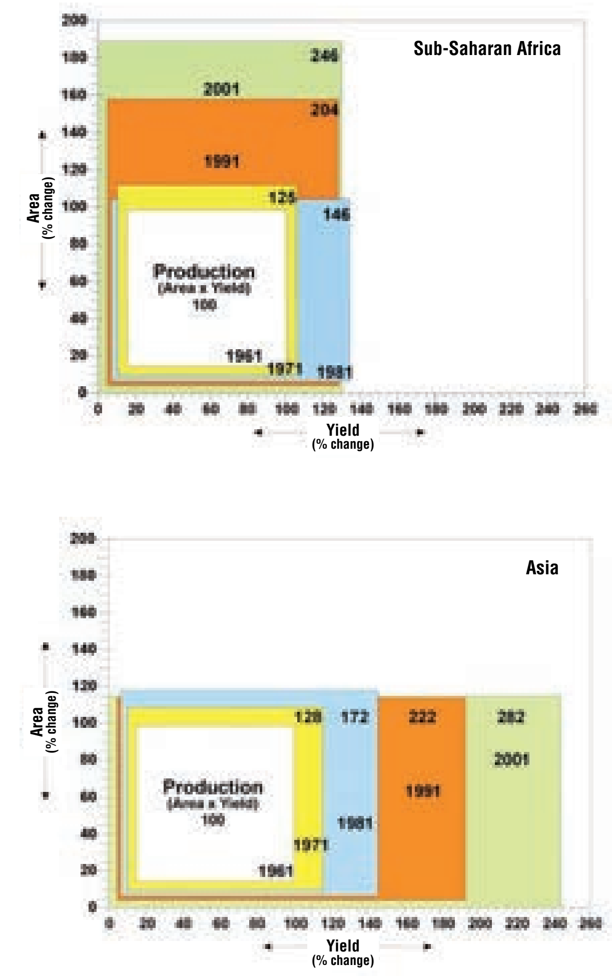


Figure 2: Comparison of changes in cereal production in SSA (above) due to changes in area and yield (1961=100) with those in Asia (below). (Source: Henao and Baanante, 2006)

Expansion, intensification and diversification to increase agricultural productivity imply:

– increasing water productivity (water use efficiency),
– enhancing soil organic matter and soil fertility (carbon and nutrient cycling),
– improving plant material (species and varieties), and
– producing more favourable micro-climates.

Agricultural production and food security in SSA today and in the future

– Population growth is 2.1% per annum: doubling of the population expected within 30-40 years.
– In 1997-99, 35% of the population had insufficient food to lead healthy and productive lives.
– Average cereal yields: of 1 tonne per hectare.
– Cereal availability per capita decreased from 136 kg/year in 1990 to 118 kg/year in 2000.
– 73% of the rural poor live on marginal land with low productivity.
– Approximately 66% of Africa is classified as desert or drylands; 45% of the population lives in drylands.
– In 2000, US$ 18.7 billion were spent in Africa for food imports and 2.8 million tonnes of food aid: this represents over a quarter of the world's total.
– 83% of people live in extreme poverty; the number of people and thus their demands on food, water and other resources are increasing.
– Energy needs and the demand for firewood and biofuel are growing even faster than food needs. This increases deforestation and pressure on vegetation, crop residues and on manure (which is often used as fuel). In many countries 70% of energy comes from fuelwood and charcoal.
– Climate change, with increased variability and extremes, puts an extra constraint on food security.
– Land is the source of employment for 70% of the population.
– Agriculture will remain the main engine of growth at least for the next few decades.
– Land degradation is severe and ongoing.
– Land productivity, food security, poverty reduction / human development and wellbeing are strongly linked

(Sources: Henao and Baanante, 2006; Castillo et al, 2007; FAO, 2007; IAASTD, 2009b TerrAfrica, 2009; WB, 2010)

Water use efficiency

Water use efficiency is defined as the yield produced per unit of water. Optimal water use efficiency is attained through minimising losses due to evaporation, runoff or drainage. In irrigation schemes, conveyance and distribution efficiency addresses water losses from source to point of application in the field. Often the term water productivity is used: this means growing more food or gaining more benefits with less water. Commonly it is reduced to the economic value produced per amount of water consumed.

In the drylands of the world, water is – by definition - the most usual limiting factor to food production due to a mixture of scarcity, and extreme variability, long dry seasons, recurrent dry spells and droughts, and occasional floods. Water scarcity and insecure access to water for consumption and productive uses is a major constraint to enhancing livelihoods in rural areas of SSA (Castillo et al., 2007; FAO, 2008b). Hence, improving water use efficiency to minimise water losses is of top-most importance.

Under the principle of the water cycle, all water remains within the system. However, at local and regional level, water can follow very different pathways and losses may be high, depending on land (and water) management. In relation to agriculture, water is often referred to as being 'blue' or 'green'. Blue water is the proportion of rainfall that enters into streams and recharges groundwater – and is the conventional focus of water resource management. Green water is the proportion of rainfall that evaporates from the soil surface or is used productively for plant growth and transpiration (Falkenmark and Rockstöm, 2006; ISRIC, 2010).

Figure 3 illustrates three major sources of water loss in agricultural production, namely surface runoff, deep percolation and evaporation from the soil surface. Surface runoff can, however, sometimes qualify as a gain when it feeds rainwater harvesting systems. Similarly, deep percolation of water can be a gain for the recharge of groundwater or surface water. However, the main useful part ('productive green water') is the soil water taken up by plants and transpired back to the atmosphere.

Many land users in developing countries could raise water productivity and water use efficiency by adopting proven agronomic and water management practices. There is considerable potential especially under low yield conditions where a small increment in water translates into a significant increase in yield (Figure 4).

Expansion to steep slopes, intensification and diversification all combined in the Uluguru Mountains of Tanzania (Hanspeter Liniger).

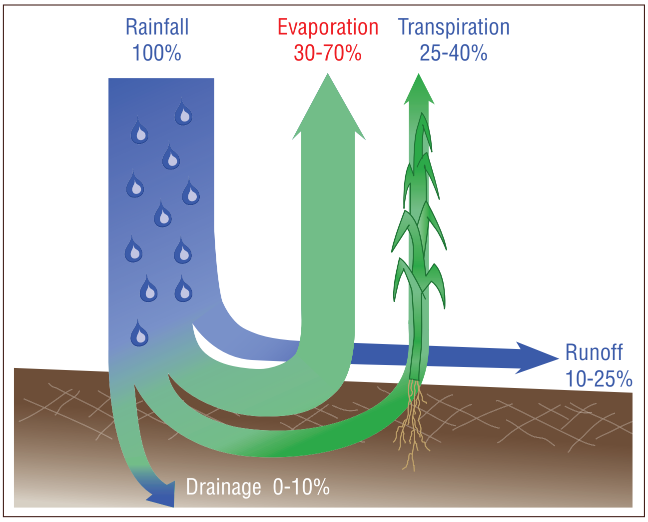


Figure 3: Productive water (transpiration) and water losses (evaporation and runoff) without water conserving measures in dry lands.

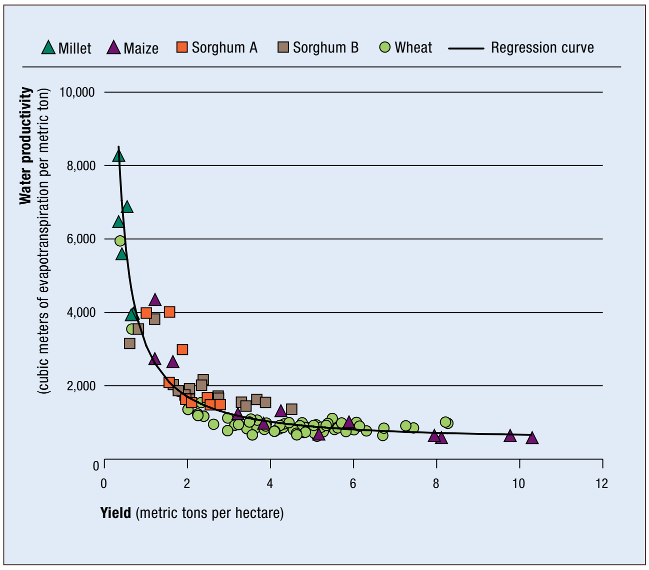


Figure 4: Water productivity and cereal yield under various management and climatic conditions: for cereal yields of less than 1 t/ha four to eight times more water is used per tonne compared to yields above 3 t/ha as the proportion used for grain (cf vegetative production is much less). (Source: Rockström et al., 2007)

Local practice combining deep tillage and ridging stops runoff but increases evaporation from the bare soil surface; under the plants the protected soil remains moist (Hanspeter Liniger).

Wastage of scare and precious water – the disturbed water cycle

- Depending on land management practices, between 30 and 70% of the rainfall on agricultural land in semi-arid areas is lost as non-productive evaporation from the soil surface or from intercepted rainfall.
- An additional 10-25% of that rainfall is lost as direct runoff without being harvested.
- As a result of these losses, only 15% to 30% of rainfall is used for plant growth.
- This low water use efficiency is closely linked to low or degraded soil cover, leaving soils exposed to solar radiation, wind and heavy rain storms and subsequent aridification and land degradation. Soil organic matter has major effects on water infiltration and nutrient availability.

(Sources: Liniger, 1995; Rockström, 2003; Molden et al., 2007; Gitonga, 2005)

Water use efficiency in rainfed agriculture: In Sub-Saharan Africa, some 93% of farmed land is rainfed (Rockström et al., 2007). The water challenge in these areas is to enhance low yields by improving water availability for plant growth: that is to maximise rainfall infiltration and the water-holding capacity of soils - simultaneously reducing surface erosion and other land degradation. Full response to water investments is only achievable if other production factors, such as soil fertility, crop varieties, pest and disease control, and tillage and weeding practices are improved at the same time (Figure 5).

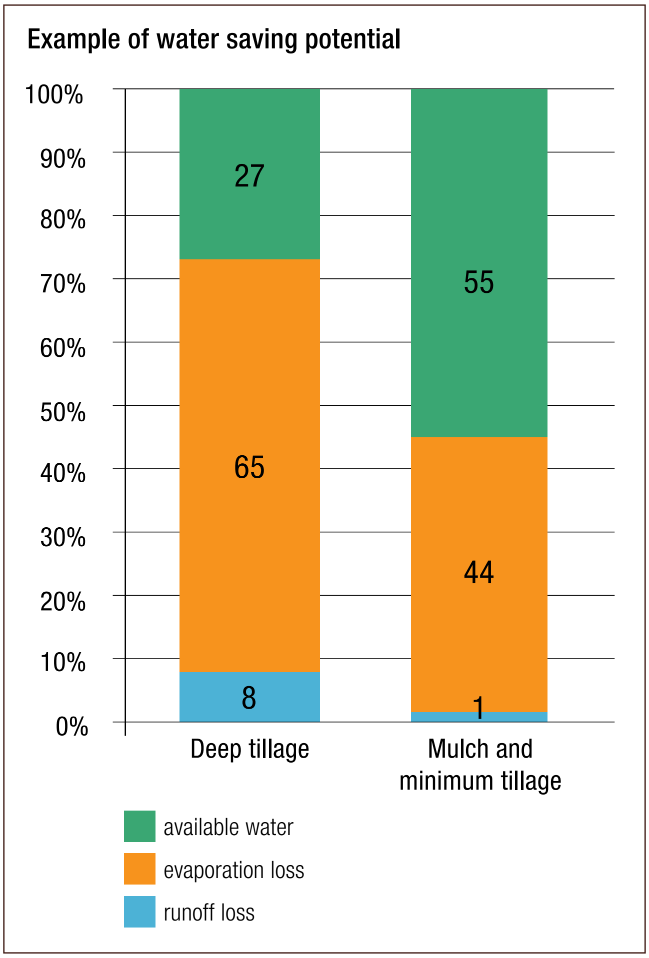


Figure 5: Water use efficiency in a semi-arid to subhumid environment comparing a local practice (deep tillage) with conservation agriculture comprising minimum tillage for weed control, mulching and intercropping of maize and beans. Under the local practice, total water loss was over 70%, with evaporation being the main contributor to this. Under mulch, the loss was reduced to 45%.The productive use of the water was doubled, and yields in some seasons even tripled (Gitonga, 2005).

Given the large water wastage through inappropriate land use practices there are significant opportunities to raise yields under rainfed agriculture and improve degraded ecosystems through better water management. All best practices in this regard fall under the five strategies listed in the box below. Management of rainwater is a main entry point into SLM.

Each of the best practices presented in Part 2 of these guidelines include improved water management and water use efficiency; some of them are particularly focused on coping with water scarcity - such as water harvesting in drylands or protection against evaporation loss and runoff, through conservation agriculture, agroforestry or improved grazing land management.

Different strategies for improved rainwater management

Divert / drain runoff & runon

Where there is excess water in humid environments, or at the height of the wet seasons in subhumid conditions, the soil and ground water can become saturated, or the soil's infiltration capacity can be exceeded. Thus safe discharge of surplus water is necessary. This helps avoid leaching of nutrients, soil erosion, or landslides. It can be achieved through the use of graded terraces, cut-off drains and diversion ditches etc.

Impede runoff (slow down runoff)

Uncontrolled runoff causes erosion - and represents a net loss of moisture to plants where rainfall limits. The strategy here is to slow runoff, allowing more time for the water to infiltrate into the soil and reducing the damaging impact of runoff through soil erosion. It is applicable to all climates. This can be accomplished through the use of vegetative strips, earth and stone bunds, terraces etc.

Retain runoff (avoid runoff)

In situations where rainfall limits plant growth, the strategy is to avoid any movement of water on the land in order to encourage rainfall infiltration. Thus water storage is improved within the rooting depth of plants, and groundwater tables are recharged. This is crucial in subhumid to semi-arid areas. The technologies involved are cross-slope barriers, mulching, vegetative cover, minimum / no tillage etc.

Trap runoff (harvest runoff)

Harvesting runoff water is appropriate where rainfall is insufficient and runoff needs to be concentrated to improve plant performance. Planting pits, half moons etc. can be used. This can also be applied in environments with excess water during wet seasons, followed by water shortage: dams and ponds can further be used for irrigation, flood control or even hydropower generation.

Reduce soil evaporation loss

Water loss from the soil surface can be reduced through soil cover by mulch and vegetation, windbreaks, shade etc. This is mainly appropriate in drier conditions where evaporation losses can be more than half of the rainfall.

Water use efficiency in irrigated agriculture: Irrigated agriculture consumes much more water than withdrawals for industrial and domestic purpose. The demand for irrigation water by far exceeds water availability. Due to water scarcity in SSA, the potential demand for irrigation water is unlimited and causes competition and sometimes conflicts. This is not just a question of drinking water supplies for people, livestock and wildlife but also environmental water requirements – which keep ecosystems healthy. Currently, only 4% of the agricultural land in SSA is irrigated - producing 9% of the crops (IAASTD, 2009b). Many irrigation schemes suffer from water wastage, and salinisation is also a common problem.

Irrigated Agriculture in SSA

- The agricultural sector is by far the biggest user of water resources worldwide; around 70% of annual water withdrawals globally are for agricultural purposes.
- In SSA, 87% of the total annual water withdrawals in 2000 were for agriculture, 4% for industry and 9% for domestic use.
- In SSA less than 4% of agricultural land is irrigated, compared to 37% in Asia and 15% in Latin America.
- The irrigated area in SSA is concentrated in South Africa (1.5 million ha), and Madagascar (1.1 million ha). Ten other countries (Ethiopia, Kenya, Mali, Niger, Nigeria, Senegal, Somalia, Tanzania, Zambia and Zimbabwe) each have more than 100,000 irrigated hectares.
- About half of the irrigated area comprises small-scale systems. In terms of value, irrigation is responsible for an estimated 9% of the crops produced in SSA.
- Inappropriate irrigation can result in soil salinisation. Tanzania for example has an estimated 1.7–2.9 million hectares of saline soils and 300,000–700,000 hectares of sodic soils, some of it now abandoned. This has not only detrimental effects on agriculture but also on water supply and quality.

(Sources: World Resources Institute (WRI), 2005; Falkenmark et al., 2007; Zhi You, 2008; IAASTD, 2009b)

Water use efficiency in irrigation systems needs to be disaggregated into conveyance, distribution and field application efficiency. Improved irrigation water management requires considering the efficiency of the whole system. Figure 6 illustrates the sequences of water losses, and Table 2 indicates the efficiency of different irrigation systems.

Table 2: Irrigation efficiency of different irrigation systems.

Irrigation System	Irrigation efficiency	Installation costs
Flooded fields (e.g. rice)	20–50%	low
Other surface irrigation (furrows etc.)	50–60% and higher	low
Sprinkler irrigation	50–70%	medium-high
Drip irrigation	80–90%	high

(Source: Studer, 2009)

Given water scarcity and widespread water wastage and poor management, best practices for irrigated agriculture include the following:

1. Increased water use efficiency: in conveying and distributing irrigation water as well as applying it in the field. Conveyance and distribution can be improved through well maintained, lined canals and piping systems – and above all avoiding leakages. In the field, reducing evaporation losses can be achieved by using low pressure sprinkler irrigation during the night or early morning, and avoiding irrigation when windy. Additionally, deep seepage of water beyond rooting depth needs to be avoided.

2. Spread of limited irrigation water over a larger area, thereby not fully satisfying the crop water requirements i.e. deficit irrigation. It allows achieving considerably higher total crop yields and water use efficiency compared to using water for full irrigation on a smaller area (Oweis and Hachum, 2001).

3. Supplementary irrigation by complementing rain during periods of water deficits, at water-stress sensitivity stages in plant growth. Supplementary irrigation is a key strategy, still underused, for unlocking rainfed yield potential and water productivity / water use efficiency.

Supplementary irrigation

- Yields of sorghum in Burkina Faso and maize in Kenya were increased from 0.5 to 1.5–2.0 metric tonnes per hectare with supplementary irrigation plus soil fertility management (Rockström et al., 2003; Molden et al., 2007).
- A cost-benefit study of maize-tomato cropping systems using supplementary irrigation found annual net profits of US$ 73 in Burkina Faso and US$ 390 in Kenya per hectare. In comparison traditional systems showed net income losses of US$ 165 and US$ 221, respectively (Fox et al., 2005).

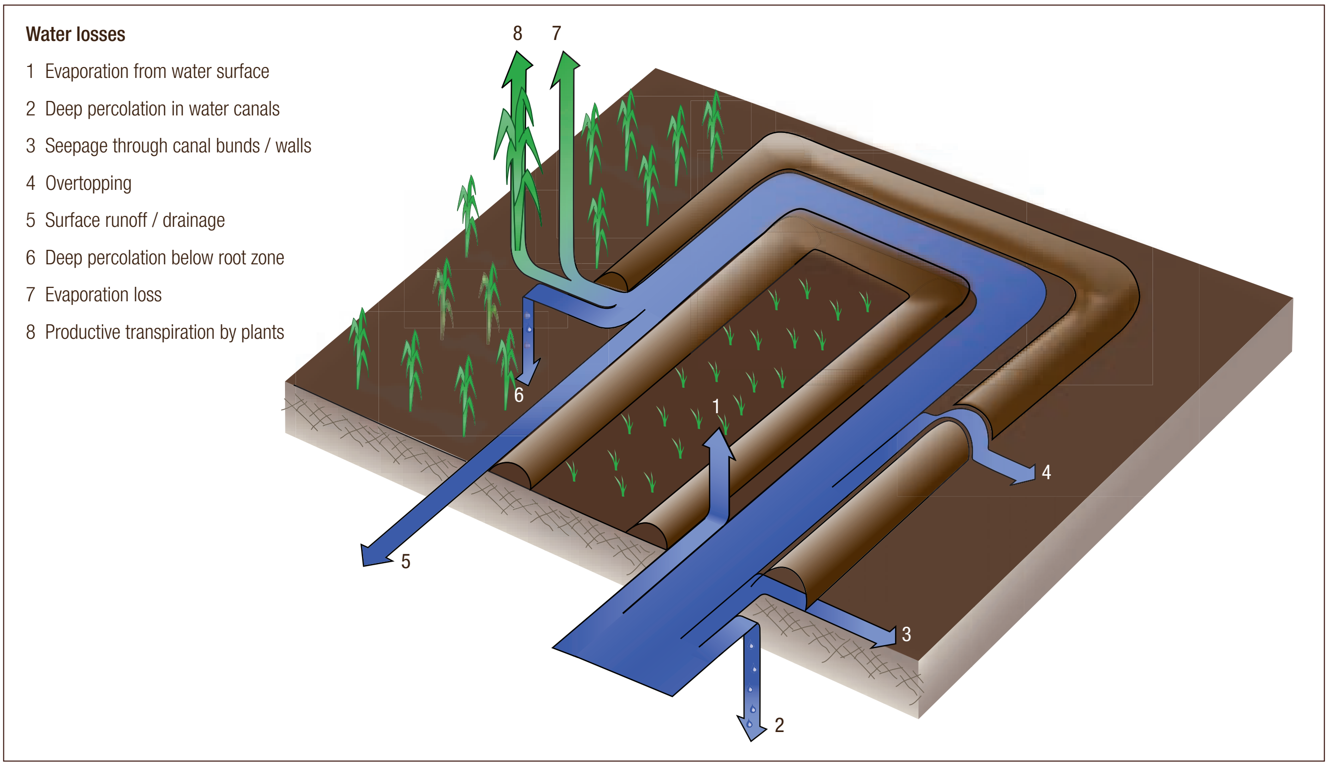


Figure 6: Water losses in irrigation systems: from source to plant illustrating the small fraction of water used productively for plant growth compared to the total water directed to irrigation systems (based on Studer, 2009).

4. Water harvesting and improved water storage for irrigation during times of surplus and using the water for (supplementary) irrigation during times of water stress. Small dams and other storage facilities as described in the SLM group of rainwater harvesting, which are combined with community level water management, need to be explored as alternatives to large-scale irrigation projects (IAASTD, 2009b).

5. Integrated irrigation management is a wider concept going beyond technical aspects and including all dimensions of sustainability. It embraces coordinated water management, maximised economic and social welfare, assured equitable access to water and water services, without compromising the sustainability of ecosystems (Studer, 2009).

Improving water productivity in rainfed and irrigated agriculture (Principles)

'More crop per drop' by:

– reducing water loss
– harvesting water
– maximising water storage
– managing excess water

Any efforts towards better water management must be combined with improved soil, nutrient, and crop management, and these synergies can more than double water productivity and yields in small-scale agriculture (Rockström et al, 2007).

There is need for a 'green water revolution' to explore the potential of increasing water use efficiency for improved land productivity. First, priority must be given to improved water use efficiency in rainfed agriculture; here is the greatest potential for improvements not only related to yields but also in optimising all round benefits. Practices that improve water availability relate to soil cover and soil organic matter improvement, measures to reduce surface runoff (see 'Cross-Slope Barriers') as well as to collect and harvest water.

For irrigated agriculture, conveyance and distribution efficiency are key additional water saving strategies. The emphasis should be on 'upgrading' rainfed agriculture with water efficient supplementary irrigation.

Soil fertility

Healthy and fertile soil is the foundation for land productivity. Plants obtain nutrients from two natural sources: organic matter and minerals. Reduced soil fertility undermines the production of food, fodder, fuel and fibre. Soil organic matter, nutrients and soil structure are the main factors influencing soil fertility. Many of Africa's soils are heavily depleted of nutrients, and soil organic matter is very low: below 1.0% or even 0.5% in the top soil (Bot and Benites, 2005).

Soil organic matter is a key to soil fertility. Organic matter includes any plant or animal material that returns to the soil and goes through the decomposition cycle. Soil organic matter (SOM) is a revolving nutrient fund: it contains all of the essential plant nutrients, and it helps to absorb and hold nutrients in an available form (Bot and Benites, 2005). Soil organic matter has multiple benefits; it is also fundamental for good soil structure through the binding of soil particles, for water holding capacity, and it provides a habitat for soil organisms.

Soil texture also influences soil fertility. The presence of clay particles influences the soil's ability to hold nutrients. Very sandy soils usually have a lower nutrient holding capacity than clay soils, and hence need particular attention in terms of soil fertility management.

Declining soil fertility: The reason for a decline in SOM and the closely linked nutrient content is simply that the biomass and nutrient cycle (Figure 7) is not sustained, meaning more material in the form of soil organic matter and / or nutrients (especially the macro-nutrients of nitrogen, phosphorous and potassium) leaves the system than is replenished. This results from various causes:

- removal of crop products and residues (plant biomass),
- loss through soil erosion,
- leaching of nutrients (below the rooting depth),
- volatisation of nutrients (e.g. nitrogen),
- accelerated mineralisation of SOM through tillage.

The gains or replenishments are derived from residues of plants grown or nutrient accumulation (e.g. nitrogen fixing), external input of organic matter, manure and fertilizer, and nutrients through the weathering and formation of the soil.

Nutrient deficit in SSA's soils

Nutrient depletion in African soils is serious:

– Soils on cropland have been depleted by about 22 kg nitrogen (N), 2.5 kg phosphorus (P), and 15 kg potassium (K) per hectare per year.

– Nutrient losses due to erosion range from of 10 to 45 kg of NPK/ha per year.

– 25% of soils are acidic with a deficiency in phosphorus, calcium and magnesium, and toxic levels of aluminium.

– Main contributing factors to nutrient depletion are soil erosion by wind and water, leaching and off-take of produce.

Low use of fertilizer:

– With an average annual application of 8-15 kg/ha, the use of fertilizer in Africa compares very poorly to an average global value of 90 kg/ha.

– Land users in Niger use manure on 30-50% of their fields at a rate of 1.2 tonnes/ha, which results in a production of only about 300 kg grain/ha.

Nutrient amount removed is higher than input:

– Negative nutrient balance in SSA's croplands - with at least 4 times more nutrients removed in harvested products compared with the nutrients returned in the form of manure and fertilizer.

– Current annual rates of nutrient losses are estimated to be 4.4 million tonnes of N, 0.5 million tonnes of P, and 3 million tonnes of K. These losses swamp nutrient additions from chemical fertilizer applications, which equal 0.8, 0.26, and 0.2 million tonnes of N, P, and K, respectively.

– Negative nutrient balance: 8 million tonnes of NPK/year.

(Sources: Sanchez et al., 1997; Sanchez, 2002; FAOSTAT, 2004; McCann, 2005; Henao and Baanante, 2006; Verchot, et al, 2007; Aune and Bationo, 2008; WB, 2010)

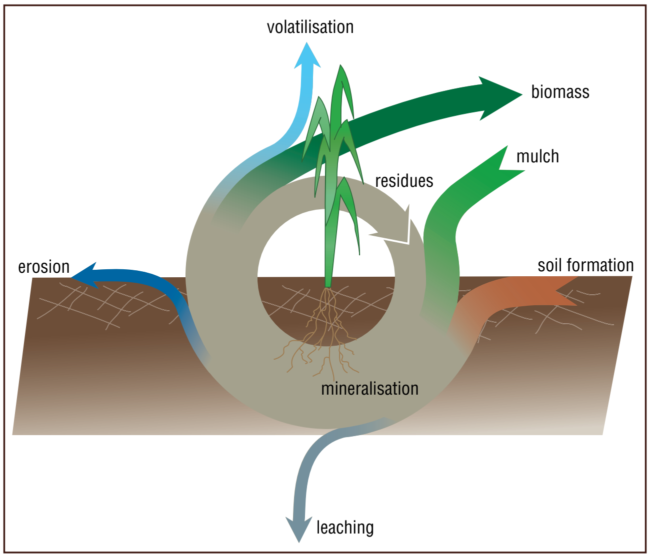


Figure 7: The nutrient and carbon cycle showing the main losses and gains / replenishments of soil organic matter, biomass and nutrients.

Enhancing and improving soil fertility through SLM: SLM practices should maintain or improve a balanced SOM–nutrient cycle, meaning that net losses should be eliminated and organic matter and / or nutrients added to stabilise or improve the soil fertility.

Replenishment of soil nutrients is a major challenge for SSA. As illustrated in the box on page 28, SSA soils have a significantly negative nutrient balance. Replenishment and reduced loss of soil nutrients can be achieved through the following options:

1. Improved fallow-systems: The deliberate planting of fast-growing species - usually leguminous - into a fallow for rapid replenishment of soil fertility. These can range from forest to bush, savannas, grass and legume fallows. The case study on 'Green Manuring with Tithonia' in Cameroon presented in Part 2 shows the importance of nutrient fixing plants planted either in sequence, intercropped or in rotation.

2. Residue management: A practice that ideally leaves 30% or more of the soil surface covered with crop residues after harvest. It requires residue from the previous crop as the main resource (thus burning is discouraged) – it also helps reducing erosion, improving water infiltration and therefore moisture conservation. There are positive impacts also on soil structure and surface water quality (see SLM group 'Conservation Agriculture').

3. Application of improved compost and manure: Compost (mainly from plant residues) and manure (from domestic livestock) help to close the nutrient cycle by ensuring that these do not become losses to the system. By building up SOM they help maintain soil structure and health, as well as fertility. Furthermore they are within the reach of the poorest farmers (see case studies on: 'Night Coralling' in Niger and 'Compost Production' in Burkina Faso).

4. Tapping nutrients: This takes place through the roots of trees and other perennial plants when mixed with annual crops (e.g. in agroforestry systems). Trees act as nutrient pumps: that is they take up nutrients from the deep subsoil below the rooting depth of annual crops and return them to the topsoil in the form of mulch and litter. This enhances the availability of nutrients for annual crops.

Composting, manuring and mulching in a banana plantation, Uganda. (William Critchley)

5. Application of inorganic fertilizer: Inorganic fertilizers are derived from synthetic chemicals and / or minerals. However there is a debate around the use of fertilizer in SSA. The mainstream view is that fertilizer use needs to be increased from the current annual average of about 9 kg/ha to at least 30 kg/ha. The other side points towards undesirable environmental impacts, such as soil acidification, water pollution and health problems (IAASTD, 2009b). However, without a combination of organic matter application and inorganic fertilizer, soil fertility is unlikely to meet production demands: thus the concept of 'Integrated Soil Fertility Management' should be supported. The examples of 'Microfertilization' in Mali and 'Precision Conservation Agriculture' in Zimbabwe presented in Part 2 show that it is possible to substantially increase millet and sorghum yields and profitability by using micro-doses of inorganic fertilizer in combination with techniques that conserve and concentrate soil moisture and organic matter.

6. Minimum soil disturbance: Tillage systems with minimum soil disturbance such as reduced or zero tillage systems leave more biological surface residues, provide environments for enhanced soil biotic activity, and maintain more intact and interconnected pores and better soil aggregates, which are able to withstand raindrop impact (and thus reduce splash erosion). Water can infiltrate more readily and rapidly into the soil with reduced tillage, and this also helps protect the soil from

erosion. In addition, organic matter decomposes less rapidly under these systems. Carbon dioxide emissions are thus reduced. No tillage, as described in the case studies on large and small scale conservation tillage in Kenya presented in Part 2, has proven especially useful for maintaining and increasing soil organic matter.

Improving soil fertility and the nutrient cycle (Principles)

- Reduce 'unproductive' nutrient losses: leaching, erosion, loss to atmosphere.
- Reduce mining of soil fertility: improve balance between removal and supply of nutrients - this is achieved through:
  - cover improvement (mulch and plant cover),
  - improvement of soil organic matter and soil structure,
  - crop rotation, fallow and intercropping,
  - application of animal and green manure, and compost (integrated crop-livestock systems),
  - appropriate supplementation with inorganic fertilizer,
  - trapping sediments and nutrients (e.g. through bunds; vegetative or structural barriers / traps).

These should be enhanced through improved water management and an improved micro-climate to reduce losses and maintain moisture.

Plants and their management

Improved agronomy is an essential supplement to good SLM practices. The Green Revolution in Asia made great advances in increasing agricultural production in the 1960s and 70s based on improved agronomic practices. As illustrated in figure 2, Africa has, over the last 50 years, increased its agricultural production mainly through expansion of agricultural land. The 'original' Green Revolution has largely failed in Africa (see next box) although achievements in crop breeding have been made and efforts are still ongoing to achieve the following:

- higher yielding varieties,
- early growth vigour to reduce evaporation loss,
- short growing period and drought resilience,
- better water use efficiency / water productivity in water scarce areas,
- tolerance to salinity, acidity and / or water logging,
- disease and pest resistance.

'Improved' varieties have potential advantages but their additional demands on applications of fertilizers, pesticides or herbicides need to be taken into account – as does costs and supply of seeds. They often create dependency on seed producers.

Organic agriculture and low external input agriculture have emerged in response to these concerns – but also because they relate more closely to the traditions and values of African agriculture. Organic agriculture improves production by optimising available resources, maximising nutrient recycling and water conservation. According to IFOAM (2009) organic agriculture is based on the principles of health, ecology, fairness and care. In Part 2 an example on 'Organic Cotton' in Burkina Faso is presented. All the strategies involved seek to make the best use of local resources.

Some advancements and drawbacks of the 'Green Revolution' in SSA

Cereal yields have remained largely stagnant at around 1 tonne/ha from the 1960s to 2000 in the SSA region. This is in stark contrast to the experience of the 'original' Green Revolution in Asia during the 1960s and 70s. Here, intensified production of cereals (especially wheat and rice) led to large production increases due to the introduction of new, high-yielding varieties. The new varieties however required irrigation and large amounts of chemical fertilizers and pesticides to produce their high yields. This then raised concerns about costs and potentially harmful environmental effects. It led to a loss of agro-biodiversity and the genetic pool through dependence on monocultures and replacement of land races (FAO, 2008a).

Agricultural intensification in SSA has largely failed because it has not addressed (1) depletion of organic matter through removal of crop residues for fodder and fuel, insufficient return of organic matter to the soil – causing low response to fertilizers; (2) degradation of soil structure through reduced organic matter combined with destructive tillage practices – leading to compaction, sealing, crusting, decreased infiltration and increased erosion; (3) adverse changes in the soil nutrient balance due to failure to replace essential nutrients removed from the soil and / or imbalanced fertilizer application – e.g. pushing production with nitrogen application but not replacing other essential nutrients, which become the limiting factor; (4) pollution of soil and water though inappropriate application of fertilizers, pesticides and herbicides.

(Source: IAASTD, 2009b)

A major limiting factor to plant productivity are weeds. Good SLM practices can reduce the weed infestation considerably by providing cover by crops, residues and mulch, and by minimum soil disturbance. On grazing land the control of undesirable species should be a key focus. In forests the problem of invasives is also a concern.

Adverse impacts of pest and diseases are various and a major threat to agricultural production. One way forward that resonates with SLM is to select more resistant species and varieties and follow the principles of integrated pest management (IPM) using biological and natural mechanisms as far as possible. IPM is an ecological approach with the main goal of significantly reducing or even eliminating the use of pesticides, through managing pest populations at an acceptable level as described in the case study 'Push-pull integrated pest and soil fertility management' from Kenya presented in Part 2.

However, improved agricultural production does not help if the post harvest management is lacking. Given the high rates of post harvest losses (reaching 30-100%), major efforts are needed to secure the harvest from damage.

A 'new' green revolution? The aim of a 'new' green revolution in SSA is to promote rapid and sustainable agricultural growth based on the smallholder farmer sector with minimal resources (and minimal government support), to ensure that smallholders have good seeds and healthy soils, access to markets, information, financing, storage and transport and last, but not least, policies that provide them with comprehensive support (TerrAfrica, 2009). In contrast to the 'original' green revolution in Asia, the 'new' green revolution intends to be both pro-poor and pro-environment.

Statement by Kofi A. Annan

Chair of the Board of the Alliance for a Green Revolution in Africa (AGRA)

'…..To feed the continent's 900 million people, Africa needs its own food security. This can only be achieved through an uniquely African Green Revolution. It must be a revolution that recognises that smallholder farmers are the key to increasing production, promotes change across the entire agricultural system, and puts fairness and the environment at its heart….. '

(AGRA, 2010)

Screening for drought tolerance of pigeon peas and lablab. (Hanspeter Liniger)

There is still huge potential to increase plant productivity through a 'new' green revolution. The major challenges are the following:

- Using breeding advances while increasing diversity: more productive and resilient varieties of crops, adapted to thrive in a variety of environmental conditions;
- Capitalising on the enormous plant genetic resources in SSA by including local land races and wild varieties into breeding schemes. Exchange of seeds among small-scale farmers is an efficient way to release and spread plant varieties. This includes not only crops but also improved fodder production on grassland / grazing land as well as fibre and fuel production in agroforestry systems and on forest land;
- Recognising that integrated soil fertility management and IPM are key;
- Developing more effective partnerships and networks for an interactive research system - making indigenous knowledge and local innovation available;
- Stressing the role of gender in agriculture: the recognition that the majority of smallholders in SSA are women must be brought into all supporting policy and practice;
- Marketing of produce (including value chain development) and procuring basic inputs are often critical constraints.

Improving planting materials and plant management (Principles)

Improve planting material and minimising impact of weeds, pest and diseases, and post-harvest losses

Through supporting:

- selection and experimentation with local germplasm and exchange of seed materials;
- nutrient and water management of improved plant species and varieties based on locally available inputs (such as manure, compost and micro-dosed application of fertilizers);
- optimising planting dates, planting geometry etc.;
- mixed plant systems to benefit from synergies between different plants (intercropping, relay planting, rotations etc);
- weed management;
- IPM (Integrated Pest Management);
- post harvest management.

Micro-climate

Micro-climate conditions can be substantially influenced by land management, particularly by practices reducing wind and improving shade. Ground cover, be it vegetative or through mulching, is the key factor in determining the micro-climate. Improved micro-climates have the following positive impacts:

1. Improve soil moisture and air humidity: Higher productivity per unit of water is achievable under humid rather than under dry air condition (Tanner and Sinclair, 1983). Evaporation (unproductive water loss from the soil surface) can be minimised by protecting the soil either with crops or mulch material. Practices including mulching, cover cropping, intercropping, agroforestry, shelterbelts, as well as no or minimum tillage protect the soil from excessive heating, exposure to wind and moisture loss, favour moist conditions around plants and improve performance and productivity.

2. Protect from mechanical damage: To protect plants from mechanical impact of heavy rain, storms and wind, dust and sand storms a 'protective' micro-climate can be created through the improvement of cover, for example establishing trees as shelterbelts and windbreaks.

3. Balancing temperature extremes and radiation: Excessive soil and air temperatures and radiation during hot seasons or spells can be reduced to favour plant (and animal) production through increased cover and shade. This is preferably achieved through increased vegetative cover as the evapotranspiration has a cooling effect, creating a favourable micro-climate. In highlands and mountains in SSA the constraint is high fluctuations with low minimum temperatures. This is particularly an issue in the highlands of Ethiopia, and in eastern and southern Africa where crops are grown over 3,000 m altitude. In southern Africa cold is an issue in winter. In these environments trees and cover can protect again cold winds - but the shading may slow down the warming up of the soil.

Creation of a favourable micro-climate (Principles)

In dry and warm areas:

- reduce strong winds and storms (avoid drying out and mechanical damage);
- protect against high temperature and radiation;
- keep conditions as moist as possible;

In humid areas:

- protect against storms (mechanical impact and soil degradation).

All of these improvements can be achieved through windbreaks, shelterbelts, agroforestry, multistorey cropping and good soil cover through vegetation or mulch.

In cold highlands and southern Africa with winter seasons land management may need to protect crops against cold winds or frost.

Improved livelihoods

There would be little importance attached to SLM - and its uptake - if the livelihoods of millions were not at stake. Increased and sustained agricultural production, the provision and securing of clean water and maintaining a healthy environment are essential for improved livelihoods in SSA. Despite the constraints and problems land users have, they are willing to adopt SLM practices that provide them with higher net returns, lower risks or a combination of both.

Costs and benefits

For improved livelihoods and for adoption and spreading of SLM, costs and benefits play a central role. Given the urgent needs in SSA, investments in SLM should aim at both short-term (rapid) and long-term (sustained) paybacks. Thus inputs for both initial establishment and continued maintenance afterwards need to be compared with benefits. Figure 8 illustrates the different positive paybacks from SLM interventions:

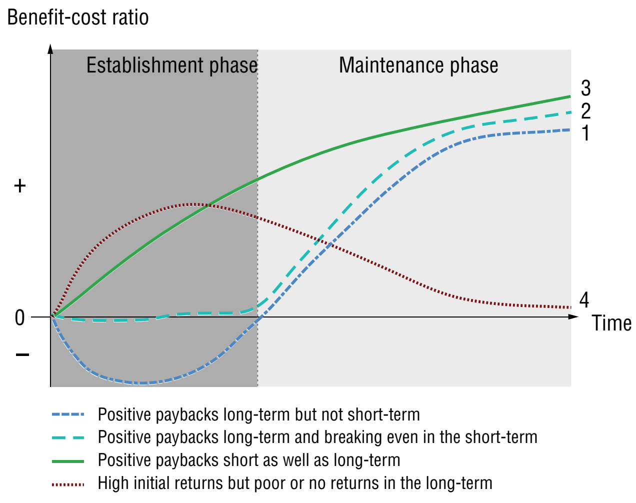


Figure 8: Benefits and costs of SLM over time, short-term establishment phase and long-term maintenance phase.

1 Long-term but not short-term: many land users in SSA might be constrained to make these long-term investments, thus might need a kick-start, where the establishment costs are partly funded by aid and external sources. The maintenance costs however would need to be covered by local sources and direct paybacks.

2 Long-term and breaking even in the short-term: thus increased benefits but also higher inputs. Depending on the wealth of the land users, the initial investments are not possible without external assistance (see scenario 1).

3 Short as well as long-term: This is the ideal case, where land users receive rewards right from the beginning. The question remains whether they need some initial support for investments (micro-credit, loans, access to inputs and markets etc). However, due to the rapid and continuous returns, land users have the possibility of paying back loans and credits quickly.

4 High initial returns but poor or no returns in the long-term: These options are tempting for land users but will lose attractiveness in the long-run as the returns are not sustained. This has occurred where high yielding varieties and inorganic fertilizers were applied but yield responses fell away after a few years (see box 'Green Revolution' page 30).

While establishment costs can be partly funded by aid and external sources, maintenance costs must be covered locally by land users to avoid the 'dependency syndrome' of continuous aid and to ensure self-initiative and ownership.

Experiences with implementation of SLM, show the need for accurate assessment of benefits and costs (in monetary and non-monetary terms) and short- and long-term gains. However, this is seldom done and data are few. Assessments of benefits and costs are very site specific and therefore pose a great challenge for the spread of SLM in SSA. Without proper assessments, land users and development agencies cannot make informed decisions about which technologies and approaches are the most viable options for a particular natural and human environment - and where incentives for land users are needed.

Inputs challenges for land users

Land users may require additional inputs to take up SLM practices. These are related to materials (machinery, seeds, fertilizers, equipment, etc.), labour, markets, and knowledge. Some of the SLM practices require few extra or different inputs and little change compared to current practices; others mean a complete change in machinery, inputs and management. Some considerations are:

- Small-scale land users in subsistence agriculture have fewer options and resources to invest than commercial or large-scale farmers with a high level of mechanisation.
- A clear distinction between initial investment for the establishment and the maintenance of SLM practices is essential. Initial investment constraints need to be overcome and may require external assistance especially when benefits mainly accrue in the long-term. Thus any material and financial support should build on currently available resources. Special attention needs to be given to poor and marginalised land users.

High labour costs for ridging and low returns (left) compared to less demanding mulching with high benefits (right). (Hanspeter Liniger)

- Labour availability is a major concern and depends on the health of people and competition with other income generating activities. Malaria, HIV-AIDS and water-borne diseases significantly affect labour productivity. Conflicts with off-farm work, including the seasonal migration of labour force (often men) can be a major constraint for SLM. Single (often female) headed rural households need practices with reduced labour inputs.

- Access to inputs and equipment such as machinery, seeds / seedlings, fertilizers, etc. is essential. Introduction of SLM is only possible if markets for inputs and products are secured.

- Access to knowledge related to SLM practices and their introduction is a prerequisite for all land users. Practices that are easy to learn, and build on existing experiences and knowledge, have the best chance of being taken up.

Apart from the costs, benefits, access to inputs, markets and knowledge, there are other elements related to improved livelihoods such as the need for practices to be:
- socially and culturally acceptable: aesthetics (a non-linear contour may be visually unacceptable for example) and beliefs (some areas are 'untouchable' because of spirits) norms and values;
- flexible enough to allow (and even encourage) local adaptation and innovation;
- clearly seen to add value to the land and to the quality of life.

Improving livelihoods (Principles)

– provision of short (rapid) and long-term (sustained) benefits
– assistance for establishment might be needed for small-scale subsistence land users if costs are beyond land users' means
– assistance for establishment if short-term benefits are not guaranteed
– maintenance costs need to be covered by the land users to ensure self-initiative

Changes towards SLM should build on – and be sensitive to - values and norms, allow flexibility, adaptation and innovation to improve the livelihoods of the land users.

Improved ecosystems: being environmentally friendly

The principles of increased production presented above, to be truly sustainable should also aim at improving ecosystem functions and services. Best practices must be environmentally friendly, reduce current land degradation, improve biodiversity and increase resilience to climate variation and change.

Prevent, mitigate and rehabilitate land degradation

Assessments in SSA show the severity of land degradation and the urgency to improve natural resources and their use through SLM (see box page 35).

Depending on what stage of land degradation has been reached, SLM interventions can be differentiated into prevention and mitigation of land degradation or rehabilitation of already degraded land (Figure 9) (WOCAT, 2007).

Prevention implies employment of SLM measures that maintain natural resources and their environmental and productive function on land that may be prone to degradation. The implication is that good land management practice is already in place: it is effectively the antithesis of human induced land degradation.

Mitigation is intervention intended to reduce ongoing degradation. This comes in at a stage when degradation has already begun. The main aim here is to halt further degradation and to start improving resources and their ecosys-

Land Degradation in Africa:

– 67% of Africa's land is already affected by land degradation. 4 - 7 % of SSA is severely degraded – the highest proportion of any region in the world.
– The cumulative loss of productivity is: 25% of cropland, 6.6% of pasture land.
– Soil degradation in Africa is attributable to: overgrazing (50%); poor agricultural management practices (24%); vegetation removal (14%); and overexploitation (13%).

Soil erosion by water and wind: mainly loss of topsoil / surface erosion, gully erosion and offsite degradation effects.

– Annual yield losses due to soil erosion estimated as averaging 6.2 %.
– Erosion by water: 46% of land area.
– Erosion by wind 38% of land area mainly in drylands.

Chemical soil degradation: mainly fertility decline and reduced organic matter content, salinisation.

– Four times the amount of nutrients removed in cropland compared to the amount returned with manure and fertilizer. Africa loses an equivalent of 4 billion USD per year due to soil nutrient mining.
– 30% of irrigated land lost due to salinisation: Kenya (30%), Namibia (17%), Nigeria (34%), Sudan (27%) and Tanzania (27%).
– Losses of irrigated land due to waterlogging: DR Congo (20%), Mauritania (50%) and Gambia (10%).

Physical soil degradation: compaction, sealing and crusting, waterlogging.

Biological degradation: reduction of vegetation cover, loss of habitats, quantity / biomass decline, detrimental effects of fires, quality and species composition / diversity decline, loss of soil life, increase of pests / diseases, loss of predators.

– Although the continent hosts only 17% of the world's forests, Africa accounted for over half of global deforestation during 1990-2000.
– In most parts of Africa, deforestation rates exceed planting rates by a factor of 30:1. The rate of 0.6 per year for the last 15 years is among the highest globally (largely in humid and sub-humid West Africa).
– 89% of deforestation is attributed to clearing for agriculture. Of these, 54% are attributed to subsistence agriculture and the other 35% to intensive agriculture.
– In South Africa and Lesotho, alien plants cover about 10 million ha (more than 8 percent of total land area), and are spreading at 5% per year

Water degradation: aridification, change in quantity of surface water, change in groundwater / aquifer level, decline of surface water quality, decline of groundwater quality, reduction of the buffering capacity of wetland areas.

– 70% of Africa's soils suffer from periodic moisture stress.
– Some 86% of African soils are under soil moisture stress.
– Water tables have dropped in many regions and many wells have dried up.
– More fluctuations in river, stream and spring flows, with more frequent flooding in the rainy season and longer periods of water shortage in the dry season.

Sources: Oldeman 1994 and 1998; Versveld et al, 1998; Reich et al. 2001; FAOSTAT, 2004; FAO, 2007; SARD, 2007; WOCAT, 2008a; WB, 2010)

Figure 9: Prevention, mitigation and rehabilitation of land degradation less than half a kilometre apart. (Hanspeter Liniger)

tem functions. Mitigation impacts tend to be noticeable in the short to medium term: this then provides a strong incentive for further efforts.

Rehabilitation is required when the land is already degraded to such an extent that the original use is no longer possible, and land has become practically unproductive and the ecosystem seriously disturbed. Rehabilitation usually implies high investment costs with medium- to long-term benefits.

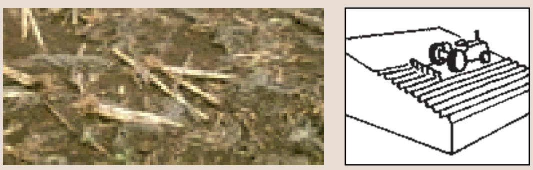
Major efforts and investments have been made in the implementation of structural measures. They are conspicuous in showing efforts made towards SLM. However they are input intensive and often could be substituted by less demanding agronomic, vegetative and management measures. As a rule of thumb priority should be given first to agronomic and / or vegetative measures with as little outside input as possible and only then apply structural measure if the 'cheaper' options are not adequate. In addition, structural measures should be combined as much as possible with vegetative or agronomic measures to protect the structures and make them directly productive (e.g. fodder grass on earth bunds). Frequently, measures can be implemented together, combining different functions and creating synergies. Combinations of measures that lead to integrated soil and water, crop-livestock, fertility and pest managements are promising as they increase both ecosystem - and livelihood - resilience.

Improve biodiversity

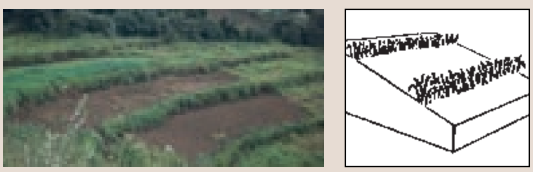
A key concern in sustainable land management and protecting ecosystem functions in SSA is conserving biodiversity. Sub-Saharan Africa has both remarkable richness and abundance of biological diversity. The world's second largest area of rainforest after South America's Amazon Basin is found in Central Africa. It shelters some of the greatest biological diversity of Africa in terms of vegetation and wildlife and plays a vital role in worldwide ecological services

Categories of SLM Measures

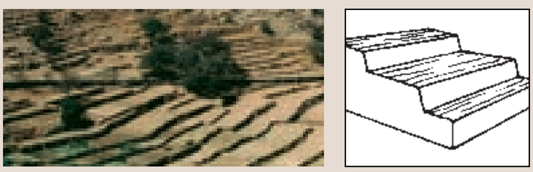
The measures for prevention, mitigation and rehabilitation of land degradation and restoration of ecosystems services can be classified into four categories (WOCAT, 2007):



Agronomic measures: measures that improve soil cover (e.g. green cover, mulch); measures that enhance organic matter / soil fertility (e.g. manuring); soil surface treatment (e.g. conservation tillage); subsurface treatment (e.g. deep ripping).



Vegetative measures: plantation / reseeding of tree and shrub species (e.g. live fences; tree crows), grasses and perennial herbaceous plants (e.g. grass strips).



Structural measures: terraces (bench, forward / backward sloping); bunds banks / level, graded); dams, pans; ditches (level, graded); walls, barriers, palisades.

Management measures: change of land use type (e.g. area enclosure); change of management / intensity level (e.g. from grazing to cut-and-carry); major change in timing of activities; control / change of species composition.

Any **combinations** of the above measures are possible, e.g.: Terrace (structural) with grass strips and trees (vegetative) and contour ridges (agronomic).

(Owen, 2004). Furthermore, dryland biodiversity has distinguishable features that are often overlooked. These include heterogeneity, diversity of micro-organisms, presence of wild relatives of globally important domesticated species, and traditionally adapted land use systems (pastoralism, parklands, mixed farming, mixed seed cropping, etc.) (Bonkoungou, 2001; Mortimer, 2009). Sustainable management of natural forests, woodlands, wetlands, grasslands, savannas and deserts results in the protection of biodiversity and environmental quality and at the same time offers opportunities for food security and poverty alleviation. SSA has of the world's most attractive and rich national parks and reserves, which apart from their intrinsic value, offer employment and revenue from tourism.

Women are guardians of West Africa's crop diversity

Women play a dominant role in every part of West Africa's food systems. Often they are responsible for managing small parcels of land on the family farm or for growing food in small gardens around the home. At a time when diets are becoming increasingly simple, and nutritious traditional foods are being replaced by refined carbohydrates and fat, the role of women in promoting diversified diets rich in traditional crops is of vital importance (Smith, 2008).

Plant and animal biodiversity are central to human well-being, most notably in food production but also as a source of fibre for clothing, wood for implements, shelter, and fuel, and for natural medicines, as well as having strong cultural and spiritual significance. Agricultural biodiversity encompasses domesticated crop plants, livestock and fish (etc.), wild crop relatives, wild food sources, and 'associated' biodiversity that supports agricultural production through nutrient recycling, pest control and pollination. Agro-biodiversity is the result of the careful selection and inventive development of land users whose livelihood depends on the sustained management of this biodiversity. Land users value having agricultural biodiversity in their farming systems and small-scale farming is far less of a threat to biodiversity than large-scale mechanised systems (Mortimer, 2009). Promotion of crop genetic diversity is part of their coping strategies for mitigating weather unpredictability; it also spreads availability of food products over time (Bonkoungou, 2001).

Giraffes in the Amboseli Nationalpark, Kenya. (Hanspeter Liniger)

Sub-Saharan Africa is the cradle of vitally important international agro-biodiversity. It is the centre of origin of, for example sorghum (*Sorghum vulgare*) and both bulrush millet (*Pennesetum typhoides*) and finger millet (*Eleusine coracana*), as well as the cowpea (*Vigna unguiculata*) various yams, and coffee (Harrison et al., 1969,1985). There are important endemic species also, such as *rooibos* tea, which is restricted to South Africa. Because African farming depends, still, very largely on local landraces of a wide variety of crops, the wealth of its agro-biodiversity must not be underestimated. In the protection of agro-biodiversity the precautionary principle needs to be applied: maintain as many varieties of plants and domestic animals as possible for their future potential.

Climate change: a fresh challenge – a new opportunity?

Climate change is a major concern for SSA, bringing with it various new challenges. Without doubt, there is huge potential and opportunity for SLM in climate change mitigation and adaptation. Climate change science shows how important the land is, in terms of a carbon source and a carbon sink. SLM practices not only contribute to building up carbon in the land but can also give protection against climate variability. There is evidence of current

Afforestation around Mt. Kenya. (Hanspeter Liniger)

adaptations and innovation in SLM technologies and approaches, demonstrating response to climate change: this experience needs to be acknowledged, investigated and tapped (Woodfine, 2009).

The concept of dealing with environmental (including climate) change is not new to land users. Traditional SLM practices can serve as an entry point for efforts to enhance system resilience, but will not be enough on their own, in the medium to long-term, for coping with climate change (FAO, 2009b). Strong transdisciplinary research efforts are needed, and additional emphasis should be given to monitoring and assessment (M&A) of off-site impacts of land degradation and SLM. Increased occurrence of extreme climatic events leading to disasters such as floods, land slides, mud flows and droughts also have national, and global, impacts. The role of SLM to prevent and / or reduce disasters must be acknowledged and investigated.

Mitigation and adaptation are discussed in the following section. Mitigation in the context of climate change means reducing greenhouse gases and thus their impacts, while adaptation means amending practices to cope with the impacts of changing climate (FAO, 2009b). SLM is concerned with both. With respect to mitigation, SLM practices can help sequester carbon in the vegetation as well as in the soil; in terms of adaptation suitably versatile and 'climate proof' SLM technologies and approaches are key to maintaining productive land and ecosystem function. SLM is good for farmers: it is helpful in the challenges posed by climate change also. Climate change acts as a spur to encourage better SLM – and it provides new funding windows for the reasons set out above.

Mitigation of climate change: Land users in Sub-Saharan Africa can contribute to global efforts to mitigate climate change by adopting SLM technologies that sequester carbon both above and below ground and avoid emissions of greenhouse gases. Various SLM technologies presented in this document can make major contributions, and need to be acknowledged as such. While mitigation of climate change is not a priority for poor farmers, the same SLM practices that benefit them directly, can help sequester carbon and reduce emissions.

Sequestering carbon above and below ground can be achieved through:
- afforestation, reforestation and improved forest management practices;
- agroforestry and silvopastoral systems, integrated crop-livestock systems which combine crops, grazing lands and trees;
- improved management of pastures and grazing practices on natural grasslands, including optimising stock numbers and utilising rotational grazing to maintain ground cover and plant biodiversity;
- improved tillage practices – such as conservation agriculture – to increase soil organic carbon (SOC) content through permanent soil cover with crops and mulch, minimum soil disturbance, fallows, green manures, and crop rotations; and
- micro-dosing with fertilizer to increase biomass production, yields and SOC.

Reducing emissions of carbon dioxide through:
- reduced land degradation and deforestation, loss of biomass and OM;
- reduced use of fire in rangeland and forest management;
- reduced machine hours for agriculture by adoption of conservation tillage practices / conservation agriculture systems; and
- practices requiring lower doses of agrochemicals.

Climate change in Africa

Africa's climate ranges from humid equatorial regimes, through seasonally-arid tropical and hyper-arid regimes, to sub-tropical Mediterranean-type climates. All these climates demonstrate various degrees of variability, particularly with regard to precipitation. Africa is especially vulnerable to climate change because of its geographic exposure, low incomes, and greater reliance on climate sensitive sectors such as agriculture.

Climate change:

– Africa is considered at more risk from climate change than other regions.
– During the 20th century, most of Africa already experienced a warming of approximately 0.7°C and large portions of the Sahel experienced a rainfal decrease: East and Central Africa an increase in precipitation.
– Droughts and floods have increased in frequency and severity across Africa over the past 30 years, particularly in southern and eastern Africa (around the coast of the Indian Ocean e.g. Mozambique).
– Predictions regarding climate changes are uncertain but scenarios indicate additional temperature increase of 3-4°C and rise of sea level by 15-95 cm by 2100, and an increase in the frequency of extreme weather events – droughts, floods and storms. The length of growing period is likely to decrease in many parts of SSA.
– The general trend of currently marginal areas becoming more marginal is apparent. In aggregate, Africa will be left worse-off.

Climate change mitigation:

– Most African countries contribute little to the world's total greenhouse gas emissions.
– Land use change and deforestation in Africa account for 64% of its greenhouse gas emissions.
– 30-50% of savanna is burnt annually in Africa accelerating the release of GHG and the loss of organic matter. Carbon stocks in the soil are more than twice the carbon in living vegetation.
– Above ground carbon stock has been reduced through deforestation and replacement of land use systems with less permanent biomass. Afforestation and reduced deforestation in Africa have the potential to reduce global GHG emissions by about 6.5%.
– Soil organic carbon in most of SSA's drylands has been reduced in the topsoil - due to land degradation - to less than 1%, whereas SLM can increase SOC to a level of 2-3%.

Climate change adaptation:

– Adaptation to climate variability and extremes is not new to land users in SSA. Yet traditional coping strategies are not sufficient, additional and innovative efforts are required.
– Adaptation to high climate variability and more extreme events are a major concern in SSA especially on marginal agricultural prone to desertification.

Environmental impacts of climate change:

– physiological effects on crops, pasture, forests and livestock (quantity, quality)
– changes in land, soil and water resources (quantity, quality)
– changes in and shifts of vegetation
– increased weed and pest challenges
– sea level rise, changes to ocean salinity

Socio-economic impacts of climate change:

– decline in yields and production
– increased number of people at risk of hunger and food insecurity
– reduced marginal GDP from agriculture
– fluctuations in world market prices
– migration and civil unrest

(Sources: Desanker and Magadza, 2001; Desanker, 2002; Stern, 2007; FAO, 2009a; FAO, 2009b; Pender et al., 2009; Woodfine, 2009; WB, 2010)

Reducing emissions of methane and nitrous oxide through:

- improved nutrition for ruminant livestock;
- more efficient management of livestock waste (manure);
- more efficient management of irrigation water on rice paddies; and
- more efficient nitrogen management on cultivated fields, reducing volatile losses through better agronomic practices (rotations, fallows, manuring and micro-dosing).

To increase carbon stocks above ground, afforestation, reforestation and agroforestry systems are important, but additional attention must be given, and efforts made, to restore biomass and ground cover on grasslands (through improved grazing land management) as well as permanent cover on crop land (see SLM group on 'Conservation Agriculture'). Carbon markets for funding the spread need to be further explored and are emerging opportunities (refer to page 45) for land users to implement SLM.

Soil organic carbon (SOC) increase can be achieved by implementing SLM practices which add biomass to the soil, cause minimal soil disturbance, conserve soil and water, improve soil structure, enhance activity and species diversity of soil fauna – increasing 'biological tillage' and strengthen mechanisms of carbon and nutrient cycling (see SLM group on 'Integrated Soil Fertility Management') (FAO, 2009a).

Adaptation to climate change: Adaptation to climate change means dealing with its impacts and this can be achieved by adopting more versatile and climate change resilient technologies – but also through approaches which involve flexibility and responsiveness to change. In this latter context land users need to be aware of alternative SLM practices.

Implementing SLM practices which increase soil organic matter will be beneficial in adapting to climate change. These will increase 'the resilience of the land', and thus 'climate proofing' through enhanced fertility, soil structure, water infiltration and retention, soil life and biomass production (Scherr and Sthapit, 2009).

Surface mulch or plant cover established under several SLM practices generally protect soil from wind, excess temperatures and evaporation losses, reduce crop water requirements and extend the growing period. This could prove critical in many areas of SSA affected by climate change. All practices improving water management increase resilience to climate change. This can be achieved through reducing water losses and harvesting of rainwater to improve water storage in the soil but also in reservoirs.

Practices diversifying incomes and reducing risks of production failure, for example integrated crop-livestock systems and improved or more appropriate plant varieties provide additional opportunities for adaptation.

Thus avoiding or reversing any form of land degradation, thereby improving the ecosystem health as well as improving the micro-climate, increases resilience to climate variability and change, and results in improved agricultural production. There is no one silver bullet solution to solve the problems which land users face due to climate change. However, the following generalisation can be made: Virtually all of the SLM practices identified in these guidelines contribute (in varying degrees) both to climate change mitigation and adaptation strategies.

Synergies between adaptation and mitigation: Synergies between reduced land degradation, conserved biodiversity, food security, poverty reduction and climate change mitigation and adaptation through SLM generate multiple benefits. A multifocal approach to SLM that takes into account all ecosystem services and human wellbeing is more likely to succeed than one focused exclusively on climate change mitigation and adaptation. SLM is not limited to smallholder land users; many SLM practices can make medium to large-scale commercial land use more sustainable and resilient to climate variability and can contribute to climate change mitigation.

Yet, some mitigation responses may conflict with food security – and vice-versa. For instance, plant production for biofuels leads to competition for land and water resources. Adaptation and mitigation synergies or antagonisms in agriculture, forestry, and fisheries at the global, regional, and local levels are poorly documented. Therefore further research and efforts related to knowledge management are needed to identify locations and conditions where food security adaptation and mitigation benefits intersect in a cost-effective way (FAO, 2009a; FAO, 2009b).

Climate change mitigation and adaptation (Principles)

Mitigation:

- Increase carbon stock above and below ground: improve plant cover, increased biomass, mulch, organic and green manure, minimum soil disturbance, water and soil conservation – e.g. through forestation, agroforestry, conservation agriculture, residue management.
- Reduce emissions of greenhouse gases: reduce vegetation and soil degradation, reduce fire, reduce machine hours, improve livestock and irrigation management, more efficient use of fertilizers and manure

Adaptation:

Identify and promote versatile and resilient technologies

- improve soil cover and microclimatic conditions: through mulch, crops, grass, trees
- improve soil fertility: through soil organic carbon, soil structure, nutrient cycling
- improve water harvesting, storage (in soils, reservoirs etc), and distribution
- reduce water losses: evaporation, uncontrolled runoff, leakage in irrigation systems

Encourage adaptation approaches and strategies

- give land users SLM options
- encourage local innovation

Triple-win solutions

For food security and overall development in SSA, increased land productivity for food, fodder, fibre and fuel is the urgent priority. This can be achieved by:

- Intensification of agricultural production: which still has great potential, yet there remain challenges in finding sustainable practices to continued improvements.
- Diversification of agricultural production: which can help strengthening resilience to changes (be it induced by climate, markets or policies).
- Expansion of the agricultural area: though this has very limited potential. In most regions good and suitable land has already been used.

For intensification, diversification, and / or expansion, four land productivity principles guide the way towards SLM in SSA, namely (Figure 10):

1. improved water productivity and water use efficiency on rainfed and irrigated land;
2. improved soil fertility;
3. improved plant management: plant material and control of weeds, pest and diseases;
4. improved micro-climate.

This underlines the fact that good cover conditions, improved soil organic matter, water saving or harvesting, nutrient recycling, and improved management of plants, livestock and control of pests and diseases are key entry points for best SLM practices. SLM practices are related to maximum soil cover, minimum soil disturbance, enhancement of biological activity, integrated plant nutrition management, development of integrated crop / livestock / agroforestry systems, flexible management of traditional pastoral systems and reduced use of burning (Woodfine, 2009).

Best land management practices are win-win-win solutions. All SLM practices presented in Part 2 aim at tripple win: improving productivity, livelihood and ecosystems. Figure 11 summarizes the issues related to productivity, ecosystem concerns, livelihood and human well-being. Table 3 lists principles, strategies and practices to improve land productivity and yields.

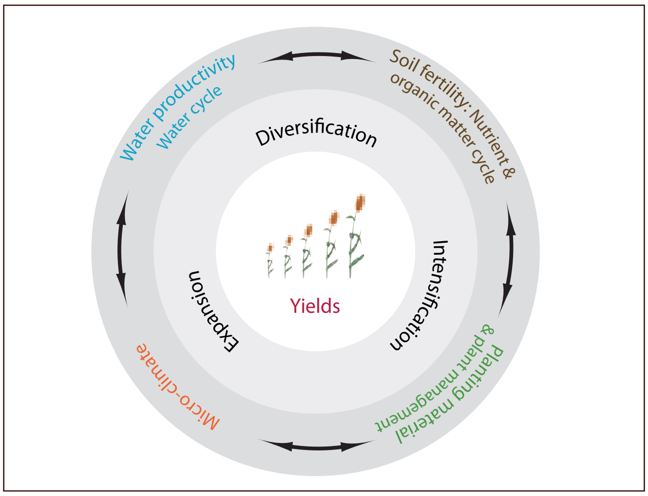


Figure 10: Key to improved land productivity and food security.

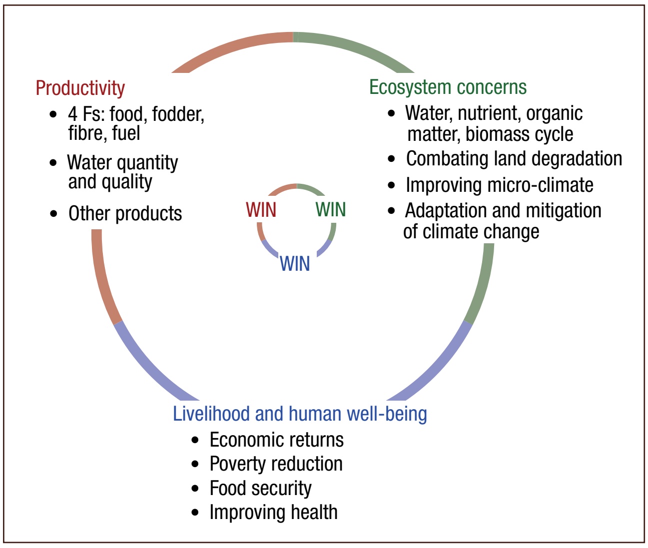


Figure 11: Win-win-win solutions for livelihood, ecosystem and productivity.

Table 3: Strategies and practices to improve land productivity and yields

Principles	Aim	Strategies	SLM practices (Case studies see Part 2)
Water use efficiency and productivity	**Increase plant water availability in rainfed agriculture**	minimise run-off; maximise rainfall infiltration and storage in the soil	soil cover, composting, contour cultivation, conservation agriculture, life barriers, soil / stone bunds, terracing, *fanya juu*, etc.
		reduce non-productive evaporation	good plant cover, intercropping, mulching, windbreaks, agroforestry, etc.
		harvest & concentrate rainfall through runoff to crop area or for other use	planting pits, semi-circular bunds, microbasins, contour bunds, stone lines, vegetative strips, trash lines, runoff and floodwater farming, small dams, etc.
	Increase plant water availability in irrigated agriculture	minimise water losses from irrigation system	lining of canals, deep and narrow instead of shallow and broad canals, good maintenance, pipes, etc.
		efficient and effective application of water	watering can irrigation, drip irrigation, micro sprinklers, low pressure irrigation system, improved furrow irrigation, supplemental irrigation, deficit irrigation, etc.
		recharge aquifer / groundwater; water collection to enable off-season irrigation	small dams, farm ponds, subsurface tanks, percolation dams and tanks, diversion and recharging structures, etc.
	Increase plant water uptake	increase productive transpiration	afforestation, agroforestry, optimum crop rotation, intercropping, improved crop varieties, planting date, etc.; vigorous plant and root development through soil fertility and organic matter management, disease and pest control, weed management, etc.
Soil fertility	**Improve nutrient availability and uptake**	reduce nutrient mining and losses	composting and manuring (e.g. corralling) integrated fertility management (organic combined with inorganic), microfertilization, green manuring, rotations including legumes, improved fallows with leguminous trees and bushes, enrichment planting of grazing land, rotational grazing, etc.
		improve soil nutrient holding capacity and plant nutrient uptake capacity	minimum to no till, improve soil biotic activity, increase soil organic matter, mulching, manage avoid burning (residue management), etc; adapted varieties, etc.
Plants & their management	**Maximise yields**	use best suited planting material and optimise management	choice of species, varieties, provenances, etc.; short season varieties, drought tolerant varieties, pest and disease resistant varieties, etc.; planting dates, plant geometry, fertility and water management, etc.
Micro-climate	**Create favourable growing conditions**	reduce evapotranspiration	windbreaks, agroforestry, hedges, living barriers, parklands, good soil cover, dense canopy, etc.
		optimise temperature and radiation	agroforestry, vegetative and non vegetative mulch, etc.
		reduce mechanical damage of plants	windbreaks, barriers, vegetative and non vegetative mulch, etc.

Hanspeter Liniger

ADOPTION AND DECISION SUPPORT FOR UPSCALING BEST PRACTICES

According to FAOSTAT 2008 it is estimated that less than 3% (5 million ha) of total cropland in SSA are under SLM using low-cost productivity enhancing land management practices (WB, 2010). This involves only about 6 million small-scale land users (Pender, 2008) and shows that adoption of SLM is alarmingly low, obviously excluding indigenous technologies.

Adoption - uptake and spread

Success in adoption of SLM depends on a number of factors. It depends primarily on the availability and suitability of best SLM practices that increase yields and at the same time reduce land degradation (as discussed in the chapter on 'increasing land productivity').

A study based on the WOCAT database showed that in SSA the single most important factor for adoption of SLM practices was increased short-term land productivity, followed by short establishment time, and practices that were 'easy to learn' (Stotz, 2009). An IWMI study analysing a number of technology information sheets underlines these findings (Drechsel et al., 2005). In that study, the most important adoption drivers for conservation, water harvesting and rangeland technologies in SSA were yield increase and accessibility to information, followed by secured land tenure. Additional important influential factors were improved nutrient availability on cropland and labour demand on rangeland.

When adapted to suit local contexts, there is potential for the best practices presented in Part 2 of the guidelines to be upscaled and replicated across SSA. However, this is not enough. For upscaling, an enabling environment is of paramount importance; this includes institutional, policy and legal framework, local participation as well as regional planning (landscape or watershed), capacity building, monitoring and evaluation, and research.

Institutional, policy and market bottlenecks in the context of SLM adoption

Institutional:

– Inappropriate national and local political agendas
– Lack of operational capacity
– Overlapping and unclear demarcation of responsibilities
– Ineffective decentralisation
– Lack of good governance

Policy / Legal framework:

– Often there are laws in favour of SLM, but they are not followed
– Enforcement is difficult, costly and can create adverse relationships between government and land users

Land tenure and user rights:

– Inappropriate land tenure policies and inequitable access to land and water
– Insecurity about private and communal rights
– Modern laws and regulations not considering traditional user rights, by-laws and social and cultural norms which may enhance conflicts and insecurity

Market and infrastructure:

– Insecure prices of agricultural products (crop, animal, timber, fuel / firewood, …)
– Increasing input prices and costs for the inputs (materials, equipment, labour, …)
– Access to markets for inputs and output

(Sources: TerrAfrica, 2007 and 2009; Drechsel et al., 2005)

Institutional and policy framework

While natural resources and climatic factors define the possible farming systems, national and international policies and institutional changes will continue to determine the socio-economic factors that underscore the continuation of land degradation or alternatively create an enabling environment for SLM to spread.

Policies in support of SLM are needed to promote and address the complexity of sustainable land use, in particular policies providing incentives for SLM investments at household, community, regional and national level (TerrAfrica, 2008). Policies must address the root causes of land degradation, low productivity and food insecurity and simultaneously establish socially acceptable mechanisms for encouragement or enforcement.

Improvement of national policy frameworks: There are clear opportunities to improve national policy frameworks in support of SLM and to overcome bottlenecks that hinder the spread of SLM (see also box left):

Creating an enabling institutional environment:
- strengthening institutional capacity
- clarifying roles and responsibilities
- furthering collaboration and networking between institutions involved in implementation as well as research
- enhancing collaboration with land users
- strengthening and integrating farmer-extension-research linkages
- securing finances (budgetary provision for extension)

Setting-up a conducive legal framework:
- creating acceptance of rules and regulations or setting up mechanisms of control and enforcement
- defining meaningful laws for local land users to support compensation mechanisms
- recognising customary rights in the local setting

Improving land tenure and users' rights is a key entry point:
- providing basic individual and collective security of resource use (mainly for small-scale land users)
- clarifying tenure and user rights to private and communal land, including locally negotiated tenure systems, regulations and land use. Protecting the rights of land under customary tenure
- looking for pragmatic and equitable solutions in cases where land tenure reforms are ongoing
- increasing land title registration and linking this to land use planning through a cadastral system
- promotion of women's land rights in land registration and customary land tenure systems

Improving access to markets for buying inputs and selling agricultural products and other outputs:
- developing and strengthening local informal markets
- securing accessibility by improving infrastructure (especially access roads)
- better understanding of the impact of macroeconomic, liberalisation and trade policies on prices
- facilitating markets for raw and processed products derived from SLM

- exploring and promoting access to regional, national as well as international markets, including niches for SLM products such as fair trade, organic, environmentally-friendly, certification of origin labels as well as ecotourism (see next paragraphs)
- develop favourable and fair international trade regulations

Land users and communities are likely to invest in improving the land and its natural resources given good institutional support, a conducive legal framework, access to markets, and clarity about land tenure and user rights (TerrAfrica 2008 and 2009).

Trends and new opportunities: To make SLM and its products, impacts and services more valuable or to connect SLM with emerging global environmental issues, emerging trends and opportunities need to be further explored. These may include:

- Processing of agricultural products: This can reduce post-harvest losses and produce higher value products where the market exists. It also generates additional income and job opportunities.

- Certified agricultural products: Look for opportunities under 'Fair Trade' with its focus on social criteria, equitable and just remuneration of producers; and 'Organic' with a focus on environmental health (production without chemical inputs, namely pesticides, herbicides, inorganic fertilizers). For forest products there exists a certification for sustainably managed forests (FSC – Forest Stewardship Council), with a growing global demand. For 'SLM-grown' produce a certification label could also be introduced (see case study on 'Organic Cotton').

- Market for bio-energy / fuel: Although heavily debated by the public and scientific communities due to the trade-off with food security and ecoystems, biofuels are gaining increased commercial attention. Driven by factors such as oil price spikes and the need for greater energy security, there are rapidly developing markets for bio-energy products.

- Payments for Ecosystem Services (PES): PES is the mechanism of offering incentives to farmers or land users in exchange for managing their land to provide ecological services. Through PES, those who benefit pay for the services and those who provide, get paid. This is a relatively new source of funding with considerable potential for expansion. New PES related markets for greenhouse gases, carbon, water and biodiversity are emerging globally (see case study on 'Equitable Payments for Watershed Services').

The most promising PES opportunities are:

- Carbon sequestration and GHG reductions: These offer payment possibilities for mitigating climate change. Many PES-projects ('carbon offsetting') have been started in SSA, paying for carbon storage in forest plantations. Forests-based transactions for the cost of emissions reductions can range between 1 to 15 US$ per tonne of carbon sequestered (Envirotrade, 2010).

- Payment for biodiversity and protection of natural resources: By environmental interest groups through international support for protection (e.g. establishment of parks, reserves) or through enhancing ecotourism, where local communities are the main beneficiaries. Ecotourism in preserved natural habitats is becoming increasingly popular in parts of SSA. Though agro-ecotourism is poorly developed as yet. Environmental interest groups can solicit considerable funds and goodwill for SLM, and there is a strong consumer demand for ecotourism. However, there can be no ecotourism business without sustainable managed ecosystems and biodiversity.

- Payment by downstream users, watershed management payments for protection and sustainable management of upper catchments resulting in clean water, reduced sedimentation of reservoirs, increased hydro-power generation, and reduced floods (ISRIC, 2010).

PES is not yet widely used in developing countries – and there are various constraints to its implementation, for example to establish fair and trustworthy distribution mechanisms down to the local level. However, it presents a promising and flexible approach to enhancing and recognising the role of land users in sustaining and improving the ecosystem.

New financing mechanisms - such as PES - are emerging especially in relation to sustainable forest management, restriction of deforestation and exploitation of natural forests. Today, almost one-fifth of global carbon emissions come from deforestation. Preventing forest loss is the cheapest method of limiting carbon dioxide emissions. However, since the market lacks a well-functioning system for compensating farmers, it is currently more economically beneficial for farmers to clear forests than to keep them. As far as the developing world is concerned, natural forests are, ironically, more valuable to the international community than to the local inhabitants.

The emergence of these financial mechanisms implies that regional / national and global community are beginning to take responsibility for protecting the world's forests, and are willing to pay / compensate the rural people for putting aside the axe. If there is no global shift in the readiness to pay for services including better climate, clean air, good water, greater biodiversity (etc.), we will continue to lose valuable ecosystems and their services. All possible efforts need to be made to quantify services and to show consequences on global human wellbeing. Local communities need to be recognised as - and renamed as - stewards and custodians of natural forests and their services.

The UN-REDD, a collaborative partnership between FAO, UNDP and UNEP, supports countries in developing capacity to Reduce Emissions from Deforestation and forest Degradation (REDD) and is a first step in taking these responsibilities (UN-REDD, 2009).

Participation and land use planning

SLM technologies need approaches that enable and empower people to implement, adopt, spread and adapt best practices. Over the last 50 years the involvement and role of local land users has changed, with a swing from top-down, to bottom-up, to a multilevel-multistakeholder (multi-dimensional) approach. In the top-down approaches there was little or no involvement of land users in planning and decision-making. They worked through payments or coercion during the implementation phase. In the 'farmer first', bottom-up approaches local land users were empowered, though this sometimes led to inequalities. This happened typically with river water abstraction where downstream users found themselves deprived of water. Empowerment must be for all, not just favoured groups. Furthermore gender-related aspects need to be taken into account while developing an approach to stimulate SLM.

Rural women have been involved in agricultural production since the invention of agriculture. Their work in 'smallholder agriculture' has become more visible over the last few decades. They continue to increase their involvement in two types of agricultural production, smallholder production and agro-export agriculture - a trend called 'feminisation of agriculture' (Lastarria-Cornhiel, 2006).

As presented in more detail in Part 2, current promising approaches underlie the following principles:

1. People-centred approaches: People and their actions are a central cause of land degradation, and thus need to be at the centre of SLM. There must be genuine involvement of land users throughout all phases.

2. Multi-stakeholder involvement: This includes all actors, with their various interests and needs, with respect to the same resources. It includes local, technical and scientific knowledge and mechanisms to create a negotiation platform.

3. Gender consideration: Gender roles and responsibilities need to be considered seriously, since in smallholder agriculture women are taking over more of the agricultural tasks once done only by men such as land preparation, and they are investing more work in cash crop production.

4. Multi-sectorial approaches: Successful SLM implementation brings together all the available knowledge in different disciplines, institutions and agencies including government, non-governmental and private sectors.

5. Multi-scale integration: This unifies local, community but also the landscape, watershed or transboundary level, and up to the national and international level also. It implies that not only are local on-site interests considered, but off-site concerns and benefits also. This means that the concept of 'freedom of local land users' might be narrowed down in the interest of a larger community. However, it also opens up possibilities for additional markets, as well as compensation or funding mechanisms. While local benefits from investments in SLM already might be a sufficient incentive for land users, off-site concerns and benefits need to be negotiated.

6. Integrated land use planning: This assesses and assigns the use of resources, taking into account demands from different users and uses, including all agricultural sectors - pastoral, crop and forests - as well as industry and other interested parties also.

Promotion and extension

In order to facilitate the adoption, adaptation and spread of SLM best practices, enhancing incentives are needed: these include awareness raising, promotion, training and financial or material support. In many countries in SSA existing extension and advisory services have been reduced or weakened over the last decades: these need reviving and revitalising due to their vital roles.

Capacity building and training: Many actors and stakeholders must be involved and work together towards successful planning, decision making and implementation of SLM. Extension of SLM practices has much to do with empowering land users. And they must be supported better through capacity building, knowledge management and training.

Two forms of extension and training especially need to be strengthened:

- Institutional capacity building: projects, extension services, research initiatives and community based grassroots organisations (e.g. user groups) to access better means for knowledge management, awareness raising and training, but also for advice and decision support towards land users and planners; increased investments in extension services for small-scale land users, with a clear focus on sustainable techniques.

- Land user capacity building and empowerment: people-centred learning and capacity building through training-the-trainers initiatives, Farmer Field Schools, farmer-based extension using local promoters and innovators, from farmer-to-farmer.

There has been a general move to more participation, devolution of powers and less authoritarianism. But empowerment requires enhanced capacity. Investment in training and building up of the capacity of land users and other local and national stakeholders must be a priority. Local

Training of farmers in the layout of contour barriers. (Hanspeter Liniger)

innovation and farmer-to-farmer extension have proven to be widespread, effective and appropriate strategies, but they are not yet sufficiently recognised.

Recent developments in information and communication technologies (ICTs) and the media provide new opportunities in awareness-raising and knowledge dissemination. The use of local radio, TV, video, mobile phones and the internet, has increased the avenues for timely and wider delivery of useful information (AfDB, UNECA, and OECD, 2009) such as weather forecasts, farm inputs, market information and also development of SLM practices.

Financial and material support (incentives & subsidies)**:** Incentives for SLM should not exclusively be seen as financial or material support, but as the intangible stimulus (or ‘internal incentive’) that a land user experiences through higher production, or through saving time and money.

Judicious use of financial and material support implies various considerations:

- The possibilities of removing some of the root causes of land degradation such as an inappropriate land policy framework, land tenure security and market access, should be assessed (WOCAT, 2007).

Monitoring of river flow: Nanyuki River (Mount Kenya region) during the wet season (above) and during the dry season (below). The river started to dry up only as of the 1980s. (Hanspeter Liniger)

- There is often a need for material and financial support in the SLM sector in developing countries. Direct support to land users depends on the amount of investment needed for SLM interventions. In view of this, financial support is more likely to be justifiable in expensive rehabilitation exercises, or SLM requiring heavy initial investments. However support for maintenance should be avoided, as it creates dependency.

- Before considering the use of direct financial and material support for input-intensive measures, alternative approaches should be explored, such as adapting existing technologies, or choosing 'simple and cheap' technologies.

- If fertilizers, agro-chemicals, seed or seedlings are subsidised, the support should aim to be one element that helps build up a more integrated approach towards soil fertility, and pest and disease management.

The lower the degree of outside financial or material support, the greater the level of genuine land user self-initiative and participation, and thus the probability that the interventions are sustainable.

Access to credit and financing schemes can be vital help for rural people to start new SLM initiatives. Thus well-functioning financial services and mechanisms (such as micro-credit) need to be established, enabling land users to take the initiative for self-financing SLM interventions.

Financial support needs to be maintained or even enhanced for institutions providing advice, plans and decision support at all levels, to ensure sufficient and effective support to land users.

Monitoring, assessment and research

Monitoring and assessment – improve SLM and justify investments: Monitoring and assessment (M&A) of SLM practices and their impacts is needed to learn from the wealth of knowledge available including traditional, innovative, project and research experiences and lessons learnt – both successes and failures. M&A can lead to important changes and modifications in approaches and technologies (WOCAT, 2007). SLM is constantly evolving, which means M&A must be ongoing and responsive. Land users have to take an active role as key actors in M&A: their knowledge and judgement of the pros and cons of SLM interventions is crucial. More investment in training and capacity building is needed for M&A generally, and specifically to improve skills in knowledge management and decision support.

Although several countries and regions have prepared land degradation maps, mapping of SLM efforts and areas under SLM has been badly neglected. M&A through such mapping can contribute to raising awareness of what has been achieved, as well as justifying further investments and guiding future decision-making (Schwilch et al. 2009).

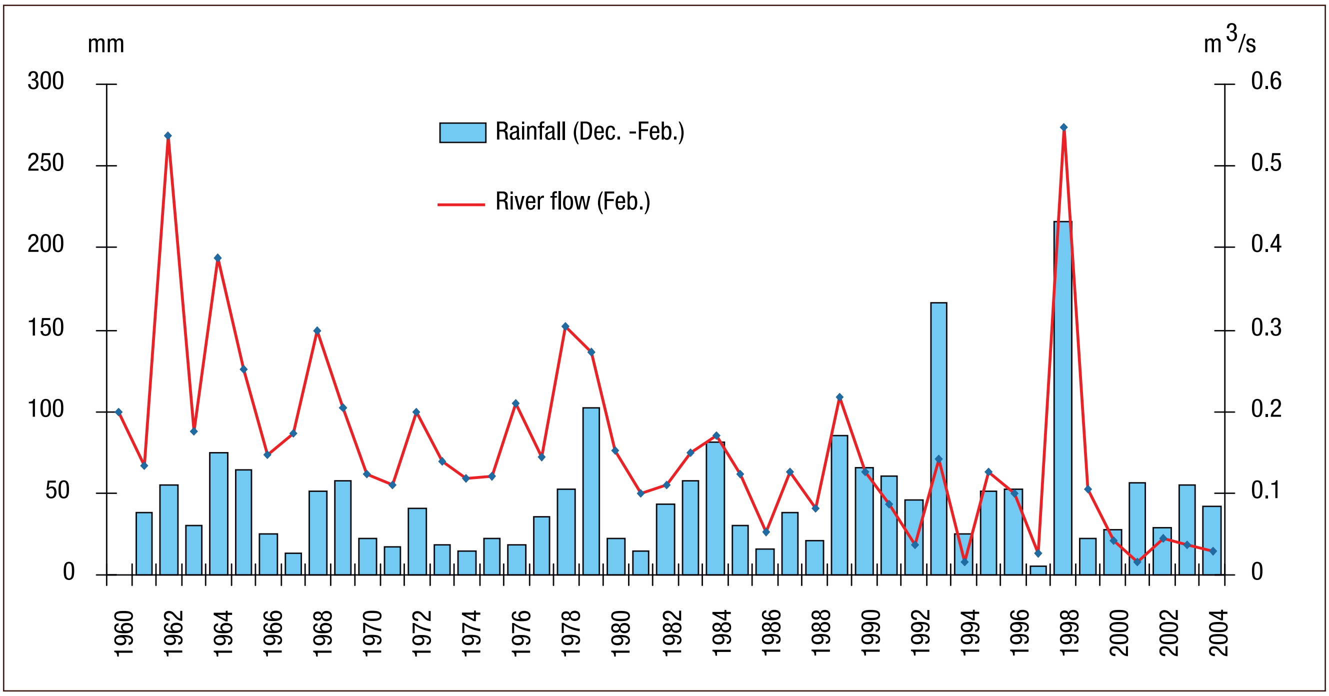


Figure 12: Monitoring of rainfall and river flow in February (dry season) document changes related to climate and impacts of land use. Timau River, Mount Kenya region (Liniger H.P., 2005)

Complexity and knowledge gaps – the role of research: The problems of land degradation are complex and so are the answers: there is a real danger of simplification. Blueprint solutions for the implementation of SLM do not take account of this complexity. Effective SLM depends on both suitable technologies and closely matched approaches for their promotion. They need to be flexible and responsive to changing complex ecological and socio-economic environments. An urgent and specific area for further investigations and research is quantification and valuation of the ecological (e.g. Figure 12), social and economic impacts of SLM, both on-site and off-site, including the development of methods for the valuation of ecosystem services. SLM research should seek to incorporate land users, scientists from different disciplines and decision-makers.

The major research challenges are:

- M&A of the local impacts of SLM and land degradation (ecological, economic and social);
- proper cost and benefit analysis of SLM intervention measures;
- M&A of regional impacts at watershed and landscape levels (including off-site and transboundary effects);
- mapping and monitoring of land degradation and the extent and effectiveness of SLM practices; and
- use of knowledge about SLM for improved decision-making at all levels (developing tools and methods for improved knowledge management and decision support).

The above challenges imply that further research and capacity building in SLM – as well as spreading and adapting SLM practices and innovations – are urgently needed. This also requires further development of decision support methods and tools for the local and national level (see following chapter).

Decision support - upscaling SLM

Land users, agricultural advisors and decision makers are faced with the challenge of finding the best land management practices for particular conditions. Thus they have the same questions to answer (see Figure 13):

- Which SLM technology and approach should be chosen?
- Where to apply them?
- How to apply them?
- Who plays what roles?
- What are the costs?
- What are the impacts?
- Do they improve food security, and alleviate poverty?
- Do they combat land degradation / desertification?
- How well are they matched to a changing climate?

Another fundamental question is where and when to invest: prevention before land degradation processes start, or rather mitigation / 'cure' after degradation has started - or rehabilitation when degradation is most severe? The costs vary considerably depending on the stage of SLM intervention (Figure 13).

Inputs and achievements depend very much on the stage of degradation at which SLM interventions are made. The best benefit-cost ratio will normally be achieved through measures for prevention, followed by mitigation, and then rehabilitation. In prevention, the 'benefit' of maintaining the high level land productivity and ecosystem services has to be measured compared to the potential loss without any intervention. While the impacts of (and measures involved in) rehabilitation efforts can be highly visible, the related achievements need to be critically considered in terms of the cost and associated benefits.

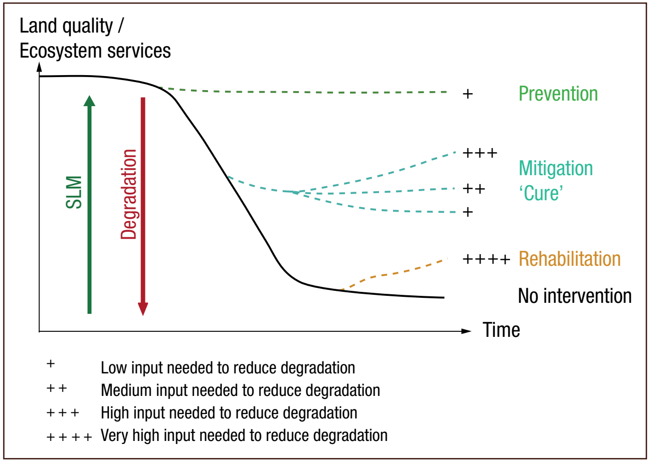


Figure 13: Stage of intervention and related costs.

Questions that need to be addressed for informed decision-making are: Where are the hot spots / priority areas for interventions? Where are the green spots? These require answers in order to make decisions on spreading best SLM practices. In the following, a 3-step decision support method is proposed to help answer these questions based on improved knowledge management and a selection mechanism involving relevant stakeholders at different levels (Schwilch et al. 2009).

Knowledge management: building the basis

Step 1 – Identification of SLM best practices involving all stakeholders: The first step for better decision support is the initial involvement of all stakeholders in SLM (e.g. through a stakeholder workshop). The aim is to identify existing prevention and mitigation strategies against land degradation and desertification. The methodology brings together scientific and local knowledge while simultaneously supporting a co-learning process oriented towards sustainable development. The objectives are: (1) to reflect on current and potential problems and solutions related to land degradation and desertification; (2) to create a common understanding of problems, potentials and opportunities; (3) to strengthen trust and collaboration among concerned stakeholders; (4) to identify existing and new SLM practices; and (5) to select a set of these identified strategies for further evaluation and documentation in the next step.

Step 2 – Documentation and assessment of existing SLM practices: There are many unrecognised SLM practices which constitute a wealth of untapped knowledge. Knowledge related to SLM often remains only a local, individual and institutional resource, unavailable to others. Therefore, existing SLM practices need to be documented and stored in a database using a standardised methodology - for example the WOCAT method and tools (Liniger and Critchley, 2008). The aim of standardised knowledge management is to accumulate, evaluate, share and disseminate experience; not just within countries but across the world. Several attempts to build up a global knowledge base on SLM have been made, but they use different formats which cannot be integrated nor compared, thus a globally accepted methodology is proposed. The main asset of this is to have a common and growing pool of SLM knowledge and with tools to share and access, and use the knowledge for better decision-making. In Part 2 of the guidelines a standardised format for documenting SLM practices is presented. It is a shortened version of the standardised WOCAT 4 page presentation of SLM Technologies and Approaches (WOCAT, 2007).

A standardised knowledge base allows thorough assessment and evaluation of the impacts and benefits of the various SLM practices. It also facilitates the comparison of different options.

Selection and fine tuning of SLM practices

Once documented, SLM experiences need to be made widely available and accessible in a form that allows all stakeholders to review existing practices, understanding their particular advantages and disadvantages – and thus to make appropriate decisions. New SLM efforts should first try to build on existing knowledge from within a location and region itself or, alternatively, from similar conditions and environments elsewhere.

Step 3 – Participatory decision-making for selection and implementation of SLM best practices: After documentation and assessment of existing SLM practices, the challenge is to decide on best practices and where to implement them. This again involves all stakeholders (e.g. in a second stakeholder workshop) and recently developed decision support tools to evaluate the best options and set priorities. These tools allow selection of SLM options, comparison and ranking of them, negotiation and finally a decision regarding which is (or are) the best-bets for specific conditions (Schwilch et al. 2009).

Whether such SLM practices are accepted or not depends on cost-effectiveness, severity of degradation, knowledge, enabling framework conditions (e.g. policies and subsidies) and on other socio-cultural and economic issues.
The key to success lies in a concerted effort by all, where special attention needs to be paid to the participatory process of selecting potential SLM interventions. Otherwise land users will neither accept nor properly implement the practice, and project success will be threatened. Stakeholder involvement is crucial at all stages.

Selection of priority areas for interventions

So far there are only few maps covering land degradation; but there are none covering SLM – nor the impacts either of land degradation or SLM. This makes sound decision-making very difficult, but likewise it is also impossible to demonstrate the needs and benefits of SLM interventions.

There is not only need to assess and monitor the different SLM practices but also the impacts of multiple SLM interventions at the larger scale. This would permit the assessment of off-site impacts and effects of upstream interventions on downstream areas. The design and the costs of downstream interventions can be reduced due to upstream investments. This does not only apply to impacts caused by the flow of water downstream, but also impacts from wind affecting off-site areas (e.g. dust storms). Showing benefits of linking upstream (on-site) with downstream (off-site) would help in setting priorities for intervention and investments.

A mapping methodology jointly developed by WOCAT and FAO-LADA generates information on degradation and SLM, and highlights where to focus investments. The mapping tool focuses on areas with land degradation ('red' spots) and on identifying where existing SLM practices ('green' spots) could be expanded. It further facilitates judgement of whether to rehabilitate, or to prevent land degradation and what the impacts on ecosystem services might be.

For different land use systems the type, extent and degree of land degradation and the causes are assessed. For areas covered with SLM practices, the extent and effectiveness is recorded and for both land degradation and SLM the impacts on ecosystem services are listed. The data is compiled through a participatory expert assessment involving local land users, supported by documents and surveys. Given this information from mapping degradation and conservation, land users, advisors and planners can set priorities for interventions, and judge where the benefits for investments made are likely to be highest or the most needed.

The combined assessment of SLM practices and mapping allows not only the expansion of SLM, but also points towards necessary adjustments and adaptations to local conditions.

Where to intervene and where to spread already well proven SLM technologies. (Hanspeter Liniger)

Conclusions for adoption and decision support

- All issues discussed under institutional and policy framework, have a strong influence on the implementation of SLM but are difficult / impossible to address at single project or local level. However, through the creation of coalitions of implementing programmes and investment frameworks (e.g. TerrAfrica) changes favourable for SLM can be induced.

- To make an impact SLM needs to be integrated within national and regional priorities through policies, strategies, and action plans (WOCAT, 2007). SLM policies must be mainstreamed into broader sectorial policy frameworks.

- Recognition that different approaches are needed in different contexts is important, and acknowledgement that not all land management problems can be solved by government intervention or donor investments. A greater engagement of civil society and empowering stakeholders at grassroots is required (TerrAfrica, 2008).

- Cutbacks in government extension services and farm credit, as a result of liberalisation policies, have deprived land users of important sources of knowledge and advice. Hence innovative extension and advisory services options need to be considered such as contracting extension services to NGOs and other third parties.

- Links need to be drawn between local and regional implications (e.g. off-site effects, highland /lowland, mountains).

- Regional / national and global communities must take responsibilities for protecting the world's forests and should be willing to pay / compensate local rural people, otherwise valuable ecosystems and services such as better climate, clean air, good water, and improved biodiversity will be lost. All possible efforts need to be made to quantify the valuable services and to show the consequences on global human wellbeing if we fail. Local communities need to be acknowledged as stewards and custodians of natural forests and their services.

- M&A and research is key for improved decision support and upscaling.

- Capacity building is needed at all levels for land users, extension workers, planners and decision-makers. Major efforts are needed for knowledge management and decision support for local selection and fine-tuning of best SLM practices but also for regional priority setting within a watershed or landscape.

Future interventions need to promote the development of joint or 'hybrid' innovation that ensures making the best of local and scientific knowledge. In this respect, current farmer experimentation – including the adaptation of traditional technologies – blended with scientific research offers real hope for the future. Local innovation has, after all, been the driving force behind the traditions that have shaped farming, and SLM, over the millennia (Critchley, 2007). However all developments must take into consideration markets, policies and institutional factors that can stimulate widespread smallholder investments.


Hanspeter Liniger

THE WAY FORWARD

Recognising the contribution of SLM to food security, improved livelihood, mitigation of widespread land degradation and climate change adaptation and mitigation, best SLM practices need to be scaled-up and SLM mainstreamed as a priority at all levels.

SLM experiences presented in this book clearly show the need for major shifts in emphasis to overcome bottlenecks and barriers for spreading SLM in SSA. These shifts concern various aspects at different levels including technologies and approaches, institutional, policy, governance, economy, knowledge management and capacity building.

General shifts	
From simplicity	**To** complexity (ecosystem)
From narrow and single sector views	**To** holistic, multi-level, multi-stakeholder views

Technology shifts	
From providing rigid 'blueprint' or 'silver bullet' technologies	**To** offering a basket of options of best practices, flexible to be adapted to local conditions and needs
From individual single measures	**To** integrated / combined measures
From focus on structural and expensive practices	**To** focus first on cheap and easy agronomic, vegetative and management measures
From introducing new 'exotic' SLM technologies	**To** identifying and building on existing practices and local innovations - if needed supplemented with new elements derived from experiences elsewhere with similar conditions
From high losses of water through runoff and evaporation	**To** improved water use efficiency in rainfed and irrigated agriculture and improved water harvesting
From 'old' green revolution	**To** 'new' green revolution: reduced reliance on external inputs (fertilizers and pesticides), pro-poor, women

Policy, Institutional, Governance shifts	
From looking at impacts of land degradation, treating symptoms	**To** looking at root causes of land degradation, curing
From focus on rehabilitation of degraded land	**To** focus on preventing and mitigating land degradation and enhancing ecosystem services
From isolated successful SLM technologies and approaches	**To** scaling-up best practices (technologies and approaches)
From local planning and interventions	**To** multi-stakeholder planning and treatment at landscape or watershed level
From top-down transfer of technology	**To** people-centered learning approach
From limited consideration for the concerns of women, youth and marginal groups	**To** adoption of approaches sensitive to cultural aspects, gender, youth and marginal groups
From contradictory or uncoordinated policies that address symptoms	**To** effective cross-sector policies that address cures
From insecure land and water user rights (hindering SLM investments)	**To** locally negotiated tenure systems, regulations, land use plans, and user rights
From inadequate laws, regulations and control mechanisms to implement SLM and land degradation control	**To** an incentive-oriented legislation which recognises ecological problems and opportunities, supports effective land and ecosystem management, and establishes socially acceptable mechanisms for their enforcement

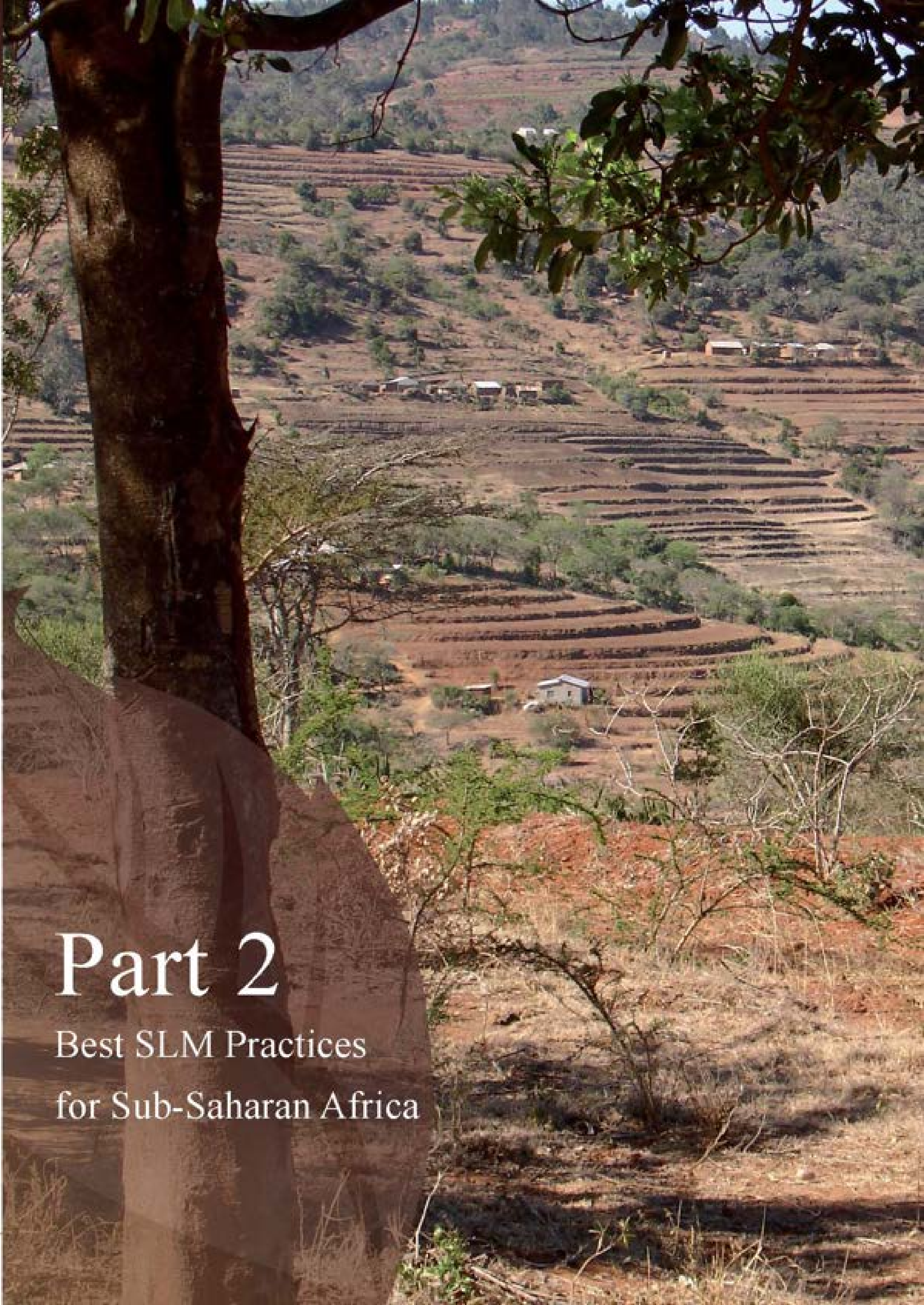
Knowledge management and capacity building shifts	
From focus on land degradation and desertification	**To** focus on SLM
From scattered and poorly documented SLM traditions and innovations as well as project experiences	**To** building common, easily accessible and standardised knowledge platforms to share and use information for decision-making
From poor knowledge on impacts of land management	**To** concerted action for monitoring and assessment of land degradation and SLM, and on-/offsite impacts on ecosystem services
From weakened advisory services	**To** major reinvestments in rebuilding rural advisory services
From poor awareness raising and capacity building related to SLM	**To** major efforts in awareness raising, training, education and capacity building
From poor use of SLM knowledge	**To** informed decision support at local and landscape / watershed level

Investment shifts	
From inadequate or contradictory economic and pricing policies that discourage investment in SLM	**To** the development of financial and market incentives that facilitate and encourage private investment in SLM
From inadequately monitored national and private sector budgets on SLM related issues	**To** traceable budgets on well defined SLM activities built within dedicated investment frameworks
From few / scattered project funding coming from poorly coordinated development partners	**To** specific budgets pooled around SLM programmes, according to Paris Declaration principles (budget support, basket funding etc.)

(Source: Elaborated by authors and based on TerrAfrica, 2009)

The final conclusions are that investment in spreading SLM practices in Sub-Saharan Africa has great scope and can deliver multiple benefits not only locally, but also regionally (e.g. in watersheds), nationally as well as globally. SLM concerns all, at all levels, and pays in many more ways than recognised. Many of the global issues such as food security, poverty, water scarcity, desertification, climate change mitigation and adaption, and biodiversity are closely related to SLM.

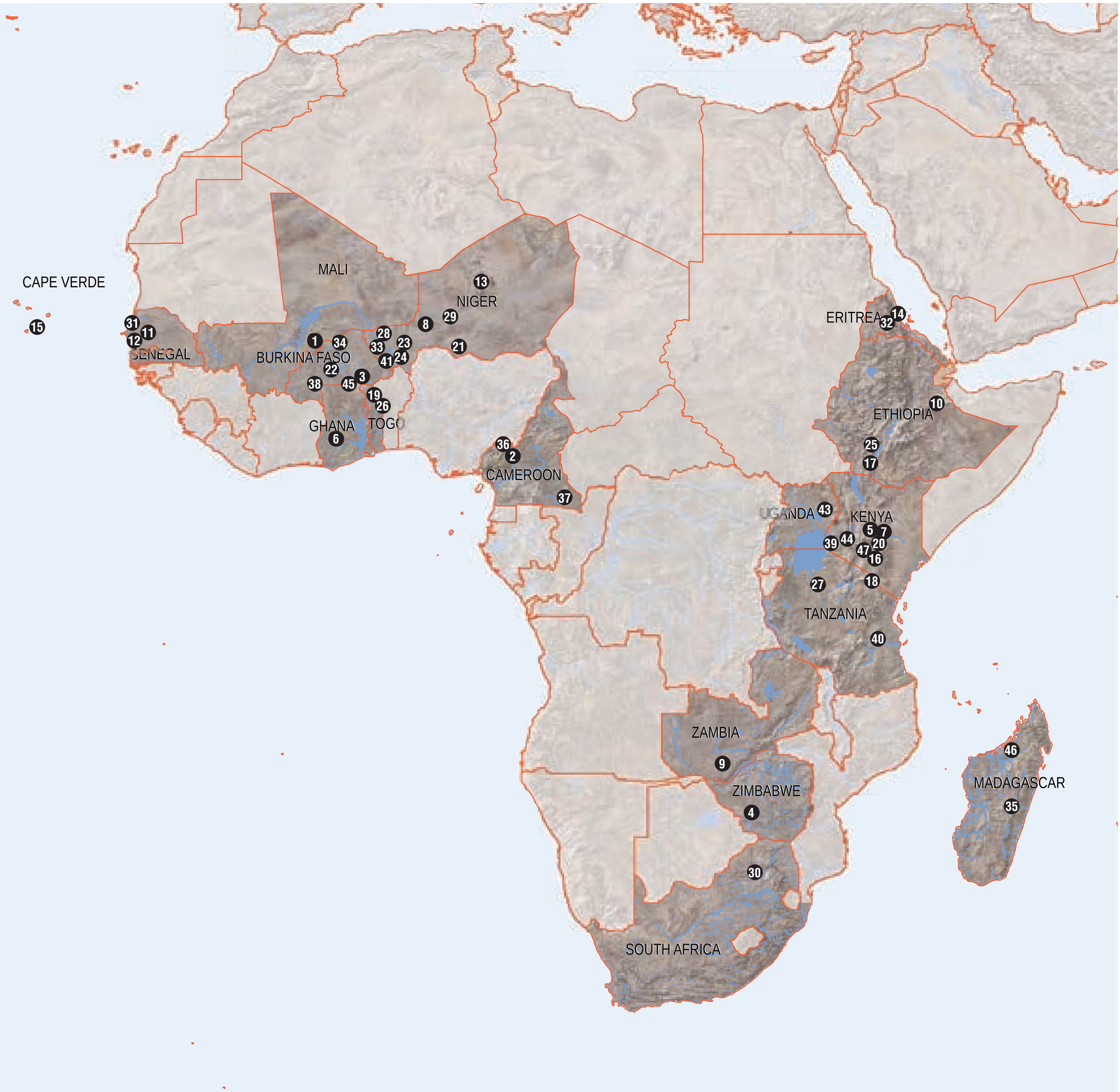
Additionally consolidated efforts are needed for knowledge management concerning SLM technologies and approaches and their spreading, not only to document and monitor valuable experiences for their own sake, but for dissemination and use in improved decision-making at the field and planning level. Given rapid changes, many adaptations and innovations concerning SLM will continue but will be untapped and unused. Consolidated action towards better use of valuable local, regional and global knowledge is needed and will be greatly beneficial in the future, as it can be anticipated that change will be even more pronounced (global markets, climate change, demands on ecosystem services, biofuel, etc.). Investment in SLM and knowledge management pays.



Part 2

Best SLM Practices for Sub-Saharan Africa

OVERVIEW OF BEST SLM PRACTICES



SLM TECHNOLOGY GROUPS AND CASE STUDIES

There is no one miracle solution ('silver bullet') to solve the problems which land users in SSA face. The choice of the most appropriate SLM practice in a particular situation will be determined by local stakeholders, based on the local topographic, soil and vegetation conditions and socio-economic context, such as farm size and assets which may make certain practices ill-advised or not feasible. The SLM groups presented in Part 2 follow the principles of best practices: increasing productivity, improving livelihoods and improving ecosystems.

Twelve groups of SLM technologies backed up by 41 case studies, are presented and these:

- Cover 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.

This selection of SLM groups and case studies does not claim to be complete or comprehensive:

- It does not cover or 'balance' all land use types, agro-ecological zones or regions;
- The selection shows the potential, and need for, further documenting of experiences to cover the broad spectrum better.

All groups and case studies are presented according to the familiar and standardised WOCAT format for documenting and disseminating SLM.

For the quantification of impacts the following categories are used in the presentation of SLM groups and case studies:

+++	= high impact
++	= moderate impact
+	= low impact
Na	= not applicable

For the Benefit-cost ratio the meaning of the symbols «+» and «–» is slightly different (as indicated under the respective tables).

INTEGRATED SOIL FERTILITY MANAGEMENT

Comparison between traditionally-cultivated, unfertilised millet field with its characteristic high-spatial variability in plant growth at Banizoumbou (left) and millet field using micro-dosing fertilization at Kara Bedji (right) in Niger. (Andreas Buerkert)

In a nutshell

Definition: Integrated Soil Fertility Management (ISFM) aims at managing 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 then maintain soil fertility by using available nutrient resources in an efficient and sustainable way. ISFM aims at making use of techniques without much additional cost to the farmer, such as organic fertilizer, crop residues and nitrogen-fixing crops, in combination with seed priming and water harvesting. A next step is the use of inorganic fertilizer, which requires financial input; however micro-fertilization can provide a cost-saving entry point.

Low cost ISFM techniques include: micro-dosing with inorganic fertilizers, manuring and composting, rock phosphate application, etc. SLM practices such as conservation agriculture or agroforestry include supplementary aspects of fertility management.

Applicability: ISFM is required in areas with low and rapidly declining soil fertility. Due to the wide variety of ISFM techniques, there is no specific climatic restriction for application apart from arid areas 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 to 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 adoption of ISFM are influenced by the availability and access to inputs such as organic fertilizers (compost, manure) and the affordability of inorganic fertilizers. 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 is needed.

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	na
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	++

Origin and spread

Origin: Composting and manuring are traditional technologies, which are often reintroduced, in an improved form, through projects / programmes. The application of inorganic fertilizer is a relatively new technology, especially when applied on small-scale farms through micro-fertilization (or 'micro-dosing'). Micro-fertilization was developed through applied participatory research for use at small-scale level.
Mainly applied in: Integrated soil fertility management is applied in all parts of SSA, however the types of ISFM can differ depending on climate, soil, etc. Micro-fertilization has been the basis for reintroduction of fertilizer use in Mozambique, South Africa and Zimbabwe in Southern Africa; and Burkina Faso, Ghana, Mali, Niger and Senegal in West Africa.

Spread of micro-fertilization in SSA.

Principles and types

For optimized soil fertility management an integrated nutrient management system including both organic and inorganic inputs must be envisaged.
1. 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. Manure is a valuable, but often neglected resource in livestock and mixed farming systems because of its bulky nature and a lack of ox-carts and wheelbarrows for transportation around the smallholding. Including animals in farm production systems reduces the reliance on external inputs. Composting is the natural process of 'rotting' or decomposition of organic matter such as crop residues, farmyard manure and waste by micro-organisms under controlled conditions. It is an attractive proposition for turning on-farm organic waste into a farm resource and is gaining more importance among small-scale farmers in SSA.
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 fungus.
Integration of nitrogen fixing crops: Green manures or cover crops are leguminous plants that are intercropped or planted in rotation with other crops and used for nitrogen fixing in the soil. 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. 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.
2. Inorganic fertilizer
Crop yields can be dramatically improved (to a certain level) 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 minimise GHG emissions and to avoid unhealthy plant growth, as well as an accelerated decomposition of soil organic matter. There is great pressure today to increase the availability and affordability of fertilizers for small-scale subsistence farmers in SSA. A low-cost method is micro-fertilization (or 'micro-dosing'). Small amounts of mineral fertilizer are applied to the planting hole at the time of sowing, and /or after emergence as a top dressing. Because soil fertility limits production, small and targeted doses of fertilizer can increase production significantly. To achieve long term soil fertility, micro-dosing should be combined with compost or manure because the small amounts of inorganic fertilizer used in micro-dosing are not sufficient to stop nutrient mining, nor do they directly build up the soil organic matter. Micro-fertilization can be the first step in lifting on-farm productivity and building the capacity of farmers to invest in manure or other organic or inorganic fertilizers.
Rock phosphate is said to have great potential, but it is yet underused because of the costs and limited availability in the local market, and the limited experience of farmers with applying it. A key issue is that the beneficial effects of rock phosphate become apparent only in the course of some years, compared to the immediate benefits of inorganic fertilizers.

Top: Compost pits with low containing walls, Ghana. (William Critchley)
Middle: *Tithonia diversifolia* as green manure in a cocoyam field, Cameroon. (Fabienne Thomas)
Bottom: One bottle cap of compound fertilizer for micro-dosing, Zimbabwe. (ICRISAT, Bulawayo)

Applicability

Land degradation addressed

Chemical soil deterioration: fertility decline through reduced soil organic matter content and nutrient loss
Physical soil deterioration: compaction, sealing and crusting
Water degradation: aridification
Soil erosion by water: loss of topsoil / soil surface

Land use

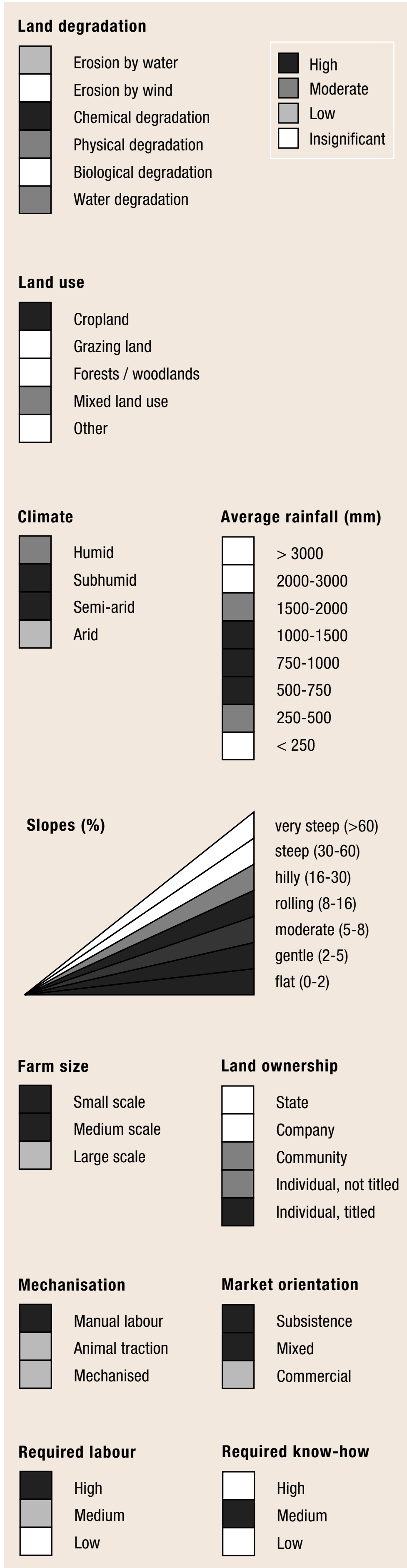
Mainly on annual cropland and mixed land (crop-livestock systems). Unsuitable for rangeland.

Ecological conditions

Climate: Compost making is most effective in subhumid to humid areas where water is available for watering. Here, above ground pits are better than the pits used in drier zones. Dry composting (covering the compost with soil and creating an anaerobic environment) is also applicable in arid areas.
Terrain and landscape: flat to hilly (transport is a heavy burden on very steep slopes)
Soils: ISFM is suitable for all types of soils, however it is difficult to increase the organic matter content of soils that are well aerated, such as coarse sands, and soils in warm-hot and arid regions because the added material decomposes rapidly. Soil organic matter levels can be maintained with less organic residue in fine textured soils in cold temperate and moist-wet regions with restricted aeration.

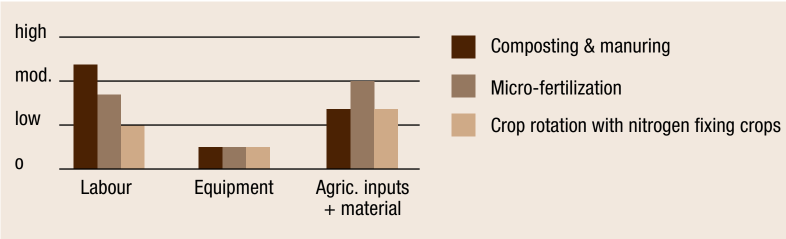
Socio-economic conditions

Farming system and level of mechanisation: Mainly manual labour for the making and spreading of compost and manure. Access to a wheelbarrow or an ox-cart aids movement of these bulky materials around the smallholding. The application of inorganic fertilizers can be undertaken manually in smallholder systems where small targeted applications are promoted. For large-scale commercial farming, fertilizer spreaders or combined seed and fertilizer drills are available. Crop rotation with nitrogen fixing crops can be integrated in either a manual or mechanised agricultural system.
Market orientation and infrastructure: Applicable for subsistence (self-supply), mixed (subsistence / commercial) farming and even commercial farming. The application of inorganic fertilizer (through micro-fertilization) is suitable for all types of crop production from subsistence to commercial.
Land ownership and land use / water rights: Individual land use rights or communal and individual not-titled land use rights influence the type and level of investment in soil fertility amendments and management.
Skill / knowledge requirements: Medium knowledge requirement regarding the careful application of inorganic fertiliser (N and P) to avoid loss, reduce GHG emissions and decomposition of soil organic matter, and appropriate use of crop rotations with nitrogen fixing legumes.
Labour requirements: Depending on the technology the level of labour required ranges considerably. Composting and manuring may require high labour inputs, depending on the distance of transport. Green cover crops involve a lower workload, since this can be integrated into the seasonal agricultural activities.
The application of inorganic fertilizer through a micro-dosing technique does not increase labour demand significantly since seeds and fertilizer are added simultaneously.



Economics

Maintenance costs



(Source: WOCAT, 2009)

Comment: Organic-based ISFM-techniques have lower cash requirements than the use of inorganic fertilizer; therefore they can more easily reach poorer households.
ISFM-techniques are agricultural measures / activities which have to be conducted every year / season, etc. The initial investment or establishment costs are negligible.

Production benefits

	Yield without SLM (kg/ha)	Yield with SLM (kg/ha)		Yield gain (%)	
Micro-fertilizing, (Mali) Sorghum Pearl millet	 500–800 200	 1100-1800[1] 300-370[1]	 900-1500[2] 400-500[2]	 30-50%[1] 48-70%[1]	 70-84%[2] 123-143%[2]
Zai+Micro-fertilizing, Sorghum (Burkina Faso) Sorghum (Ghana) Cowpea (Burkina Faso)	 552 290 590	 900-1200 400-650 950-1200		50-100%	
Tithonia - Green manure, (Cameroon) Beans	370	410-570		10-55%	

[1] application of 0.3 g fertilizer per hole; [2] application of 6 g fertilizer per hole.
(Sources: Aune, et al., 2007; WOCAT, 2009; ICRISAT))

Benefit-Cost ratio

	short term	long term	quantitative
Micro-fertilizing	+++	+++	Value-cost ratio, Mali: 3.5-12 (for 0.3 g), Sorghum 0.4-1.2 (for 6 g), Pearl Millet
Manuring & Fertilizer & 50% Crop Residues	+++	+++	Value-cost ratio, Nigeria: 20.8, Rice 5.9, Maize 3.5, Millet
Composting & Manuring	++	+++	
Green Manure	++	+++	
Overall	++	+++	

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive
(Sources: Aune, et al., 2007; WOCAT, 2009 and IFPRI, 2010)

Comment: Micro-dosing shows an acceptable value-cost ratio (VCR) for land users. Even though the crop yield for the application of 6 g fertilizer is better than for 0.3 g fertilizer, the 0.3 g treatment appeals better to farmers because of the higher VCR and the better return on investment, low financial risk, low cash outlay and low workload required.

Example: Micro-fertilization, Mali
Aune et al. (2007) tested the agronomic, economic and social feasibility of micro-fertilizing in Mali. Two different amounts of fertilizer were applied to the holes, 6 g and 0.3 g. Both applications gave higher yields for pearl millet and sorghum in comparison to the control plot. Yields of sorghum increased by 34% and 52% compared with the control after applying 0.3 g of fertilizer per planting station for the years 2000 and 2001 respectively. For pearl millet, the corresponding yield increase was 48% and 67% for 2001 and 2003 respectively. Higher yield increases were observed when 6 g of fertilizer was applied per planting station than when 0.3 g of fertilizer was applied. The application of 0.3 g fertilizer has shown the better value-cost ratio (VCR), due to reduced workload and less inputs needed. The VCR varied from 3.4 to 12 in the 0.3 g treatment, and from 0.4 to 1.2 in the 6 g treatment. Application of 0.3 g of fertilizer appeals to farmers because of the good return on investment, low financial risk, low cash outlay and low workload required. Micro-dosing has been strongly promoted by ICRISAT. The amount of fertilizer recommended can be easily measured with a bottle cap which equates to approximately 6 g fertilizer. However, the study of Aune et al. has clearly shown that smaller amounts may have a better benefit / cost ratio. Nevertheless, for the long term sustainability micro-dosing should be combined with organic fertilization such as composting or manuring, otherwise nutrient mining cannot be stopped.

Example: Zimbabwe
Different studies have shown the high benefits of integrated soil fertility management compared to the application of single inorganic or organic fertilizers. The integration of manure and fertilizer on maize in Zimbabwe resulted in a return to labour of about US$ 1.35 per day, while the best single fertilizer or manure treatment yielded only US$ 0.25. Returns to integrated biomass transfer and rock phosphate systems on kale and tomatoes in Kenya showed returns to labour of between US$ 2.14 to US$ 2.68 as compared to a best return of US$ 1.68 when only one of the options was used. More economic analyses of farmer-managed ISFM systems are needed. However, existing evidence suggests that organic or ISFM systems may be remunerative where purchased fertilizer alone remains unattractive (Place et al., 2003).

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	+++ increased crop yields ++ fodder production / quality increase + diversification of production	++ reduced risk and loss of production	+++ improved food and security
Economic	++ increased farm income ++ easy to maintain and to establish ++ simple technology using locally available material + reduced expenses on agricultural inputs (with manuring)	++ stimulation of economic growth + less damage to off-site infrastructure	+++ improved livelihood and well-being
Ecological	+++ increased organic matter and soil fertility ++ improved soil cover ++ reduced soil erosion by (water and wind) ++ improved excess water drainage ++ improved rainwater productivity ++ biodiversity enhancement + increased soil moisture + improved micro-climate	+ increased water availability + reduced degradation and sedimentation + intact ecosystem	++ reduced degradation and desertification incidence and intensity ++ increased resilience to climate change + enhanced biodiversity
Socio-cultural	++ improved conservation / erosion knowledge ++ 'is owned by the farmer' + community institution strengthening + changing the traditional gender roles of men and women	+ increased awareness for environmental 'health' + attractive landscape	+ protecting national heritage

	Constraints	How to overcome
Production	• Need for water (for composting for optimal growth) • Availability of manure and compost and competition for materials (compost for animals or mulching; manure for house construction or fuel)	➜ furthering local market for organic fertilizers (manure and compost)
Economic	• Increased labour demands especially over using organic nutrient sources • Transportation of manure over too long distances not profitable • Affordability of inorganic fertilizers for small-scale land users – inflexible packaging in 50 kg bags • Lack of access to credit for investments (especially for inorganic fer-tiliser)	➜ purchase of inorganic fertilizer in a land user group and/ or provide small packages of fertilizers (e.g. 1-2 kg) ➜ ensure financial services and access of land users to small credits
Ecological	• It takes time to rejuvenate poor soils in SSA - the amount of organic material added is small relative to the mineral proportion of the soil • Waterlogging • Termites eating up trash; trash can harbour pests and diseases • Source of weeds; green manure could become a weed • Wrong application of inorganic fertilizer can lead to unhealthy plant grow and increased decomposition of soil organic matter • Inappropriate use of inorganic fertilizer and large applications of inorganic nitrogenous fertilisers can be a direct source of GHG emissions.	➜ needs integrated soil fertility management which encompasses organic and inorganic fertilizers in order to optimise the nutrient application ➜ control through weeding ➜ adequate training is necessary: better to use too little than too much fertilizer ➜ due to limited physical and economic access of smallhold-ers to N-fertilizer, excessive use is not (yet) widespread in SSA. Appropriate and efficient use of N-fertiliser reduces the problem of GHG-emissions particularly if ammonium nitrate is used rather than urea
Socio-cultural	• Requires adequate knowledge especially for the right application of inorganic fertilizer • Some efforts do not have an immediate visible impact (e.g. rock phosphate, compost, etc.)	➜ effective and not too costly information provision and technical support ➜ appropriate awareness raising and information

Adoption and upscaling

Adoption rate

The use of animal manure and legume intercropping are well-established, whereas other practices like improved composting and micro-fertilization are relatively new and not yet widespread. So far, widespread adoption of ISFM practices has been hindered by high prices, and accessibility and availability of material and markets.

Upscaling

Profitability: The land user's decision is mainly influenced by perceived profitability of the system. Low-cost and resource-efficient methods should be promoted as a starting point for production intensification.

Access and availability of inputs must be ensured. Local markets for organic fertilizers such as manure or compost must be improved. Markets for green manure seeds do not yet exist to a significant degree. Inorganic fertilizers should be made available and methods promoted like micro-fertilization using only small amounts.

Access to financial services is needed and credit must be easily accessible by land users to facilitate investments in ISFM.

Access to markets and infrastructure: Functioning markets and market access is important for producing cash crops.

Awareness raising and promotion about the different options for better soil fertility management is needed.

Knowledge on ISFM: Capacity building on different and appropriate soil fertility techniques and educational programmes for the right application of inorganic fertilizers are needed (to reduce emissions of GHGs). Low adoption rates can be tackled by emphasising participatory learning and action-oriented research with stakeholders.

Incentives for adoption

In particular, there needs to be greater access to credit and economic rewards so that land users can make investments in soil fertility management. Users of inorganic fertilizer will need to develop a market-oriented approach. In many cases, small-scale land users cannot operate as individuals because that will make the purchase of fertilizer too expensive.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	+++
Training and education	++
Land tenure, secure land use rights	++
Access to markets	++
Research	+
Infrastructure	+

Example: Kenya

Place et al. (2003) have compiled different rates of adoption for ISFM techniques. In Kenya, between 86% and 91% of farmers used manure in semi-arid and semi-humid zones east of Nairobi. Compost was adopted by about 40% of farmers in the more favourable parts of these zones, but by relatively few in the more arid sites. In the more humid western highlands, Place et al. (2002a) found that 70% of households used manure and 41% used compost. It was found that 49% of Rwandan farmers' plots received organic nutrient inputs, and Gambara et al. (2002) found legume rotations and green manure systems practiced in 48% and 23% respectively of focal extension areas in Zimbabwe. While the relative adoption rates between organic and mineral nutrients vary by location, the incidence of organic practices (especially natural fallowing and animal manure) often outpaces the use of mineral fertilizers (Place et al. 2003).

References and supporting information:

Aune J.B., A. Bationo. 2008. Agricultural Intensification in the Sahel – The ladder approach. Agricultural Systems 2008.

Aune J.B., D. Mamadou and A. Berthe. 2007. Microfertilizing sorghum and perl millet in Mali – Agronomic, economic and social feasibility. Outlook on Agriculture, Vol. 36. No. 3. pp 199-203.

Enyong L.A., S.K. Debrah, and A. Batiano. 1999. Farmers' perceptions and attitudes towards introduced soil-fertility enhancing technologies in western Africa. Nutrient Cycling in Agroecosystems 53: 177–187.

FAO. 2005. The importance of soil organic matter – Key to drought-resistant soil and sustained food and production. FAO Soils Bulletin 80.

ICRISAT. 2004. SATrends ISSUE 41, http://www.icrisat.org/satrends/apr2004.htm, accessed on 14 September 2009.

ICRISAT. 2008. International Crops Research Institute for the Semi-Arid Tropics - Eastern and Southern Africa Region. 2007 Highlights. PO Box 39063, Nairobi, Kenya: ICRISAT. 52pp.

Mati B. M. 2005. Overview of water and soil nutrient management under smallholder rainfed agriculture in East Africa. Working Paper 105. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Misra R.V., R.N. Roy, and H. Hiraoka. 2003. On-farm composting methods. FAO Land and Water Discussion Paper 2. Food and Agricultural Organization of the United Nations, Rome.

Osbahr H., Ch. Allan. 2003. Indigenous knowledge of soil fertility management in southwest Niger. Geoderma 111 (2003) 457–479.

Place F., Ch. B. Barrett, H.A. Freeman, J.J. Ramisch, B. Vanlauwe. 2003. Prospects for integrated soil fertility management using organic and inorganic inputs: evidence from smallholder African agricultural systems. Food Policy 28 (2003) 365–378.

Thomas F. 2005. Agroökologische Innovationen am Beispiel der Nutzung von Tithonia diversifolia (Mexican Sunflower) zur nachhaltigen Verbesserung der Nahrungsmittelsicherheit. Diplomarbeit, Departement der Geowissenschaften der Universität Freiburg, Einheit Geographie.

WOCAT. 2009. WOCAT databases on SLM technologies and SLM approaches. www.wocat.net, accessed on 15 September 2009

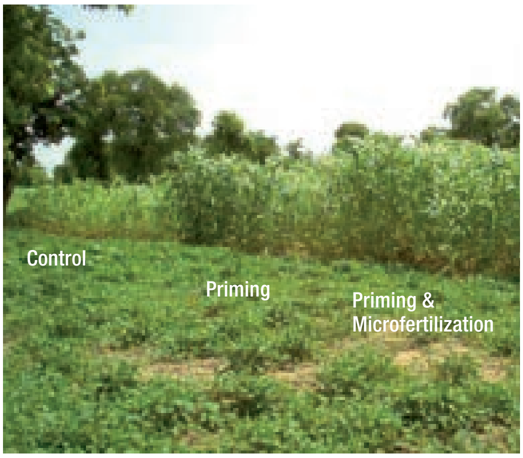
Woodfine, A. 2009. Using sustainable land management practices to adapt to and mitigate climate change in Sub-Saharan Africa: resource guide version 1.0. TerrAfrica. www.terrafrica.org

SEED PRIMING AND MICROFERTILIZATION - MALI

Seed priming and microfertilization have been found to be effective in increasing pearl millet and sorghum yields under dryland cropping systems. It is also applicable for cowpeas, groundnuts and sesame. Seed priming consists of soaking seeds for 8 hours prior to sowing and microfertilization is the application of small amounts of mineral fertilizer to the planting hole.

Seed priming should be carried out after a rain shower sufficient for sowing (15-20 mm) at the beginning of the rainy season. After soaking, the seeds should be air-dried for 1 hour prior to sowing (to reduce the stickiness of the seeds and to reduce risk of burning by fertilizer). Fertilizer (NPK 16-16-16; or Diammonium Phosphate) is applied at a micro-dose of 0.3 g per planting station, equivalent to 3-8 kg fertilizer/ha, dependent on plant population density. The air-dried seeds and the fertilizer can be applied simultaneously by first mixing the seeds and the fertilizer and thereafter taking a pinch of the mixture between thumb and forefinger.

Priming increases water use efficiency because seeds start germinating immediately after sowing. Results from Mali (Koro and Segou) show that yields can be increased by 50% if microfertilization is combined with seed priming. Other benefits are reduced labour constraints (thanks to simultaneous application) and risk reduction. Seed priming and microfertilization can be practiced independently from each other; however, the combination reduces the risk of crop failure and shows best results in terms of yield increase. Microfertilization has also been mechanised in Mali.



SLM measure	Agronomic
SLM group	Integrated Soil Fertility Management
Land use type	Annual cropping (pearl millet)
Degradation addressed	Soil fertility decline
Stage of intervention	Mitigation
Tolerance to climate change	Increased tolerance to droughts (particularly at beginning of growing season) due to better plant establishment

Establishment activities

Note: Seed priming and microfertilization are agronomic measures which are carried out repeatedly each cropping season. All activities are listed under maintenance / recurrent activities (below). There is no establishment phase (as defined by WOCAT).

Maintenance / recurrent activities

1. Soak seeds for 8 hours prior to sowing (onset of rainy season, late June).
2. Mix seeds and NPK fertilizer (16-16-16) or DAP at a ratio of 1:1 before sowing.
3. Sow seeds and fertilizer simultaneously and cover with soil.

Note: Seed priming can be started after sufficient rain for sowing has been received. If the method fails, it can be repeated again.

Option: If farmers have the resources to buy higher amount of fertilizer and if the season is promising, they can apply 2 g fertilizer per pocket at first weeding (20 days after sowing). This results in higher yields but also requires an additional operation for the farmer, tripling the labour inputs for fertilizer application. If this practice is adopted, it is not necessary to apply 0.3 g fertilizer at sowing.

All activities are carried out by manual labour; microfertilization has partly been mechanised, using an ox-drawn implement.

Labour requirements

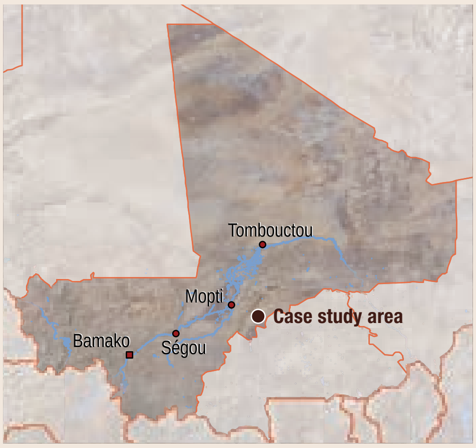
For establishment: na
For maintenance: low

Knowledge requirements

For advisors: low
For land users: low

Photo 1: Priming – soaking the seeds for 8 hours. (Adama Coulibaly)
Photo 2: Effect on yields of priming and of the combination microfertilization & priming compared to control plot. (Adama Coulibaly)
Photo 3: Farmers practicing microfertilization with animal traction. (Jens B. Aune)

Case study area: Koro, Mopti Region, Mali



Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	0
Equipment	0
Agricultural inputs	0
TOTAL	**0**

No establishment costs.

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 6 person-days	1
Equipment / tools: planting stick / hoe	0
Agricultural inputs: 47 kg superphosphate fertilizer	2
TOTAL	**3**

Remarks: Sowing can alternatively be mechanised, which will cause establishment costs (purchase of the sowing machine).

Benefit-cost ratio

Inputs	short term	long term
Establishment	na	na
Maintenance	very positive	very positive

Remarks: The technology has a benefit-cost ratio of 10 (increased production value is 10 times higher than the costs for additional fertilizer). Compared to the 6 g microfertilization method (using bottle caps) cost-benefit ratio of 0.3 g treatment is 8-20 times higher.

Ecological conditions

- Climate: semi-arid; rainy season: late June – middle of October
- Average annual rainfall: 400-800 mm
- Soil parameters: low fertility and low soil organic matter
- Slope: mainly flat (0-2%), partly gentle (2-5%)
- Landform: plains
- Altitude: 260 m a.s.l.

Socio-economic conditions

- Size of land per household: 2-20 ha
- Type of land user: small-scale / large-scale; poor, average and rich land users
- Population density: no data
- Land ownership: community
- Land use rights: individual / communal
- Level of mechanisation: mainly manual / partly animal traction
- Market orientation: mixed (subsistence and commercial)

Production / economic benefits

+++ Increased crop yield: combined effect of seed priming and microfertilization 50%, seed priming alone 25%
+++ Increased production of straw / biomass
++ Decreased financial resources needed for purchasing fertilizer, makes the technology feasible for poor small-scale farmers
++ Risk minimisation: decreased risk of crop failure; and low financial risk in the case of crop failure; seed priming reduces the risk of fertilizer application
++ No additional labour inputs (the technology does not significantly increase sowing time due to simultaneous application of seeds and fertilizer)
++ Increased land productivity / clearance of new land is avoided
+ Earlier harvest (food security)

Ecological benefits

+++ Reduced susceptibility to beginning-of-season droughts; less burning effect if drought after sowing
++ Reduced exposure of plants to droughts (compared to 6 g treatment)
++ Increased resistance to Striga (pest)

Socio-cultural benefits

+ Can be mechanised

Off-site benefits

+ Improved nutrition and both on-farm and off-farm employment

Weaknesses ➜ and how to overcome

- Dependence partly on availability of mineral fertilizer ➜ the technology should be combined with complementary methods for maintenance of soil fertility, such as increased recycling of crop residues as mulch and manure application.

Adoption

Trend for spontaneous adoption is high. Microfertilization has become a very popular technology in some area in Mali. Field officers from NGO's report that in some villages in the 'Dogon area' in the Mopti region more than 50% of the farmers are using the technology on their own initiative. NGOs working in the Mopti and Segou regions are currently actively promoting seed priming and microfertilization.

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Key references: Aune JB, Doumbia M, Berthe A (2007): Microfertilizing sorghum and pearl millet in Mali - Agronomic, economic and social feasibility in Outlook on AGRICULTURE Vol 36, No 3, 2007, pp 199–203 ■ Aune JB, Doumbia M, Berthe A (2005): Integrated Plant Nutrient Management Report 1998-2004; Drylands Coordination Group Report 36, Norway ■ Aune JB, Bationo A (2008): Agricultural intensification in the Sahel. Agricultural Systems 98: 119-125; ■ Habima, D. 2008. Drylands ecofarming: An analysis of ecological farming prototypes in two Sahelian zones: Koro and Bankass. M.Sc Thesis, UMN, Ås, Norway

GREEN MANURING WITH TITHONIA - CAMEROON

Tithonia diversifolia hedges grow along roadsides or farm boundaries. The green leaf biomass is very suitable as green manure for annual crops, since the plant has a high content of nitrogen and phosphorus, and decomposes quickly after application to the soil: its nutrients are released within one growing season.
At an early stage of plant growth, fresh green leaves and stems are cut, chopped and applied on the cropland as green manure after the first pass of ridging. The fresh material is spread over the half-made ridges at a rate of 2 kg per m^2 and then covered with about 5-10 cm of soil to finish the ridges. Sowing of crop seeds is done only after a week or more, because of heat generation during the decomposition process of the leaves (which could damage the seeds).
Tithonia biomass enhances soil organic matter and soil fertility, resulting in higher crop yields. The treatment supplies the crop with nutrients at the early stage of the growing process, and thus improves the establishment of the crops through the early development of a good rooting system. The technology is especially beneficial for maize: yields in the study area increased by over 50%.
Tithonia can also be applied as mulch 6 to 8 weeks after planting the crop. Covering the mulch with a little soil facilitates nutrient release. Tithonia green manuring - before planting - and mulching can be combined, which is especially applicable to maize, beans and cabbage cultivation. Tithonia hedgerows have to be cut back regularly; otherwise it can spread fast and become a weed. Interplanting Tithonia in the field is not recommended due to root competition with crops.

SLM measure	Agronomic
SLM group	Integrated Soil Fertility Management
Land use type	Annual cropping
Degradation addressed	Soil fertility decline and reduced organic matter content
Stage of intervention	Mitigation and prevention
Tolerance to climatic change	No data

Establishment activities

1. Planting Tithonia along farm / field boundaries and along roadsides (if not growing naturally).

Maintenance / recurrent activities

1. Regular cutting of Tithonia plants: cutting back hedges in the dry season (Dec./Jan.) ensures that fresh material can be harvested from March to May.
2. Collect any organic material on the cropland and place it in the furrows of the previous cropping season (which will become the ridges of the new cropping season) in February.
3. Harvesting and chopping green leaves and stems of Tithonia (March-May).
4. Transport to farm and spread fresh Tithonia material on half-done ridges; and cover with earth.
5. Let decompose the green manure for at least 1 week before sowing the crops.
6. Apply a mulch layer of fresh Tithonia material (6-8 weeks after sowing; optional).

All activities carried out manually (using cutlasses and hoes). Cutting back is done annually, harvesting and spreading 1-2 times a year.

Labour requirements

For establishment: low
For maintenance: high

Knowledge requirements

For advisors: moderate
For land users: moderate

Photo 1: Effects of applying *Tithonia diversifolia*: cocoyam with green manure (left ridge) and cocoyam without green manure (right ridge).
Photo 2: Application of organic material to build ridges for the next cropping season.
Photo 3: Hedge of *Tithonia diversifolia*, known also as Mexican sunflower. (All photos by Fabienne Thomas)

Case study area: Akiri, North-West Province, Cameroon

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	–
Equipment	–
Agricultural Inputs	–
TOTAL	**no data**

Remarks: Costs for planting Tithonia along farm / field boundaries and along roadsides (if not growing naturally) are not known.

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 6 person-days	80
Equipment / tools: planting stick / hoe	30
Agricultural inputs: 47 kg superphosphate fertilizer	0
TOTAL	**110**
% of costs borne by land users	100%

Remarks: Labour costs are the main factor affecting the costs. Labour inputs depend a lot on transport distance between Tithonia hedge and cropland.

Benefit-cost ratio

Inputs	short term	long term
Establishment	na	na
Maintenance	positive	positive

Remarks: The closer to the field Tithonia is planted, the better is the benefit-cost ratio.

Ecological conditions

- Climate: subhumid
- Average annual rainfall: mainly 2,000-3,000 mm, partly 1,500-2,000 mm; rainy season mid March – mid October
- Soil parameters: medium fertility, medium soil organic matter, medium drainage
- Slope: mainly hilly (16-30%), partly mountain slopes (30-60%)
- Landform: hill and mountain slopes
- Altitude: 1,000-1,500 m a.s.l.

Socio-economic conditions

- Size of land per household: mainly 1-2 ha, partly 2-5 ha
- Type of land user: poor small-scale farmers
- Population density: 70-100 persons/km^2
- Land ownership: individual
- Land use rights: individual
- Market orientation: mainly subsistence, partly mixed (subsistence and commercial)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased crop yield (over 50%, especially beneficial for maize)
\+ Increased farm income
\+ Cheap fertilizer

Ecological benefits

++ Increased soil fertility
\+ Increased soil moisture
\+ Improved soil cover
\+ Windbreak

Socio-cultural benefits

\+ Improved knowledge about green manure
\+ Health: Tithonia has also a medicinal use (anti-inflammatory effect)
\+ Life barrier: hedges avoid uncontrolled entering of cattle into cropland

Weaknesses ➜ and how to overcome

- Can spread as a weed on cropland (if planted close to fields) and also outside the area where it is used; some farmers consider the plant as poisonous ➜ advisory service is important, good information on proper management of Tithonia; regular cutting.
- Labour-intensive technology (harvest, transport, regular cutting, chopping and spreading) ➜ providing / subsidising transport equipment such as wheelbarrows would make transport more effective and time-saving.
- Might lead to conflicts if too many farmers want to use it ➜ clarify user rights; replant Tithonia plants and grow new hedges.

Adoption

There is a strong trend towards spontaneous adoption. In the villages where the technology has been implemented the interest of other farmers is big. All land users in the case study area have adopted the technology without any external support. Total area of land treated with the technology in the case study area is 0.3 km^2.

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Key references: WOCAT. 2004. WOCAT database on SLM Technologies, www.wocat.net ■ Thomas F. 2005. Agroökologische Innovationen am Beispiel der Nutzung von Tithonia diversifolia (Mexican Sunflower) zur nachhaltigen Verbesserung der Nahrungsmittelsicherheit. Diplomarbeit. Departement für Geowissenschaften – Geographie Universität Freiburg.

COMPOST PRODUCTION - BURKINA FASO

Compost is produced in shallow pits, approximately 20 cm deep and 1.5 m by 3 m wide. During the dry season after harvesting, layers of chopped crop residues, animal dung and ash are heaped, as they become available, up to 1.5 m high and watered. The pile is covered with straw and left to heat up and decompose. After 15–20 days the compost is turned over into a second pile and watered again. This is repeated up to three times – as long as water is available. Compost heaps are usually located close to the homestead. Alternatively, compost can be produced in pits up to 1 m deep. Organic material is filled to ground level. The pit captures rain water, which makes this method of composting a valuable option in dry areas.

The compost is either applied immediately to irrigated gardens, or kept in a dry shaded place for the next sorghum seeding. In the latter case one handful of compost is mixed with loose soil in each planting pit (*zai*). Compost in the pits conserves water and supplies nutrients. This enables the sorghum plants to establish better, grow faster and reach maturity before the rains finish. Vulnerability to droughts and risk of crop failure is reduced.

As compost is applied locally to the crop, not only is the positive effect maximised, but the weeds between the pits do not benefit either. It is the high water retaining capacity of the compost that makes the main difference, and is much more important than the additional nutrients, which only become available in subsequent years, and do not completely replace all the nutrients extracted by the crops. During the dry season, after harvest, fields are grazed by cattle of the nomadic pastoral *Peuhl*, who also herd the agriculturalists' livestock.

SLM measure	Agronomic
SLM group	Integrated Soil Fertility Management
Land use type	Mixed: agropastoral
Degradation addressed	Fertility decline; Erosion by water; Soil moisture problem; Compaction and crusting
Stage of intervention	Mitigation and rehabilitation
Tolerance to climate change	No data

Establishment activities

1. Dig two compost pits (3 m by 1.5 m and 20 cm deep) at the beginning of the dry season (November).
2. Cover the bottom of each pit with 3 cm clay layer.

Duration of establishment: 1 week

Maintenance / recurrent activities

1. Put 20 cm layer of chopped crop residues (cereal straw) into the compost pit and water with one bucket (November).
2. Add 5 cm layer of animal manure.
3. Add 1 cm layer of ash.
4. Repeat steps 1–3 until the compost pile is 1.0–1.5 m high.
5. Cover pile with straw to reduce evaporation, and leave to decompose. Check heating process within the heap by inserting a stick.
6. Turn compost after 15 days into the 2nd pit, then after another 15 days back into the 1st pit. Turning over is done up to 3 times (as long as water is available).
7. Water the pile after each turning with 3 buckets of water.
8. Store ready compost in dry shady place (January).
9. Transport compost to the fields by wheelbarrow or donkey-cart (before onset of rains) and apply a handful per planting pit before planting (after the first rains).

Labour requirements

For establishment: low
For maintenance: medium

Knowledge requirements

For advisors: moderate
For land users: low

Photo 1: Application of one handful of compost in planting pits. (William Critchley)
Photo 2: Sorghum yields with and without compost application. (Reynold Chatelain)
Photo 3: Compost pits with low containing walls: Pit compost requires little or no additional water and is preferable in dry zones. (William Critchley)

Case study area: Boulgou Province, Burkina Faso

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 2 person-days	2
Equipment: hoe, digging stick, bucket	10
Construction material: clay (0.5 m³)	0
TOTAL	**12**
% of costs borne by land users	100%

Remarks: Establishment costs are for two pits which are needed to manure one hectare.

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 20 person-days	20
Equipment: wheelbarrow renting	6
Agricultural inputs: manure (100 kg)	2
Material: ash, straw	0
Compost transportation	2
TOTAL	**30**
% of costs borne by land users	100%

Remarks: Costs relate to production and application of 1 tonne of compost per ha (the product of one full compost pit). The compost is directly applied to planting pits at a rate of 7–10 t/ha (equal to actual rates applied in small irrigated gardens). If compost is produced in deep pits, production is cheaper because there is less work involved.

Benefit-cost ratio

Inputs	short term	long term
Establishment	very positive	very positive
Maintenance	very positive	very positive

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 750-1,000 mm (partly 500-750 mm)
- Soil parameters: fertility is mainly low, partly medium; depth is 50-80 cm; partly 20-50 cm; drainage is mainly poor, partly medium; organic matter content is low and further decreasing; soil texture is mainly clay, partly sandy (in depressions)
- Slope: mainly gentle (2-5%), partly moderate (5-8%)
- Landform: plains / plateaus
- Altitude: 100-500 m a.s.l.

Socio-economic conditions

- Size of land per household: < 1 ha or 1-2 ha
- Type of land user: small-scale; poor
- Population density: no data
- Land ownership: communal / village
- Land use rights: communal (organised)
- Level of mechanisation: manual labour
- Market orientation: mainly subsistence (self-supply), in good years mixed (subsistence and commercial)

Production / economic benefits

+++ Increased crop yield
+++ Increased farm income (by several times in dry years, compared to no compost use)
++ Increased fodder production and fodder quality

Ecological benefits

+++ Increased soil moisture
++ Increased soil fertility
++ Improved soil cover
++ Efficiency of excess water drainage
+ Reduced soil loss

Socio-cultural benefits

+ Community institution strengthening
++ Improved conservation/ erosion knowledge
++ Integration of agriculturalists and pastoralists

Weaknesses ➜ and how to overcome

- The modest quantity of compost applied is not enough to replace the nutrients extracted by the crops in the long term ➜ small amounts of nitrogen and phosphorous fertilizer need to be added and crop rotation practised.
- The short / medium term local benefits are not associated with a positive overall, long term ecological impact because there is a net transfer of organic matter (manure) to the fields from the surroundings ➜ improve management of the vegetation outside the cropland, avoiding overgrazing etc. to increase manure production.
- Needs considerable water and thus also extra-labour ➜ pit composting helps to reduce water requirement in drier areas and at the same time reduces labour input.

Adoption

Composting has been applied in Boulgou Province of Burkina Faso since 1988. 5,000 families adopted the technology (without external incentives), total area of manured fields is 200 km². Even some pastoralists use it in their gardens. There is a strong trend towards growing spontaneous adoption, with extension from farmer to farmer. The pastoral *Peuhl* have started to systematically collect the manure for sale, since the increased demand for manure in composting has led to doubling of the price.

Main contributors: Jean Pascal Etienne de Pury, CEAS Neuchâtel, Switzerland; www.ceas.ch

Key references: WOCAT. 2004. WOCAT database on SLM Technologies, www.wocat.net ■ Ouedraogo E. 1992. Influence d'un amendement de compost sur sol ferrugineux tropicaux en milieu paysan. Impact sur la production de sorgho à Zabré en 1992. Mémoire de diplôme. CEAS Neuchâtel, Switzerland ■ Zougmore R., Bonzi M., et Zida Z. 2000. Etalonnage des unités locales de mesures pour le compostage en fosse de type unique étanche durable. Fiche technique de quantification des matériaux de compostage, 4pp

PRECISION CONSERVATION AGRICULTURE - ZIMBABWE

Precision Conservation Agriculture (PCA) is a combined technology that encompasses four basic principles: (1) minimum tillage – use of small planting basins which enhance the capture of water from the first rains and allow efficient application of limited nutrient resources with limited labour input; (2) the precision application of small doses of nitrogen-based fertilizer (from organic and / or inorganic sources) to achieve higher nutrient efficiency; (3) combination of improved fertility with improved seed for higher productivity; and (4) use of available residues to create a mulch cover that reduces evaporation losses and weed growth.
Crop mixes are adapted to the local conditions and household resource constraints. Cereal / legume rotations are desirable. PCA spreads labour for land preparation over the dry season and encourages more timely planting, resulting in a reduction of peak labour loads at planting, higher productivity and incomes. Over four years these simple technologies have consistently increased average yields by 50 to 200%, depending on rainfall regime, soil types and fertility, and market access. More than 50,000 farm households apply the technology in Zimbabwe.
PCA strategies are promoted by ICRISAT, FAO and NGOs in Southern Africa focusing on low potential zones with the most resource-poor and vulnerable farm households.

SLM measure	Agronomic
SLM group	Combined: Integrated Soil Fertility Management and Conservation Agriculture
Land use type	Annual cropping (cereals)
Degradation addressed	Soil fertility decline and reduced organic matter; Soil erosion by water; Sealing and crusting
Stage of intervention	Prevention and mitigation
Tolerance to climate change	Increased resilience to droughts

Establishment activities

Note: PCA is based on agronomic measures which are carried out repeatedly each cropping season. All activities are listed under maintenance / recurrent activities (below). There is no establishment phase (as defined by WOCAT).

Maintenance / recurrent activities

1. Spreading residues (after harvesting).
2. Winter weeding.
3. Land preparation: mark out basins using planting lines and dig planting basins (dry season).
4. Application of available fertilizer: manure at a rate of a handful per planting basin (1,500-2,500 kg/ha) and micro-doses of basal fertilizer at a rate of 1 level beer bottle cap per pit (92.5 kg/ha); cover lightly with clod-free soil (soon after land preparation).
5. Planting at onset of rains; cover seed with clod-free soil.
6. First weeding when weeds appear.
7. Second Weeding (Dec.-Jan.; when cereals are at 5 to 6 leaf stage).
8. Apply micro-dose of top dress fertilizer (Ammonium Nitrate) at a rate of 1 level beer bottle cap per basin (83.5 kg/ha) (cereals at 5 to 6 leaf stage).
9. Third weeding.
10. Harvesting.

Hand hoes, planting lines marked at appropriate spacings.

Labour requirements

For establishment: high
For maintenance: medium to low

Knowledge requirements

For advisors: high
For land users: high

Photo 1: Excavation of planting pits (Dimensions: 15 cm by 15 cm by 15 cm; Spacing: varies between 60 – 90 cm, depending on average rainfall).
Photo 2: Mulch cover on planting pits.
Photo 3: Application of a micro-dose of basal fertilizer (a compound applied prior to planting in the bottom of the planting pit).
Photo 4: Application of a handful of organic manure.
Photo 5: Application of micro-dose of top dressing.
(All photos by ICRISAT)

Case study area: Bulawayo, Zimbabwe

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	0
Equipment	0
Agricultural inputs	0
TOTAL	**0**

No establishment costs.

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 124 person-days	108
Equipment: hand hoes	7
Agricultural inputs: fertilizer	69
TOTAL	**184**
% of costs borne by land users	no data

Remarks: Labour costs do not include harvesting (8 person-days/ha). Initially, fertilizers were partly subsidised by project, at a later stage farmers purchased more as they increased the area and became more self-reliant. Most households start applying chemical fertilizer from the 2nd year on (at least 1 bag).

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	positive	very positive

Remarks: Initial results suggest a cost-benefit ratio of US$ 3.5 per US$ invested. Returns to labor have been about two times higher than conventional practices.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 450-950 mm
- Soil parameters: low fertility, medium depth, good drainage, low organic matter content
- Slope: average slope is 1-7%
- Landform: plains, footslopes
- Altitude: 500-1,500 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-3 ha
- Type of land user: small-scale; poor / average level of wealth
- Population density: 10-50 persons/km^2
- Land ownership: communal (not titled)
- Land use rights: communal
- Market orientation: subsistence
- Level of mechanisation: manual labour / animal traction
- Opportunity to introduce commercial crops as part of the rotation if market access developed

Production / economic benefits

+++ Increased crop yield (400 kg/ha before, 1520 kg/ha after; increase varies between 50-200%)
+++ Increased fodder production (600 kg/ha before, 2200 kg/ha after)
+++ Increased farm income
+++ Increased product diversification
++ Reduced risk of production failure

Ecological benefits

++ Increased water quality
++ Increased soil moisture and reduced evaporation
++ Increased soil organic matter
++ Increased beneficial species
+ Weed control (timely weeding in combination with mulching)
+ Improved soil cover

Socio-cultural benefits

+++ Communities institution strengthening
+++ Improved situation of socially and economically disadvantaged groups (gender, age, status, ethnicity etc.)
+++ Improved food security / self-sufficiency (household meets food needs from less land)

Weaknesses ➜ and how to overcome

- Availability of residues and willingness to use as mulch ➜ long term demonstrations required.
- Access to basal and top dress fertilizers ➜ input market development and identification of enabling government policies. If the access to nitrogen fertilizer can be improved there is a great chance that households will move from a food insecure state to one of surplus.
- Lack of rotations and legumes poorly adopted ➜ increase access to quality legume seeds and develop output markets.

Adoption

5% of land users have applied the SLM technology. There is evidence of spontaneous adoption, with more than 50,000 households with at least 0.3 ha of basins in 2008. The average area per household increased from 1,500 m^2 in 2004 to more than 3,500 m^2 in 2008.

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Key references: Hove L, Twomlow S. 2008. Is conservation agriculture an option for vulnerable households in Southern Africa? Paper presented at the Conservation Agriculture for Sustainable Land Management to Improve the Livelihood of People in Dry Areas Workshop, United Nations Food and Agricultural Organization, 7-9 May, 2007. Damascus, Syria ■ Mazvimavi K., and S. Twomlow. 2009. Socioeconomic and institutional factors influencing adoption of conservation farming by vulnerable households in Zimbabwe. Agricultural Systems, 101 (1), p.20-29 ■ Pedzisa I., I. Minde, and S.Twomlow. 2010. An evaluation of the use of participatory processes in wide-scale dissemination of research in micro dosing and conservation agriculture in Zimbabwe. Research Evaluation, 19(2). ■ Twomlow S., J. Urolov, J.C. Oldrieve, B. Jenrich M. 2008. Lessons from the Field Zimbabwe's Conservation Agriculture Task Force. Journal of SAT Agricultural Research, 6.


Farmer explaining the difference between conventional tillage (left) and conservation tillage (right), Kenya. (Hanspeter Liniger)

In a nutshell

Definition: 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. 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 spread in 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; will cut fossil fuel needs through reduced machine use; will decrease agrochemical contamination of the environment through reduced reliance on mineral fertilizers; and will 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.

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	na
Improving non wood forest production	na
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 storms	+
Resilience to rising temperatures and evaporation rates	++
Reducing risk of production failure	+

** change from conventional tillage to no-till, carbon restored can be expected to peak after 5 to 10 years with SOC reaching a new equilibrium in 15 to 20 years (Source: West and Post, 2002 in Woodfine, 2009).*

Origin and spread

Origin: Through research activities and the development of herbicides and direct seeding equipment, no-till practices started spreading in the 1970s from the Americas and Australia to the rest of the world. In Sub-Saharan Africa, CA was introduced in the 1980s by research projects, and further developed and spread through the initiative of large-scale farmers. It must not be forgotten, however, that many traditional forms of farming in SSA (very shallow tillage with hand hoes for example) can be considered within the CA 'family'.
Mainly applied in: South Africa (2% of arable area), Zambia (0.8%), Kenya (0.3%), Mozambique (0.2%), Madagascar (0.1%)
Also applied in: Benin, Botswana, Burkina Faso, Cameroon, Ivory Coast, Ethiopia, Eritrea, Ghana, Lesotho, Malawi, Mali, Namibia, Niger, Nigeria, Sudan, Swaziland, Tanzania, Uganda and Zimbabwe

Spread of conservation agriculture in SSA.

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 build up 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 – and this has two positive effects: first, there is more water to support crop growth and the biological activity that is so important for productivity, and second, less water accumulates and thus doesn't flow across the surface, causing floods and erosion.
Seeding is done directly through the mulch (usually residues of previous crops), or cover crop (specially grown legumes). 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 hard pans 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 run-off 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 goes against tradition and dietary preference. One solution is inter-cropping 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, in other words there need to be trade-offs. This implies being flexible regarding soil cover and crop rotation, and emphasizing the role of water harvesting in dry regions.

Top: Training on the use of a jab planter for direct seeding, Burkina Faso. (John Ashburner)
Middle: Direct seeding with special animal traction equipment, Zambia. (Josef Kienzle)
Bottom: A no-till seeder at work on a large-scale farm in Cameroon. (Josef Kienzle)

Applicability

Land degradation addressed

Physical soil deterioration: reduction in soil's capacity to absorb and hold water due to degradation of soil structure (sealing, crusting, compaction, pulverization) in drought-prone situations
Water degradation: aridification due to runoff and evaporation loss
Chemical soil deterioration and biological degradation: reduction in soil organic matter and fertility decline due to soil loss and nutrient mining, reduction of biodiversity and pest risk (in tropical and subtropical conditions)
Erosion by water and wind

Land use

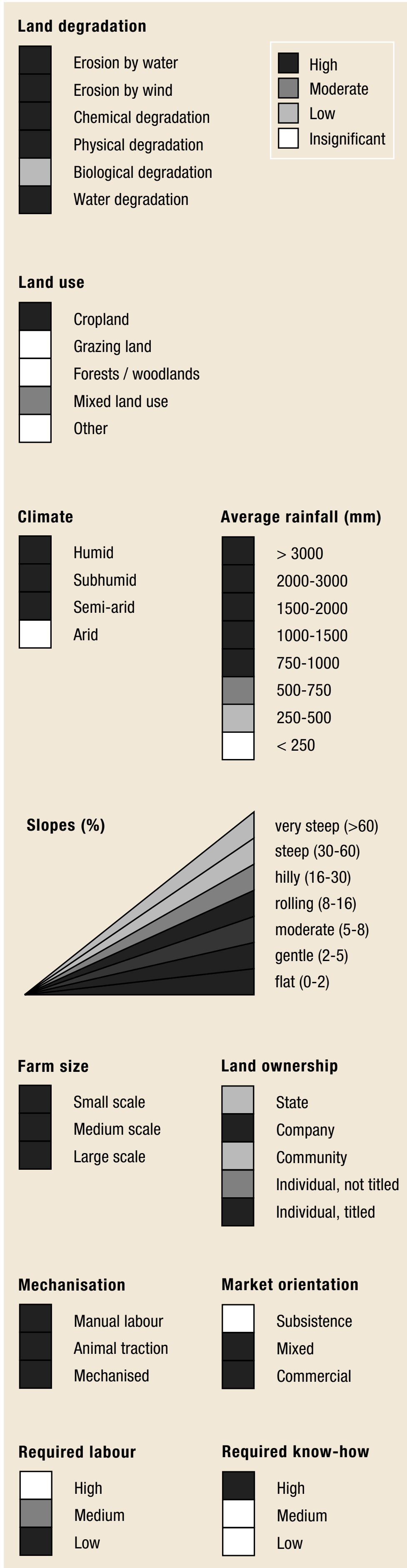
Suitable for rainfed agriculture and irrigated systems (including those in semi-arid areas).
Mainly used for annual crops: cereals (maize, sorghum), with legume cover crops (mucuna, lablab, cowpea etc.), cotton; vegetables (e.g. onions) and some perennial / plantation crops and tree crops (e.g. coffee, orchard fruits, vineyards). Also used on mixed crop / livestock systems (but competition for plant residues reduces ground cover and organic matter restoration unless alternative fodder is grown).
Although CA is often not considered to be suitable for root crops, recent studies have shown that it can be used for crops such as beet and cassava since their roots grow more evenly and, due to the better structured soil, the soil sticking to the roots is reduced. CA can be also suitable for potatoes, if sufficient mulching material is provided to protect the potatoes from sunlight. Nevertheless harvest disturbs the soil in contrast to grain crops.

Ecological conditions

Climate: CA is suitable for all climates, although its specific benefits become more pronounced in unfavourable climates, such as semi-arid zones: it is most effective where low or uneven rainfall limits crop production. CA is also suitable for subhumid and humid climates: such as the moist savanna of West Africa and part of the East African highlands. The technology has specific challenges in arid climates, however, it still performs better than tillage-based alternatives, given adequate mulch.
Terrain and landscape: Suitable for flat to moderate slopes, mechanised systems are unsuitable for slopes steeper than 16%, but hand planters are suitable for steeper slopes. Mainly applied on plateaus and valley floors. Due to the reduced runoff and erosion it is particularly suitable for steeper slopes (under manual or animal traction), where crops are grown under these conditions.
Soils: Suitable for sandy loams to clay loams, but unsuitable for compacted hard soils or those at risk of waterlogging (poorly drained), shallow soils. Compaction due to previous tillage can be dealt with through sub-soiling.

Socio-economic conditions

Farming system and level of mechanisation: can be applied at all farm scales and implemented with different levels of mechanisation. Until recently there has been little emphasis on extending CA to the small-scale level.
Small-scale farms: hand or animal (oxen) draft implements such as animal (or sometimes tractor) drawn ripper, and ripper planter; hand jab planters for manual systems, etc.
Large-scale farms: direct seed drill, knife roller, sprayer, etc. with substantial reduction in time and energy use for tillage operations.
Market orientation: suitable for subsistence or commercial systems; access to markets is important to sell surplus and to purchase inputs.
Land ownership and land use / water rights: some communally-owned lands lack security of tenure and hence render land users reluctant to practise and invest in the shift to conservation agriculture.
Skill / knowledge requirements: medium to high for land users, extension agents and technical staff (rotations / crop sequence, planting dates, weed control / use of herbicides).
Labour requirements: significantly reduced (by 10% to more than 50%) compared to conventional tillage (reduced hired labour costs, family labour ➜ more time available for other activities).

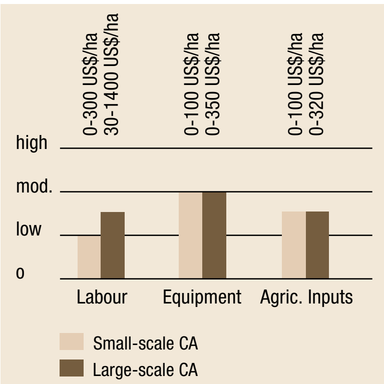


Economics

Establishment and maintenance costs

Establishment costs: CA requires substantial initial investment. Initial costs are mainly related to the acquisition of new machinery and tools. The range of the costs can be very wide – from nothing (in case of the hand-based planting pit method) to high (in case of specific no-till seeders); input levels depend on the production intensity and can be low to high, but decrease over time.

Maintenance costs: On small-scale farms the labour requirements for maintenance are usually higher at the beginning due to the burden of weeding. Compared to conventional practices, the overall workload significantly decreases - by up to 50%. Agricultural input requirements are mainly cover crop seeds and (where appropriate) herbicides for controlling weeds. On large-scale farms the maintenance costs of the machines and tractor(s) significantly decrease by eliminating farming operations like ploughing, harrowing and by reducing weeding.



(Source: WOCAT, 2009)

Production benefits

	Yield without SLM (t/ha)	Yield with SLM (t/ha)	Yield gain (%)
Ghana: Maize	0.75-1.8 (Slash-and-burn)	2.7-3.0 (Minimum tillage, direct planting)	150-400%
Kenya: Wheat Maize	 1.3-1.8 1.3-2.2	 3.3-3.6 3.3-4.5	 100-150% 100-150%
Tanzania: Maize Sunflower	 1.13-1.5 0.63-0.75	 2.25-2.9 1.5-2.7	 93-100% 140-360%

(Source: Kaumbutho and Kienzle, 2007; Boahen et al., 2007; Shetto and Owenya, 2007)

Comment: Yield increase can vary widely – mostly an initial yield increase of 10-20% is observed if all other conditions remain the same; if CA introduction comes with ripping / sub-soiling and fertilizer use, a 100% increase can eventually be observed. Only after 4-5 years of continued application of CA can a significant increase in crop yield be recorded. The ecosystem requires a number of years to adjust.

Benefit-Cost ratio

	short term	long term	quantitative
Minimum tillage and direct planting	+(+)	+++	Labour returns (Ghana): 9.2 US$/ work hour (*under conventional tillage: 5.4 US$/ work hour*)
Conservation agriculture	+(+)	+++	Profit range (Kenya): 432-528 US$/ ha (for wheat) (*under conventional tillage: 158-264 US$/ ha*)

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive
(Source: WOCAT, 2009; Kaumbutho and Kienzle, 2007; Boahen et al., 2007).

Comment: The short term benefit-cost ratio is mainly affected by the initial cost of purchasing new machinery and tools.

Example: Ghana
A study conducted on the impact of no-till in Ghana has shown a significant reduction of labour. No-till reduced labour requirements for land preparation and planting by 22%. Labour for weed control fell by 51%, 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 percent 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).

Example: 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 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 (FAO, 2007).

Example: Tanzania and Kenya
The CA project under Sustainable Agriculture and Rural Development (SARD) introduced the concept of conservation agriculture in rural areas of northern Tanzania and in western and central regions of Kenya. Through participatory assessments it was found that the net financial benefits could be higher under CA than under conventional tillage, mainly due to reduced workload / time, smaller amount and cost of fertilizer required to maintain yields, and reduced energy fuel costs for tillage and spraying operations (FAO, 2008).

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	+++ increased yield stability (mainly rainfed areas and in dry years) ++ increased crop yields + production diversification	++ reduced damage to neighbouring fields ++ reduced risk and loss of production + access to clean drinking water	+++ improved food and water security
Economic	+++ increased farm income / profitability (mainly long term) +(+) savings in labour / time (small-scale: only over the long term) +(+) lower farm inputs (fuel, machinery cost and repairs, fertilizer)	++ economic growth stimulation ++ diversification and rural employment creation (e.g. small manufacturing units) ++ less damage to off-site infrastructure	+++ improved livelihood and well-being
Ecological	+++ improved soil cover +++ improved water availability / soil moisture +++ improved soil structure (long term) ++ improved micro-climate / reduced evaporation ++ reduced soil erosion (by water / wind) ++ reduced surface runoff ++ increased organic matter / soil fertility ++ enhanced biodiversity / biotic activity (long term)	++ reduced degradation and sedimentation in rivers, dams and irrigation systems ++ improved recharge of aquifers, more regular water flow in rivers / streams + enhanced water availability + enhanced water quality + intact ecosystem	++ reduced desertification incidence and intensity ++ increased resilience to climate change ++ increased C sequestration + reduced C emissions + enhanced biodiversity
Socio-cultural	++ improved SLM / conservation / erosion knowledge + changing the traditional gender roles of men and women +/- changed cultural and traditional norms (e.g. no more burning of crop residues)	+ increased awareness for environmental 'health' + attractive landscape	+ protecting national heritage

	Constraints	How to overcome
Production	• Low biomass production (for cover) in low precipitation areas and short growing seasons • Scarcity of particular plant nutrients in humid areas due to high and fast decomposition rate (especially P)	➜ 'African adapted' CA: reduce the mulch requirement, focus on no-tillage methods (including traditional low-till systems such as *zaï* planting pits), promote efficient use of organic fertilizers, better water management, e.g. planting basins ➜ relieve deficiency by use of inorganic / organic (higher biological activity) fertilization
Economic	• Needs initial capital investment for adapted machinery and small scale equipment • External input constraints: fertilizers, cover crop seeds, herbi cides, etc. (availability, access and costs) • Availability and access to equipment on local markets • Low capacity of local manufacturers of hand / animal-driven CA equipment • Labour constraints for hand weeding (availability and costs in first years)	➜ introduce and allow access (availability and costs) to appropriate conservation equipment (tested and adapted); ability to hire or share equipment and services ➜ in some countries small clusters for production and distribution of CA equipment already exists ➜ need further support and investment ➜ change weeding practice to 'shallow weeding' or chopping and the positive long term benefits of adoption CA needs to be recognised
Ecological	• Competition between soil cover and livestock feed (how to integrate livestock and mixed cropping smallholdings) • Weed control in the early years of adoption • Crop residues on the surface may favour disease and pests (micro-climate) • Compacted soils require prior sub-soiling	➜ stall-feeding, unpalatable cover crops, link CA with intensive live-stock production ➜ flatten cover crop using e.g. knife roller, machete or grass-whip or spray with a herbicide ➜ shallow manual weed control, use of herbicides, keep soils covered by mulch to suppress weeds ➜ adapt and improve crop rotations, pest management
Socio-cultural	• Uncertain land use rights • Lack of laws and regulations for communal grazing • Lack of supporting policies and implementing institutions • Poorly developed infrastructure / restricted access to markets, • Requires information, locally specific knowledge, technical skills and innovation to find the most suitable system • Difficult to introduce crop rotations on small portions of land (half a hectare or less) • 'Project' approach to piloting CA (short time frames, availability of support, limited lead-time for institutionalising CA into existing insti-tutions and policies	➜ secure access to land ➜ enclosures, controlled grazing and residue-friendly management; communal by-laws on grazing ➜ well informed advisory service is necessary to provide training and share knowledge; the technology is flexible and allows multiple options

Adoption and upscaling

Adoption rate

Despite good quality and lengthy research only slow adoption of CA in SSA, but with an increasing trend in recent years (in South Africa, from 0% in 1988 to about 2% in 2007 of which the large majority in commercial lands). Farmers often adopt only certain components of CA (i.e. 'African-style CA').

Upscaling

Secure land use rights are a prerequisite for small-scale land users to invest in CA.
Immediate benefits must be seen by the land users to take the investment risk.
Training and capacity building: Good technical support to all stakeholders is needed. Training should include practical training, introduction of appropriate equipment and its maintenance, education on animal health and care.
Successful and innovative participatory learning approaches are needed such as Farmer Field Schools and the formation of common interest groups for strengthening knowledge about CA principles.
Farm inputs for CA such as adequate machinery, tools and herbicides need to be available and accessible to small-scale farmers for adoption of the system. Effective market systems and supply chains must be developed for producing CA equipment and other inputs for smallholders.
Disseminate knowledge: Agricultural machinery producers and agricultural, as well as political, advisors are heavily involved in developing and disseminating knowledge, advising farmers, providing relevant services or shaping local or national policies.

Incentives for adoption

Very often external support for small-scale farmers is needed in the form of credit / loans mainly for purchase of equipment, food-for-work (in emergencies), direct payments by project or government e.g. for inputs (agricultural seeds, fertilizers, etc.).

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	++
Training and education	++
Land tenure, secure land use rights	++
Access to markets	++
Research	++

Example: FAO's Emergency Programmes, Swaziland
The FAO's Emergency Programme in Swaziland has trained about 800 land users, plus advisory and other staff over six years. There is now a demand for farmers in Shewala for expansion of CA as they recognize it as 'the most sustainable way to produce food'. Important requirements for successful implementation in Swaziland are among others: a) an agreed plan to implement CA involving all stakeholders i.e. land users, extension staff, etc., b) field research comparing CA to conventional tillage, c) policy support, d) sustained and practical training for extension and research staff and for land users, e) common understanding with livestock owners, f) supply of quality seeds, g) supply of CA tools and equipment, and h) need for good farm management including timely planting, weeding, etc. (FAO, 2008).

References and supporting information:

Baudeon F., H.M. Mwanza, B. Triomphe, M. Bwalya. 2007. Conservation agriculture in Zambia: a case study of Southern Province. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations.

Baudron F., H.M. Mwanza, B. Triomphe, M. Bwalya and D. Gumbo. 2006. Challenges for the adoption of Conservation Agriculture by smallholders in semi-arid Zambia. Online: www.relma.org.

Boahen P, B.A. Dartey, G.D. Dogbe, E. A. Boadi, B. Triomphe, S. Daamgard-Larsen, J. Ashburner. 2007. Conservation agriculture as practised in Ghana. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations.

Bwalya, M. and M. Owenya. 2005. Soil and water Conservation to Conservation Agriculture Practices: experiences and lessons from the efforts Eotulelo Farmer Field School – a community based organisation. (http://www.sustainet.org/download/sustainet_publication_eafrica_part2.pdf).

Derpsch, R. 2008. No-Tillage and Conservation Agriculture: A Progress Report. In: No-Till Farming systems. 2008. Edited by Tom Goddard, Michael A. Zoebisch, Yantai Gan, Wyn Ellis, Alex Watson and Samran Sombatpanit, WASWC, 544 pp.

Ekboir, J., K. Boa and A.A. Dankyi. 2002. Impacts of No-Till Technologies in Ghana. Mexico D.F. CIMMYT.

FAO Aquastat. http://www.fao.org/nr/water/aquastat/data/query/results.html

FAO, 2002. Conservation Agriculture: Case studies in Latin America and Africa. Soils Bulletin 78.

FAO, 2005. Conservation Agriculture in Africa, A. Calegari, J. Ashburner, R. Fowler, Accra, Ghana

FAO. 2008. Investing in Sustainable Agricultural Intensification, the role of Conservation Agriculture. Part III – a framework for action. An international technical workshop investing in sustainable crop intensification: The case for improving soil health, FAO, Rome: 22-24 July 2008. Integrated Crop Management Vol. 6-2008.

Giller, K.E., E. Witter, M. Corbeels and P.Tittonell. 2009. Conservation agriculture and smallholder farming in Africa: The heretic's view. Field Crops Research.

GTZ Sustainet. 2006. Sustainable agriculture: A pathway out of poverty for East Africa's rural poor. Examples from Kenya and Tanzania. Deutsche Gesellschaft für Technische Zusammenarbeit, Eschborn.

Haggblade S., G. Tembo, and C. Donovan. 2004. Household Level Financial Incentives to Adoption of Conservation Agricultural Technologies in Africa. Working paper no. 9. Food security research project. Lusaka, zambia

Kaumbutho P. and J. Kienzle, eds. 2007. Conservation agriculture as practised in Kenya: two case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations.

Kaumbutho P., J. Kienzle, eds. 2007. Conservation agriculture as practised in Kenya: two case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations.

Mrabet, R. 2002. Stratification of soil aggregation and organic matter under conservation tillage systems in Africa, Soil & Tillage Research 66 (2002) 119–128

Nyende, P., A. Nyakuni, J.P. Opio, W. Odogola. 2007. Conservation agriculture: a Uganda case study. Nairobi. African Conservation Tillage Network, Centre de coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations.

RELMA. 2007.Wetting Africa's appetite. Conservation agriculture is turning rainfall into higher crop yields and catching on. RELMA Review Series No. 3. ICRAF, Nairobi.

Rockström, J., P. Kaumbutho, J. Mwalley, A. W. Nzabi, M. Temesgen, L. Mawenya, J. Barron, J. Mutua and S Damgaard-Larsen. 2009. Conservation Farming Strategies in East and Southern Africa: Yields and Rainwater Productivity from On-farm Action Research. Soil & Tillage Research 103 (2009) 23–32.

Shetto R., M. Owenya, eds. 2007. Conservation agriculture as practised in Tanzania: three case studies. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Food and Agriculture Organization of the United Nations.

West T.O. and W.M. Post. 2002. Soil organic carbon sequestration rates by tillage and crop rotation. A global data analysis. Soil Science Society of America Journal, 66. Available from: http://soil.scijournals.org/cgi/content/abstract/66/6/1930?etoc

WOCAT, 2009. WOCAT databases on SLM technologies and SLM approaches. www.wocat.net, accessed on 15 September 2009

Woodfine, A. 2009. Using sustainable land management practices to adapt to and mitigate climate change in Sub-Saharan Africa: resource guide version 1.0. TerrAfrica. www.terrafrica.org

SMALL-SCALE CONSERVATION TILLAGE - KENYA

Small-scale conservation tillage involves the use of ox-drawn ploughs, modified to rip the soil. An adaptation to the ordinary plough beam makes adjustment to different depths possible and turns it into a ripper. Ripping is performed in one pass, to a depth of 10 cm, after harvest. Deep ripping (subsoiling) with the same implement is done, when necessary, to break a plough pan and reaches depths of up to 30 cm.

Ripping increases water infiltration and reduces runoff. In contrast to conventional tillage, the soil is not inverted, thus leaving crop residues on the surface. As a result, the soil is less exposed and not so vulnerable to the impact of splash and sheet erosion, and water loss through evaporation and runoff. In well-ripped fields, rainfall from storms at the onset of the growing season is stored within the rooting zone, and is therefore available to the crop during subsequent drought spells. Ripping the soil during the dry season combined with a mulch cover reduces germination of weeds, leaving fields ready for planting. In case of stubborn weeds, pre-emergence herbicides are used for control.

Yields from small-scale conservation tillage can be more than 60% higher than under conventional ploughing. In addition, there are savings in terms of energy used for cultivation. Crops mature sooner under conservation tillage, because they can be planted earlier (under inversion tillage the soil first has to become moist before ploughing is done).

Earlier crop maturity means access to markets when prices are still high. There are various supportive technologies in use which can improve the effectiveness of the ripping, including (1) application of compost / manure to improve soil structure for better water storage; (2) cover crops (e.g. *Mucuna pruriens*) planted at the end of the season to prevent erosion, control weeds and improve soil quality; and (3) Agroforestry (mainly *Grevillea robusta* planted on the field or along field boundaries).

SLM measure	Agronomic
SLM group	Conservation Agriculture
Land use type	Annual cropping
Degradation addressed	Water degradation: soil moisture problem; Soil compaction; Loss of topsoil through water erosion
Stage of intervention	Mitigation
Tolerance to climate change	Increased tolerance to climatic extremes due to water conservation effect.

Establishment activities

Note: Conservation tillage is based on agronomic measures which are carried out repeatedly each cropping season. All activities are listed under maintenance / recurrent activities (below). There is no establishment phase (as defined by WOCAT).

Maintenance activities

1. Spreading of crop residue as mulch: up to 3 t/ha (before planting, dry season).
2. Application of compost / household waste: up to 4 t/ha.
3. Ripping of soil with modified plough (dry season) to a depth of 10 cm, spacing between rip lines is 20-30 cm.
4. Subsoiling: every 3 years; or as required to break a plough pan.
5. Seeding and application of mineral fertilizer (nitrogen, phosphorus) at the rate of 20 kg/ha, close to seed.
6. Legume interplanting (*Dolichos lablab*) into the cereal crop (supplementary measure): Dolichos needs replanting every 3 years.

All activities are carried out using animal traction, mulching done manually. Equipment / tools: pair of oxen, modified 'Victory' plough beam, plough unit, ripper / chisel (tindo) used for ripping / deep ripping.

Labour requirements

For establishment: medium (initially high for weeding, decreasing with years)

For maintenance: low (compared to conventional tillage)

Knowledge requirements

For advisors: moderate

For land users: moderate

Photo 1: Demonstration of conservation tillage through shallow ripping of soil using draught animals. (Hanspeter Liniger)
Photo 2 and 3: 'Victory' ploughs modified into ripper by replacing the plough blade by a metal tine to provide extra penetration. (Hanspeter Liniger and Frederick Kihara)

Case study area: Umande, Laikipia District, Kenya

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	0
Equipment	0
Agricultural inputs	0
TOTAL	**0**

No establishment costs.

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 3-5 person-days	25
Equipment	0
Agricultural inputs: seeds (50 kg), fertilizer (20 kg), compost / manure (4,000 kg)	68
TOTAL	**93**
% of costs borne by land users	100%

Remarks: Cost calculated charges for hiring equipment, draught animals and operator: these are all rolled up into the 'cost of labour' at US$ 25/ha. Conventional tillage costs US$ 37.5/ha compared with US$ 25/ha for conservation tillage operations: other costs remain more or less the same.

Benefit-cost ratio

Inputs	short term	long term
Establishment	na	na
Maintenance	positive	very positive

Remarks: Initial investments can be high (purchasing of new equipment). Costs decrease in the long term and benefits increase.

Adoption

200 families accepted the technology without incentives. The area covered by the technology is 4 km². There is a growing trend for spontaneous adoption.

Ecological conditions

- Climate: semi-arid (lower highland zone IV)
- Average annual rainfall: 500 – 750 mm
- Soil parameters: moderately deep, loamy soils; organic matter and soil fertility: mostly medium, partly low (<1%); medium drainage / infiltration
- Slope: mostly moderate (5-8%), partly rolling (8-16%)
- Landform: plains / plateaus; high altitude and rolling terrain
- Altitude: mostly 1,500 – 2,000, partly 2,000 – 2,500 m a.s.l.
- Most of the soil and water loss occurs during a few heavy storms at the beginning of each growing season.

Socio-economic conditions

- Size of land per household: mainly <1 ha, partly 1-2 ha
- Type of land users: small-scale, groups; mostly average level of wealth, partly poor land users
- Population density: 100-200 persons/km²
- Land ownership: individual titled
- Land use rights: mostly individual, partly leased
- Market orientation: mostly subsistence, partly mixed (subsistence / commercial)
- Level of mechanisation: animal traction
- More than 90% of families have less than two hectares of land, and few have alternative sources of income.

Production / economic benefits

+++ Increased crop yield (>60%)
++ Increased fodder production and increased quality
++ Increased farm income
++ Earlier crop maturity
++ Time saving

Ecological benefits

+++ Increased soil moisture; better rainwater harvesting
++ Reduced soil loss
++ Reduced evaporation
+ Improved soil cover
+ Reduced energy consumption

Socio-cultural benefits

++ Community institution strengthening
++ Improved conservation / erosion knowledge

Off-site benefits

++ Reduced downstream siltation
+ Improved streamflow characteristics
+ Reduced downstream flooding
+ Reduced river pollution (chemical contamination)

Weaknesses ➜ and how to overcome

- Male-oriented activity (heavy equipment / animals) compared to using the hoe ➜ training of women.
- Waterlogging ➜ contingency plans needed for draining excess water in very wet years (only in 1 in 10).
- No clear advantage in extreme climatic conditions ➜ make farmers aware about this so they do not become discouraged.
- More prone to weeds; may require annual use of pre-emergence herbicides ➜ mulch application reduces negative effects of weeds.
- Conflict between using residues as mulch and as livestock fodder ➜ greater yields mean more income can be generated to buy fodder, and more biomass / mulch material.
- High equipment and animal maintenance costs ➜ possible loan scheme (micro-finance option); farmer self-help groups to share costs.

Main contributors: Frederick Kihara, Nanyuki, Kenya; pdo@africaonline.co.ke
Key references: WOCAT. 2004. WOCAT database on SLM technologies, www.wocat.net. ■ Kihara F. 1999. An investigation into the soil loss problem in the Upper Ewaso Ng'iro basin, Kenya. MSc. Thesis. University of Nairobi, Kenya ■ Mutunga C.N. 1995. The influence of vegetation cover on runoff and soil loss – a study in Mukogodo, Laikipia district Kenya. MSc Thesis, University of Nairobi, Kenya ■ Ngigi S.N. 2003. Rainwater Harvesting for improved land productivity in the Greater Horn of Africa. Kenya Rainwater Association, Nairobi ■ Liniger HP. and D.B. Thomas. 1998. GRASS – Ground Cover for Restoration of Arid and Semi-arid Soils. Advances in GeoEcology 31, 1167–1178. Catena Verlag, Reiskirchen.

MINIMUM TILLAGE AND DIRECT PLANTING - GHANA

The traditional slash-and-burn land use system in the case study area – involving clearing natural vegetation followed by 2-5 years of cropping – has become unsustainable as land pressure has greatly increased, shortening fallow periods. Under the SLM practice of 'minimum tillage and direct planting', land is prepared by slashing the existing vegetation and allowing regrowth up to 30 cm height. A glyphosate-based herbicide is sprayed with a knapsack fitted with a low-volume nozzle. The residue is left on the soil surface without burning. After 7–10 days, direct planting is carried out in rows through the mulch. Maize is the main crop planted under this system. Planting is practiced manually using a planting stick.

The mulch layer has several important functions: it helps to increase and maintain water stored in the soil, reduces soil erosion, contributes to improve soil fertility (after crop residues have decomposed in subsequent seasons) and it efficiently controls weeds by hindering their growth and preventing weeds from producing seeds.

The use of herbicides requires adequate knowledge. An even better option is to introduce multipurpose cover crops to control weed populations, improve soil fertility, and enhance yields while diversifying crop production and thus reducing dependence on the use of herbicides.

Labour inputs for land preparation and weeding is considerably decreased under conservation agriculture. Women benefit most from the workload reduction since these time-consuming activities are their task. For men, the new technology usually means heavier work, especially during the 1st year, since they have to plant through the mulch. Using a jab planter makes the work easier.

SLM measure	Agronomic
SLM group	Conservation Agriculture
Land use type	Annual cropping (cereals)
Degradation addressed	Fertility decline and reduced organic matter content; Loss of topsoil by water; Reduction of vegetation cover: detrimental effects of fires; Biomass decline
Stage of intervention	Prevention and mitigation
Tolerance to climate change	The technology is tolerant to climatic extremes, contrary to the traditional slash-and-burn practice.

Establishment activities

Note: Minimum tillage and direct planting are agronomic measures which are carried out repeatedly each cropping season. All activities are listed under maintenance / recurrent activities (below). There is no establishment phase (as defined by WOCAT).

Maintenance activities

1. Initial land clearing: slash existing vegetation and allow regrowth (up to 30 cm); before onset of rainy season.
2. Spraying of pre-emergence herbicide; 300 ml (2 sachets) for every 15 litres water for annual weeds; 450 ml (3 sachets) for every 15 litres water for perennial weeds.
3. Leave residues on the soil surface without burning.
4. Planting through the mulch.
5. Spraying post-emergence herbicide; after regrowth of weeds (7-10 days after planting).
6. Harvesting.

All activities are carried out manually (each cropping season) using jab planter (or a planting stick) and knapsack sprayers.

Labour requirements

For establishment: na
For maintenance: low

Knowledge requirements

For advisors: moderate
For land users: moderate

Photo 1: Cover crop field sprayed with herbicides and left as mulch on the field to improve soil moisture and reduce soil erosion. (FAO)
Photo 2: Young maize plants are growing through a dense mulch layer. (WOCAT database)
Photo 3: Residue management on a field with mature maize plants. (Souroudjaye Adjimon)

Case study area: Sunyani and Atwima district; Brong Ahafo region; Ghana

Note: The technology 'minimum tillage and direct planting' is compared with the traditional slash-and-burn land use system.

Slash and burn (traditional): Maintenance inputs and costs per ha

Inputs	Costs (US$)
Labour: 83 person-days	142
Equipment	13
Agricultural inputs	65
Construction material	0
TOTAL	**220**

Minimum tillage and direct planting: Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 48 person-days	83
Equipment	18
Agricultural inputs	111
Construction material	0
TOTAL	**212**

Remarks: Input costs include Jab planter US$ 20; herbicides US$ 5-6/liter. A knapsack costs US$ 50, which is not affordable for small-scale farmers (they have to get organised in groups, or hire spraying gangs). Comparing to the traditional slash-and-burn system, 'minimum tillage and direct planting' has increased input costs but reduced labour costs, and results in higher yields, which makes the conversion profitable!

Benefit-cost ratio

Inputs	short term	long term
Establishment	na	na
Maintenance	neutral	positive

Remarks: Initial investments can be high (purchasing of new equipment). Costs decrease in the long term and benefits increase.

Ecological conditions

- Climate: subhumid
- Average annual rainfall: 1,400-1,850 mm (bimodal)
- Soil parameters: partly well drained with high organic matter content (forest area); partly poorly drained with low organic matter content (savanna belt)
- Slope: no data
- Landform: mainly plains, partly hill slopes
- Altitude: 220-380 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha, partly 2-5 ha
- Type of land user: small-scale; poor
- Population density: 100-200 persons/km^2
- Land ownership: communal / family land tenure; some individual (titled)
- Land use rights: individual; partly leased
- Level of mechanisation: manual labour
- Market orientation: mainly subsistence; partly mixed (subsistence and commercial)

Production / economic benefits

+++ Increased crop yield (200-300%; from 0.75-1 t/ha to 3 t/ha)
+++ Increased farm income (150%; from US$ 50 to US$ 123 net return)
+++ Decreased workload (-42%; from 83 to 48 working days): less time needed for weeding and land preparation
\+ Decreased labour constraints: critical labour shortage at weeding time is avoided
\+ Early planting (benefit from early rains; due to minimal land preparation)

Ecological benefits

+++ Improved soil cover
\+ Reduced soil loss
\+ Improved harvesting / collection of surface runoff
\+ Increased soil moisture

Socio-cultural benefits

++ Improved situation of socially and economically disadvantaged groups: women / children benefit most from workload reduction

Weaknesses ➜ and how to overcome

- Knowledge / experience is needed for adequate application of herbicides and handling of jab planters ➜ training / advisory service.
- Increased expenses and dependence on herbicides ➜ introduce multipurpose cover crops to control weed populations, improve soil fertility, and enhance yields while diversifying crop production.
- Availability of / access to herbicides and equipment is limited; some dealers sell adulterated or fake products that are harmful to the environment ➜ hire spraying gangs; provide training; set up 'rent-a-knapsack'.
- Increased labour constraints in the first year; need for a long term investment ➜ good rates of return are achieved in the 2nd year of continuous use of the technology; long term user rights are crucial.
- High amounts of soil cover impede germination of the main crop, thereby affecting productivity ➜ partial burning appears necessary in such cases to reduce the quantity of mulch on the field.
- Fields that had been ploughed for years recorded slightly lower yield with minimal tillage and herbicide application, probably due to ploughing pan formation (hindering root penetration) ➜ ripping.

Adoption

21 communities with 193 farmers (125 male, 68 female) apply the technology in the case study area (totally 2,845 km^2). Around 88% accepted the technology receiving incentives. There is little trend towards spontaneous adoption (through cross farmer visits); 30% of farmers ceased conservation farming practices after termination of projects input.

Main contributors: Souroudjaye Adjimon, Volta Environmental Conservation Organization, Ghana; volenvicon@gmail.com

Key references: Boahen P, B.A. Dartey, G.D. Dogbe, E. A. Boadi, B. Triomphe, S. Daamgard-Larsen, J. Ashburner. 2007. Conservation agriculture as practised in Ghana. Nairobi. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement,FAO. Rome, Italy.

CONSERVATION TILLAGE FOR LARGE-SCALE CEREAL PRODUCTION - KENYA

Conservation tillage (or 'No-Till') on large-scale commercial cereal farms is based on tractor-drawn equipment which allows furrow opening and planting in one pass. This technology minimizes soil disturbance, avoids formation of hard pans and considerably reduces machine hours used for crop production: time is saved as well as fossil fuels – and field operations are thus cheaper than under conventional farming. Crops can be planted early to make the best use of rainfall. During harvesting, the crop residues are chopped and left as mulch on the field (3 tonnes of crop residues per hectare give around 70-100% cover), to improve soil organic matter and protect the soil against erosion and evaporation.

Thanks to enhanced water conservation and infiltration, wheat and barley can be produced without irrigation and the risk of crop failure is reduced. Weeds are controlled with a broad spectrum herbicide (glyphosate) application (2 liters/ha) two months after harvesting and shortly before planting. The company minimizes usage of pesticides.

Conservation agriculture also includes contour planting (25 cm rows). Crop rotation is 3-4 years of wheat or barley followed by a season of legumes (for example peas) or canola (oilseed rape). If, after several years, the yields decrease due to compaction in the subsoil, crops with a strong tap root are planted (e.g. rape or sunflower) to break the hard pan - rather than using a ripper.

As a supplementary technology tree rows (e.g. pines, cypress, or eucalyptus) are planted as shelterbelts and for wood production along boundaries, in valleys or on steep slopes.

SLM measure	Agronomic
SLM group	Conservation Agriculture
Land use type	Annual cropping
Degradation addressed	Soil erosion by water: loss of topsoil; Fertility decline and reduced organic matter content; Compaction
Stage of intervention	Prevention and mitigation
Tolerance to climate change	More tolerant to prolonged dry spells and heavy rainfall events

Establishment activities

1. Purchasing no-till machinery.

Note: Conservation tillage is based on agronomic measures which are carried out repeatedly each cropping season. All activities are listed under maintenance / recurrent activities (below). There is no establishment phase (as defined by WOCAT).

Maintenance / recurrent activities

1. Harvesting and chopping of crop residues (end of growing season).
2. Herbicide application: glyphosate 4 liters/ha (2 months after harvesting and before planting).
3. Early planting, along contour (just before rains).
4. Furrow opening and planting in one pass, using direct seeder (beginning of rainy season).
5. In-crop spraying during growing season (once or more).

Labour requirements

For establishment: na
For maintenance: medium

Knowledge requirements

For land user: medium to high
For advisors: na

Photo 1: No-till wheat crop after harvesting showing crop residue on surface.
Photo 2: No-till machinery used in large scale cereal farming.
Photo 3: Discs used to cut crop residue before planting.
(All photos by Ceris Jones)

Case study area: Kisima Farm, Meru Central, Kenya

Establishment inputs and costs per farm

Machinery for no-till includes: Tractor (110,000 US$), combined harvester (160,000 US$), sprayer (160,000 US$), direct seeder (110,000 US$). Life span is 10-15 years. For conversion from conventional to conservation agriculture usually only a direct seeder is needed as new equipment. Total equipment costs are less than half of the conventional tillage.

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour	10
Equipment: 4 machine hours / ha	70
Agricultural inputs: biocides	25
TOTAL	**105**
% of costs borne by land user	100%

Remarks: Main factors affecting the costs are machinery, spraying and labour. It takes more than 3 years to fully establish the conservation tillage system. During the conversion phase yields might be lower, and costs are approx. 25% less.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	positive
Maintenance	positive	very positive

Remarks: Positive pay-backs against establishment costs depend on the point in time of the conversion. If replacement of equipment is required anyway, conversion to conservation tillage is a profitable option, since total equipment costs are lower than those for conventional agriculture.

Ecological conditions

- Climate: subhumid to semi-arid
- Average annual rainfall: 500-750 mm; two rainy seasons; rains are inadequate and / or poorly distributed
- Soil parameters: good drainage; soil organic matter is mostly medium and partly low
- Slope: moderate to rolling (5% - max. 16%)
- Landform: mainly footslopes, partly hillslopes
- Altitude: 2,000 – 2,900 m a.s.l.

Socio-economic conditions

- Size of land per household: 2,600 ha
- Type of land users: rich large-scale farmers, with employees, fully mechanised
- Population density: < 10 persons/km^2
- Land ownership: company (Ltd)
- Land use rights: leased
- Market orientation: commercial
- Level of mechanisation: highly mechanised

Production / economic benefits

+++ Increased crop yield (from 1 t/ha to 4 t/ha; after 20 years of CA)
+++ Increased farm income
+++ Increased product diversification (wheat, barley, legumes, oil seeds)
+++ Increased forest products

Ecological benefits

+++ Increased soil moisture
+++ Reduced hazard towards adverse events (drought, floods, storms, etc.)
+++ Increased biomass / above ground carbon
+++ Increased soil organic matter / below ground carbon
+++ Increased beneficial species (predators, earthworms, pollinators, e.g. lady birds)
+++ Reduced surface runoff (from 20% to almost 0%)
+++ Reduced soil loss (from around 15 to almost 0 t/ha/yr; only wind erosion during planting)

Off-site benefits

+++ Reduced downstream siltation (the heavy rains in 2003 did not cause erosion)
\+ Groundwater recharge during exceptional high rainfall seasons

Weaknesses ➜ and how to overcome

- High costs if new equipment is needed (particularly established brands) but less than half of the costs for conventional tillage equipment! ➜ encourage local production and regulation of prices or subsidising input purchase.
- Poor market for equipment ➜ establish a market association.
- During wet years more herbicides are needed, especially before planting (several sprayings) ➜ spray use is slightly more than conventional tillage. If after the harvest there are no more rains during the dry season, there is no application of herbicides needed and direct planting can be done.
- Takes more than three years to fully establish ➜ needs continuous adaptation.

Adoption

There is a strong trend towards spontaneous adoption. Neighbouring farmers are picking up the technology.

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Key references: WOCAT. 2009. WOCAT database on SLM Technologies; www.wocat.net.

RAINWATER HARVESTING

Small dam harvesting water for animals and smallholder irrigation, Kenya. (Hanspeter Liniger)

In a nutshell

Definition: 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); (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 there - RWH often needs additional measures to increase infiltration in this zone, 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 a larger catchment 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.

Resilience to climate variability: 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, it enhances aquifer recharge, and it enables crop growth (including trees) in areas where rainfall is normally not sufficient or unreliable.

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), reduced off-site damage including 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. The greater the maintenance needs, the less successfully the land users and / or the local community will adopt the technique.

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	na
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	+

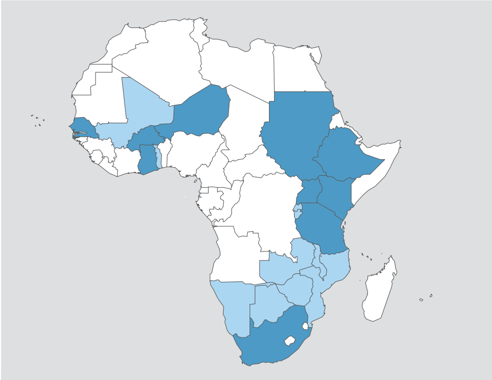
**for a duration of the first 10-20 years of changed land use management (Pretty et al., 2006)*

Origin and spread

Origin: A wide variety of traditional and innovative systems exists in the Sahelian zone e.g. Burkina Faso, Egypt, Kenya, Niger, Somalia, Sudan. In some cases these traditional technologies have been updated and (re-)introduced through projects or through the initiative of land users.
Mainly applied in: Burkina Faso, Ethiopia, Ghana, Kenya, Niger, Senegal, South Africa, Sudan, Tanzania, Uganda
Also applied in: Botswana, Burundi, Malawi, Mali, Mozambique, Namibia, Rwanda, Togo, Zambia, Zimbabwe

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 agronomic measures such as 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 from within the vicinity of the cropped area. The systems are characterised by relatively small catchment areas 'C' (<1,000 m^2) and cropping areas 'CA' (<100 m^2) with C:CA = 1:1 to 10:1. The farmer usually has control over both the catchment and the storage 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. Common technologies are *zaï* / tassa (planting pits), *demi-lunes* (half-moons), semi-circular / trapezoidal bunds, etc.
Micro-catchments such as *zaï / tassa* are often combined with conservation agriculture. This may be referred to as '**African-Adapted Conservation Agriculture**'. Its focus is on water harvesting and applying fertilizers rather than maintaining soil cover. Traditionally, CA is poorly suited to areas where water is a limiting factor and provision of permanent soil cover is a problem due to the competition between materials for mulch and livestock fodder. African style CA encompasses the following aspects: minimal soil disturbance (e.g. using jab planter), water harvesting, fertilizer application and hand weeding or low-cost herbicide.
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. The systems are characterised by a larger catchment outside the arable land with a ratio of C:CA = 10:1 to 1000:1. Common technologies are: check-dams, water diversion channels / ditches, etc.
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 roofs 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.).



Spread of Rainwater Harvesting in SSA.

Top: *Demi-lune* micro-catchments in an arid zone, Niger. (Hanspeter Liniger)
Middle: Collection and storing water in a small pond, Rwanda. (Malesu Maimbo)
Bottom: Roof catchment for domestic water use, Kenya. (Hanspeter Liniger)

Applicability

Land degradation addressed

Water degradation: aridification through decrease of average soil moisture content and change in the quantity of surface water
Erosion by water: loss of fertile topsoil through capturing sediment from catchment and conserving within cropped area
Physical soil deterioration: compaction, sealing and crusting
Chemical soil deterioration and biological degradation: fertility decline and reduced organic matter content

Land use

Mainly used on annual cropland with cereals (sorghum, millet, maize), leguminous grains / pulses (cowpeas, pigeon peas etc.) vegetables (tomatoes, onion, potatoes, etc.) and tree crops; also used on mixed extensive grazing land with trees. Micro-catchments are mainly used for single trees, fodder shrubs, or annual crops, whereas macro-catchments and concentrated runoff harvesting are mainly used for annual crops, but have also been used on mixed extensive grazing land with tree crops.

Ecological conditions

Climate: RWH techniques are most relevant in semi-arid and subhumid zones with poorly distributed rains, in particular in cereal–based areas. In more arid regions they are used for tree crops and / or establishing trees for afforestation. Micro-catchments are more suitable for areas with more reliable rainfall, whereas macro-catchments are effective in areas where few runoff events are expected.
Terrain and landscapes: Macro-catchments can be applied in depressions / valleys, whereas micro-catchments can be used on all landforms.
Soils: Clay or shallow soils with low infiltration rates in the collection area and deep soils with high moisture storage capacity in the storage areas. This makes them suitable for deep flooding for subsequent cropping on residual moisture - though waterlogging can be a problem. Sandy soils have quicker infiltration but lower storage capacity: they are thus relatively suitable for diversion schemes.

Socio-economic conditions

Farming system and level of mechanisation: Micro-catchments are mainly small-scale and constructed manually or by animal traction. Macro-catchments for runoff harvesting and small dams / ponds may be applied within medium or large-scale systems, and the construction is usually mechanised - but may be built up manually over many years.
Market orientation: Both subsistence and partly commercial.
Land ownership and land use / water rights: The absence of clear land and water use rights prevents water harvesting and conveyance techniques from being more widely spread.
Skill / knowledge requirements: For the establishment of rainwater harvesting techniques, medium to high level of know-how is required.
Labour requirements: Roof catchments, macro-catchments and small dams require high initial labour input, whereas micro-catchments usually need mainly medium labour input depending on the technique used. Micro-and macro-catchments and small dams also require a certain level of labour for maintenance. Many techniques can be implemented manually.

Land degradation

Erosion by water
Erosion by wind
Chemical degradation
Physical degradation
Biological degradation
Water degradation

High
Moderate
Low
Insignificant

Land use

Cropland
Grazing land
Forests / woodlands
Mixed land use
Other

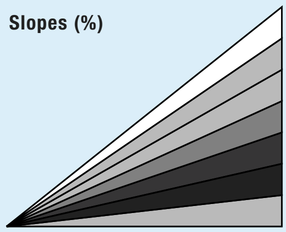
Climate

Humid
Subhumid
Semi-arid
Arid

Average rainfall (mm)

> 3000
2000-3000
1500-2000
1000-1500
750-1000
500-750
250-500
< 250

Slopes (%)



very steep (>60)
steep (30-60)
hilly (16-30)
rolling (8-16)
moderate (5-8)
gentle (2-5)
flat (0-2)

Farm size

Small scale
Medium scale
Large scale

Land ownership

State
Company
Community
Individual, not titled
Individual, titled

Mechanisation

Manual labour
Animal traction
Mechanised

Market orientation

Subsistence
Mixed
Commercial

Required labour

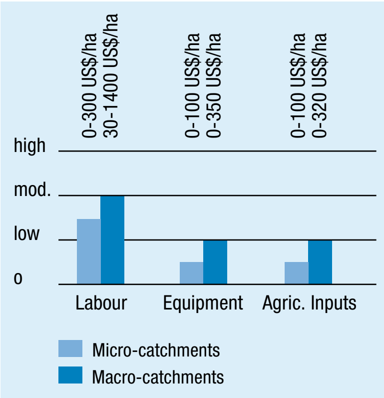
High
Medium
Low

Required know-how

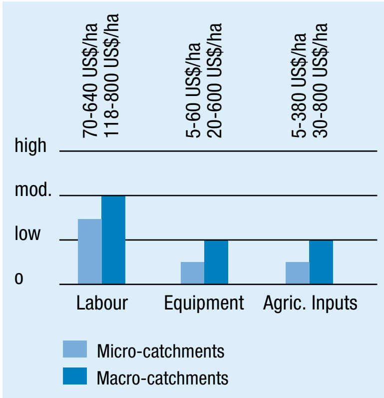
High
Medium
Low

Economics

Establishment costs



Maintenance costs



Labour is valued as 1-2 US$ per person day (Source: WOCAT, 2009)

Micro-catchments: Main costs are for labour (establishment and maintenance); inputs are mainly agricultural such as compost, fertilizer, etc., equipment is less important than for macro-catchments. Labour days can vary considerably and range between 80 - 250 person days/ha.
Macro-catchments: Main costs are for labour. Maintenance costs depend heavily on the quality of the structures; they are usually low for well-built structures. In case of breakages maintenance costs can be very high (compared to micro-catchments).
Small dams: Costs for a size of 50-80,000 m^3 approximately 120,000-300,000 US$ (this translates to about 1.5-6 US$ per m^3 of earth dam material)
Ponds: Costs about 4 US$ per 1 m^3 excavation
Roof catchments: Storage tanks cost about 200 US$ per m^3 of water (a tank is typically 10 m^3 ➜ 2,000 US$) (the same if plastic tanks are used or ferrocement tanks (except that the cement tanks are logistically much more demanding and require much greater skills). Both of them last more than 10 years.

Production benefits

Crop	Yield without SLM (t/ha)	Yield with SLM (t/ha)	Yield gain (%)
Burkina Faso Millet	0.15 – 0.3	*Zaï* + manure 0.4 (poor rainfall) 0.7 - 1 (high rainfall)	30-400%

(Source: FAO, 2001)

Comment: For roof catchments and for small dams, ponds, etc. no directly related production benefits can be shown. The main benefits are related to the availability of clean and free household, as well as irrigation water.

Benefit-Cost ratio

System	short term	long term	quantitative
Micro-catchments	+/++	++	
Small dams, etc.	– –	++/+++	
Macro-catchments	– –	++/+++	Returns to labour, 10-200 US$/PD vegetables 10 US$/PD* for maize
Roof catchments	– –	+++	
Overall	–	++/+++	

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive
**PD: person days. (Sources: WOCAT, 2009 and Hatibu, et al., 2004)*

Comment: Due to the required level of maintenance activities the costs for micro-catchments are slightly less positive in the long term than for roof catchments and small dams / ponds, etc.

Example: Niger
Cost of selected RWH techniques

Erosion control / SLM techniques	Indicative costs US$/ha
Stone lines *Cordon de pierres*	31
Stone lines with direct seeding *Cordon de pierres avec semis direct*	44
Earth bunds *Banquette en terre*	137
Earth bunds manual *Banquette en terre manuelle*	176
Half-moon for crops *Demi-lune agricole*	111
Half-moon for trees *Demi-lune forestière*	307
Planting pits *Zaï*	65

(Sources: Projet d'Aménagement Agro-Sylvo-Pastoral Nord Tillabéry (PASP); Projet Développement Rural Tahoua (PDRT))

Example: 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 for the production of 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).

Crops	Return to labour* (US$/person days)
Maize	4.6
Paddy	5.2
Tomatoes	13
Onions	87

**for RWH techniques using external runoff and storage ponds (mean return from 1998 to 2002)*

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	+ + increased crop yields (a, b, c)* ++ enhanced water availability ++ increased fodder production (a, b, c) + increased wood production (a, b, c) + diversification of production	++ reduces risk of crop failure (a, b, c) +++ access to clean and free drinking water (d) +++ reduced damage to neighbouring fields	+++ improved food and water security
Economic	+++ access to clean / free drinking water (d) ++ increased farm income	++ less damage to off-site infrastructure + stimulation of economic growth + diversification and rural employment creation	+++ improved livelihood and well-being
Ecological	+++ improved water availability ++ can be used for rehabilitation of highly degraded land (a, b) ++ improved water infiltration (a) ++ reduced velocity of runoff (a) ++ reduced net surface runoff (a and b) ++ increased net soil moisture (a) ++ reduced soil erosion and soil loss (a) ++ improved excess water drainage (a) + increases soil organic matter and soil fertility (a) + improved soil cover (a) + biodiversity enhancement + sediment traps for nutrient (a, b)	++ reduced degradation and sedimentation (a) ++ increased stream flow in dry season / reliable and stable low flows (a, b, c) + groundwater recharge + reduced groundwater / river pollution (a, b) + intact ecosystem	+++ increased resilience to climate change ++ reduced degradation and desertification incidence and intensity + enhanced biodiversity
Socio-cultural	+++ less pressure on water resources for drinking water, irrigation, etc. ++ community institution strengthening ++ improved conservation / erosion knowledge (a, b, c) ++ can reduce the time used for gathering water for domestic use	+ increases awareness for environmental 'health' ++ reduced water conflicts ++ national institution strengthening + attractive landscape	+ protecting national heritage

**a) Micro-catchments, b) Macro-catchments, c) Small dams / ponds, d) Roof catchments*

	Constraints	How to overcome
Production	• Very often RWH alone does not always lead to a significant production increase, additional fertility management is needed (a, b, c)	➜ combine with improved soil fertility management
Economic	• Increased input constraints especially for the establishment • Availability of manure to improve soil fertility especially within micro-catchments • Establishment and construction can be labour intensive and requires a high level of technical knowledge • Maintenance of the system and limited life-span of certain types of structures – for micro-catchments this mainly refers to annual agronomic activities, whereas for small dams and macro-catchments maintenance includes also reparation and protection against animals as well as siltation • Loss of land (decreased production area) especially for very small farms (a, b, c) • Lack of market (a, b, c) • Cost of transportation of the material (a, b, c)	➜ access to market for inputs and equipment and if necessary support for establishment ➜ technical support in form of training and education on the system is needed ➜ for small-dams, ponds, etc. community organisation is needed for the establishment and the maintenance with clear responsibilities ➜ most successful techniques are simple, inexpensive, easily manageable by local community (includes stone bunds, semi-circular bunds, vegetative strips)
Ecological	• Waterlogging can be a problem under poor drainage systems (a, b, c,) • Water can only be harvested when it rains	
Socio-cultural	• Conflicts in areas formerly used by nomads • Where RWH is used over a significant area, there may be upstream / downstream conflicts in terms of water availability • Socio-cultural conflicts concerning rehabilitated land • Eliminates women's burden of collecting water for domestic use (d)	➜ clear land and water use rights and improved watershed planning with allocation of water resources ➜ farmer and community involvement

Adoption and upscaling

Adoption rate

In general adoption rates remain low. Farmers hesitate to invest time and money in RWH without security of land and limited access to local markets where they can sell surpluses. However some RWH technologies like *zaï* have been widely adopted with (and in some areas, without) external support.

Upscaling

Profitability: The techniques recommended must be profitable for land users and local communities, and techniques must be simple, inexpensive and easily manageable.

Capacity building and knowledge sharing on suitable RWH techniques is needed. One of the constraints hindering adoption is lack of information, education and training

The level of maintenance is an important criterion. The techniques should be manageable at farm level and involve community action, especially for larger-scale construction such as ponds, small dams and macro-catchments which are very often out of the land user's control.

Clear land and water tenure and property rights are necessary to motivate land users to invest in RWH.

Market access: A better linkage and access to markets is necessary, and assistance for small-scale farmers to change from subsistence to commercial farming.

Micro-catchments usually need a low level of material and technical support . However, depending on the techniques, a certain level of material and / or technical support is needed, e.g. *demi-lune* / half moon techniques in West Africa require a relatively high level of material support for the establishment. In Burkina Faso the *zaï* system has been successfully spread through farmer-to-farmer visits. Farmer-to-farmer exchange can be a highly successful tool for upscaling of micro-catchment systems.

Macro-catchments and small dams are very often not within reach of small communities and usually require material and technical support for the establishment as well as community involvement / organisation in the planning and maintenance of the system.

Roof catchments: Relative high investment costs might require initial material support for the construction. Community involvement is needed for the establishment and maintenance. Trained extension services and self-help groups and organisations are very effective and needed for spreading of the technology.

Incentives for adoption

(1) For micro-catchments a low level of material and technical support is needed; (2) macro-catchments and small dams require high material and technical support for establishment; and (3) roof catchments need high levels of material and technical support for establishment.

Enabling environment: key factors for adoption	
Inputs, material, incentives, credits	++
Training and education	++
Land tenure, secure land use rights	+++
Access to markets	++
Research	++
Infrastructure	++
Genuine ownership on the part of communities	+++

References and supporting information:

AQUATSTAT. 2009. http://www.fao.org/NR/WATER/AQUASTAT/main/index.stm, access on 15 July 2009

FAO, 2008. Water and Rural Poverty - Interventions for Improving Livelihoods in sub-Saharan Africa.

FAO. 1991. A Manual for the Design and Construction of Water Harvesting Schemes for Plant Production. W. Critchley and K. Siegert

FAO. 2001. Compendium of Land and SARD Cases: Supporting Document to Task Managers' Report to CSD+10 on the Land and Agriculture Cluster for Chapters 10, 12 and 14 of Agenda 21. http://www.fao.org/wssd/land/docs/Comp_Cases2001.doc, accessed on 15 July 2009.

Hatibu N., E. M. Senkondo, K. Mutabazi and A.S.K. Msangi. 2004. Economics of Rainwater Harvesting for Crop Enterprises in Semi-Arid Areas. 'New directions for a diverse planet'. Proceedings of the 4th International Crop Science Congress, 26 Sep – 1 Oct 2004, Brisbane, Australia. Published on CDROM.

IWMI. 2009. Vallerani-System. http://www.iwmi.cgiar.org/africa/west/projects/Adoption%20Technology/RainWaterHarvesting/26-ValleranisSystem.htm

Malesu, M., J. K. Sang, J. Orodi Odhiambo, A. R. Oduor and M. Nyabenge. 2006. Hydrologic impacts of ponds on land cover change, Runoff water harvesting in Lare, Kenya, Maimbo, Technical Report No. 32. Regional Land Management Unit (RELMA-in-ICRAF), Netherlands Ministry of Foreign Affairs and Swedish International Development Cooperation Agency (Sida)

Mati B. M. 2005. Overview of water and soil nutrient management under smallholder rainfed agriculture in East Africa. Working Paper 105. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Pretty J. N., A. D. Noble, D. Bossio, J. Dixon, R. E. Hine, F. W. T. Penning de Vries, and J. I. L. 2006. Resource-conserving Agriculture Increases Yields in Developing Countries. Environmental Science & Technology, Vol. 40, No. 4.

RAF Publication. 2001. La collecte des eaux de surface en Afrique de l'Ouest et du Centre - Water harvesting in western and central Africa

UNEP. 2009. Rainwater Harvesting: A Lifeline for Human Well-Being. A report prepared for UNEP by Stockholm Environment Institute.

UNESCO. 2002. Proceedings of the International Seminar on Combating Desertification: Freshwater Resources and the Rehabilitation of Degraded Areas in the Drylands, held in N'Djamena, Chad, 30 October to 4 November 2000

Vohland K. and B. Barry. 2009. A review of in situ rainwater harvesting (RWH) practices modifying landscape functions in Africa drylands. Agriculture, Ecosystems and Environment 131 (2009) 119-127

Wateraid. 2009. Roof Catchments. http://www.wateraid.org/documents/plugin_documents/technology_notes_07_web_1.pdf, accessed on 15 July 2009

WOCAT. 2009. WOCAT database on SLM technologies and SLM approaches. www.wocat.net, accessed on 15 September 2009

Woodfine, A. 2009. Using sustainable land management practices to adapt to and mitigate climate change in sub-Saharan Africa: resource guide version 1.0. TerrAfrica. www.terrafrica.org.

TASSA PLANTING PITS - NIGER

Tassa planting pits are 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%.

Planting pits are holes of 20-30 cm diameter and 20-25 cm depth, spaced about 1 m apart in each direction. They 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 brings 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 are often combined with stone lines along the contour to enhance water infiltration, reduce soil erosion and siltation of the pits. Grass growing between the stones helps increase infiltration further and accelerates the accumulation of fertile sediment.

SLM measure	Structural
SLM group	Rainwater Harvesting
Land use type	Silvopastoral / wasteland (before), cropland (after)
Degradation addressed	Loss of topsoil (by water and wind); Soil compaction / crusting; Soil fertility decline; Soil moisture problem
Stage of intervention	Rehabilitation
Tolerance to climate change	Increased tolerance due to water harvesting

Establishment activities

1. Digging pits (*tassa*) with a hoe in the dry season (20-25 cm deep, 20-40 cm in diameter): the excavated earth forms ridges downslope of the hole. The pits are spaced 0.8-1 m apart, giving approximately 10,000 pits/ha.
2. Manuring the pits with approx. 250 g per pit (2.5 t/ha).
3. Optionally: Digging out stones from nearby sites (using a pick-axe and shovel) and aligning the stones along the contour with the help of a 'water tube level': maximum of 3 stones wide. The distance between the stone lines is a function of the slope: at a 2% slope (or less) the lines are spaced 50 m apart, at a 5% slope, spacing is 25m.

All activities are carried out by manual labour.

Maintenance / recurrent activities

1. Removing sand from the *tassa* (annually, March-May).
2. Manuring the pits with about 250 g per pit (2.5 t/ha) every second year in October / November or March-May.

All activities are carried out by manual labour.

Labour requirements

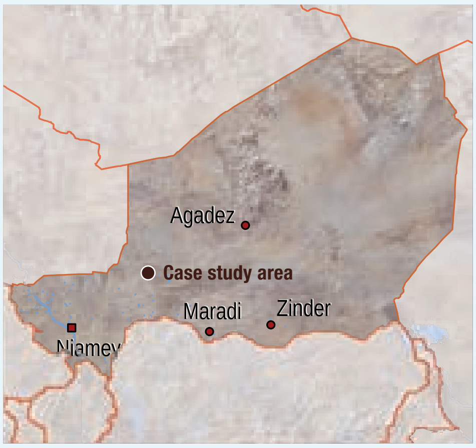
For establishment: high
For maintenance: low

Knowledge requirements

For advisors: moderate
For land users: low

Photo 1: Adding manure to the pits (*tassa*) before planting. (William Critchley)
Photo 2: Digging pits and piling up a small bund on the downstream side, using a traditional hoe. (William Critchley)
Photo 3: Sorghum growing in planting pits. (Philippe Benguerel)

Case study area: Tahoua, Niger



Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 100 person-days	150
Equipment	5
Agricultural inputs	5
TOTAL	**160**
% of costs borne by land users	100%

Remarks: Establishment costs are for 2 pits.

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 20 person-days	30
Equipment	0
Agricultural inputs	2.5
TOTAL	**32.5**
% of costs borne by land users	100%

Remarks: Labour costs are indicated for establishment of *tassa* only (without application of stone lines). Maintenance costs refer to removing sand from the pits from the second year onwards, and to manuring every second year (costs are spread on an annual basis). If applicable, costs for transporting the manure need to be added. The general assumption in these calculations is that adequate manure is readily available close by. Land users bear 100% of all costs.

Benefit-cost ratio

Inputs	short term	long term
Establishment	neutral	slightly positive
Maintenance	slightly positive	positive

Remarks: Initial labour inputs pay out on the medium to long term.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 250-500 mm
- Soil parameters: well drained, sandy, shallow soils; low to very low soil fertility; low organic matter (<1%); soil crusting
- Slope: mostly gentle (2-5%), partly flat (0-2%)
- Landform: mainly plains / plateaus, partly footslopes
- Altitude: 100-500 m a.s.l.

Socio-economic conditions

- Size of land per household: 2-5 ha
- Type of land user: small-scale farmers
- Population density: no data
- Land ownership: mostly individual, titled
- Land use rights: individual
- Market orientation: mostly subsistence, partly mixed (subsistence and commercial)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased crop yield
++ Increased farm income

Ecological benefits

+++ Improved soil cover (long term)
++ Increased soil moisture
++ Increased soil fertility
++ Increased soil organic matter
++ Reduced soil loss

Socio-cultural benefits

++ Improved conservation / erosion knowledge
+ Community institution strengthening through mutual aid in technology implementation

Off-site benefits

++ Reduced downstream flooding
+ Reduced downstream siltation

Weaknesses ➜ and how to overcome

- Implementation constraint: availability / transport of manure and transporting manure to the plateaus and slopes ➜ subsidise transport means (or supply donkey carts).
- High labour input for implementation and maintenance ➜ mechanisation of tasks: transportation of manure. However, this would raise the cost.
- Instability of planting pits in loose soil, increased erosion on steeper slopes and with heavy rains ➜ avoid sandy soils and steep slopes; combine with additional measures (e.g. stone lines).
- The effectiveness can be compromised if the various geo-morphological units (plateaus, slopes) are not treated simultaneously ➜ catchment area approach if downstream flooding is an issue.
- Possibility of land use conflicts concerning rehabilitated land, in particular with pastoralists (because grazing land is being turned into cultivated fields) ➜ better coordination / consultation before implementing the technology in an area.

Adoption

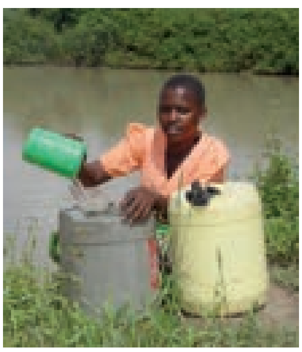
There is a moderate trend towards spontaneous adoption (for rehabilitation of the plains). Area covered by the technology was approx. 40 km^2 in 2000.

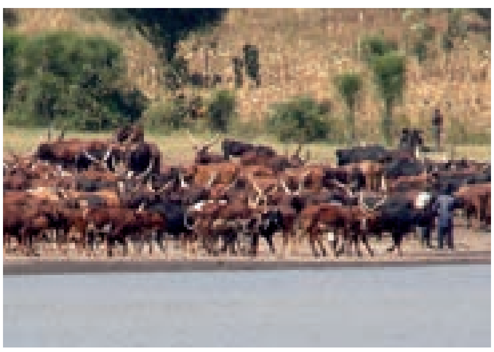
Main contributors: Adamou Oudou Noufou, Tahoua, Niger

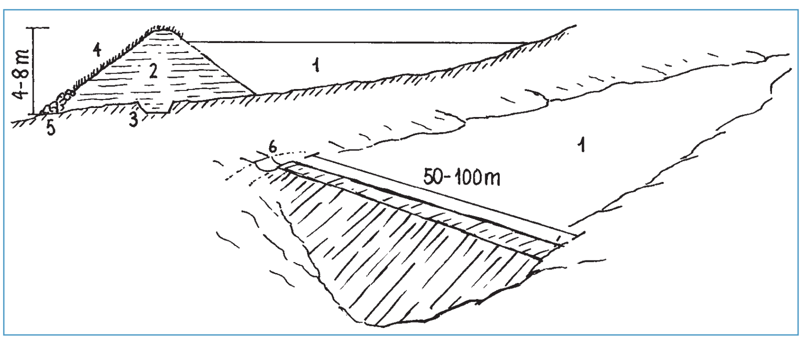
Key references: Bety A, A. Boubacar, W. Frölich, A. Garba, M. Kriegl, A. Mabrouk, Noufou O, Thienel M and Wincker H (1997): Gestion durable des ressources naturelles. Leçons tirées du savoir des paysans de l'Adar. Ministère de l'agriculture et de l'élevage, Niamey, 142 pp. ■ Hassane A, Martin P and Reij C (2000) Water harvesting, land rehabilitation and household food security in Niger: IFAD's Soil and Water Conservation Project in Illela District. IFAD, Rome, 51 pp. ■ WOCAT 2009, WOCAT Database on SLM Technologies, www.wocat.net

SMALL EARTH DAMS - ZAMBIA

Small earth dams are water harvesting storage structures, constructed across narrow sections of valleys, to impound runoff generated from upstream catchment areas. Construction of the dam wall begins with excavation of a core trench along the length of the dam wall which is filled with clay and compacted to form a central core ('key') that anchors the wall and prevents or minimises seepage. The upstream and downstream embankments are built using soil with a 20-30% clay content. During construction – either by human labour, animal draught or machine (bulldozer, compacter, grader etc.) – it is critical to ensure good compaction for stability of the wall. It is common to plant Kikuyu grass (*Pennesetum clandestinum*) to prevent erosion of the embankment. The dam is fenced with barbed wire to prevent livestock from eroding the wall.
Typical length of the embankment is 50-100 m with water depth ranging 4-8 m. An emergency spillway (vegetated or a concrete shute) is provided on either, or both sides, of the wall for safe disposal of excess water above the full supply level. The dam water has a maximum throwback of 500 m, with a capacity ranging from 50,000 – 100,000 m^3. The dams are mainly used for domestic consumption, irrigation or for watering livestock.
If the dams are located on communal lands, their establishment requires full consultation and involvement of the local community. The government provides technical and financial assistance for design, construction and management of these infrastructures. Community contribution includes land, labour and local resources. The community carries out periodic maintenance of the infrastructure – including vegetation management on embankment, desilting etc. – and of the catchment areas (through soil and water conservation practices).







SLM measure	Structural
SLM group	Rainwater Harvesting
Land use type	Cropland; Grazing land
Degradation addressed	Water degradation: reduced surface water availability
Stage of intervention	Mainly prevention and mitigation, partly rehabilitation
Tolerance to climate change	Sensitive to climatic extremes (e.g. floods); Tolerant with respect to rainfall variability, prolonged dry spells, etc.

Establishment activities

1. Site selection in consultation with community.
2. Dam survey and design: Topographical survey of dam area; using levelling equipment (dumpy level or theodolite); Determination of dam wall dimensions.
3. Dam wall construction: Excavate core trench (usually 4 m wide; 2 m deep). Excavate and transport clay-rich soil to the dam site. Construct core and embankments (slope angles 3:1). Continuously compact placed soil.
4. Construct lateral spillway(s), 5-30 m wide (depending on the flood flow and the return slope).
5. Design and installation of irrigation and drainage infrastructure (in case of crop production).
6. Completion: plant Kikuyu grass on dam embankment, spillway and irrigation canals and fence of; alternatively line with cement.

Maintenance / recurrent activities

1. Catchment conservation to minimise siltation of dam and irrigation infrastructure (continuous).
2. (Re-)planting grass on dam and irrigation infrastructure (annually, using hand hoes).
3. Desiltation of the dam (every 5-10 years): excavate and remove the silt deposited in the dam.
4. Cleaning of dam and irrigation infrastructure: remove trees / shrubs from dam / canals. If concrete lined: repair of any damages.

Establishment and maintenance of structures is carried out by human or animal labour or by machine (i.e. bulldozers or tractors with scoop).

Labour requirements

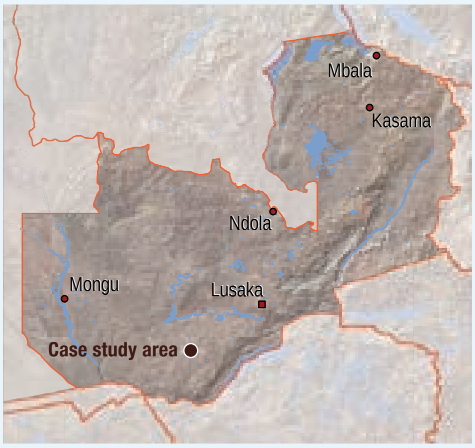
For establishment: high
For maintenance: low to medium

Knowledge requirements

For advisors: high
For land users: high

Photo 1: Manual construction of a small dam requires community action: soil is transported in bags, piled up and compacted layer by layer.
Photo 2: Fetching water for domestic use at a small dam.
Photo 3: Water point for livestock. (All photos by Maimbo Malesu)
Technical drawing: Dimensions and main components of a small dam: (1) water body; (2) dam wall (with layers of compacted soil; side slopes 3:1); (3) central core ('key'); (4) grass cover; (5) stone apron; (6) spillway (Mats Gurtner).

Case study area: Southern Province, Zambia



Establishment inputs and costs per dam

Inputs	Costs (US$)
Labour: 633 person-days	2,000
Equipment / tools: machinery, ox-ripper, hoe / pick, shovel (US$ 3/m³ of earth work)	30,000
Agricultural inputs: termicide, grass seed, fertilizer	3,000
Construction material: cement, sand, stones, abstraction pipes, screen, valve, bolts and nuts	15,000
TOTAL	**50,000**
% of costs borne by land users	20%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 63 person-days	200
Equipment / tools: hoe, axe, shovel	2,000
Agricultural inputs: grass seed, fertilizer	300
Construction material: cement, stones, building sand	1,500
TOTAL	**4,000**
% of costs borne by land users	80%

Remarks: Establishment costs are calculated for a dam with an earthwork volume of 10'000 m³ (44 m long; 8 m deep; side slopes 3:1). 20% of costs are borne by the community (in-kind contribution: labour and local materials such as sand, stones). Construction machinery can include: tipper truck, bulldozer, motor scraper, compactor, tractor, grader.

Benefit-cost ratio

Inputs	short term	long term
Establishment	negative	very positive
Maintenance	neutral	very positive

Ecological conditions

- Climate: semi-arid, subhumid
- Average annual rainfall: 700 mm (400-800 mm)
- Soil parameters: medium fertility; medium depth, well drained, medium organic matter content; loamy to sandy soil texture
- Slope: plains (2-15%) and valleys (15-40%)
- Landform: plains and valleys
- Altitude: 300-1,200 m a.s.l for mid Zambezi valley and Southern plateau respectively

Socio-economic conditions

- Size of land per household: 2 ha
- Type of land user: small-scale; land user groups; poor
- Population density: 10 persons/km²
- Land ownership: communal (not titled)
- Land use rights: communal (organised)
- Level of mechanisation: animal traction
- Market orientation: mixed (subsistence and commercial)

Production / economic benefits

+++ Increased crop yield
+++ Increased irrigation water availability
++ Increased animal production
++ Increased farm income

Ecological benefits

+++ Increased water quantity
+++ Improved water harvesting / collection
++ Recharge of groundwater table / aquifer
+ Reduced hazard towards adverse events

Socio-cultural benefits

+++ Improved food security
++ Community institutional strengthening
+ Increased recreational opportunities

Off-site benefits

+++ Increased water availability
+++ Reduced downstream flooding

Weaknesses ➜ and how to overcome

- Dams are communally owned ➜ requires strong organisation and commitment by community.
- Risk of siltation ➜ de-silting and catchment conservation is essential
- Vulnerability to climate change ➜ increase depth and design storage to last at least for two rainy seasons.
- Evaporation and seepage losses ➜ maintain minimum design depth of 4 meters; if seepage is high: provide impervious material on the upstream embankment, i.e. clay or plastic lining if necessary.

Adoption

Records of 1991 indicate at least 537 such dams exist in Zambia. In the study area there are over 293 dams serving a cattle population of 1.1 million and human population of nearly 1 million people. Communities require government or NGO support for establishment.

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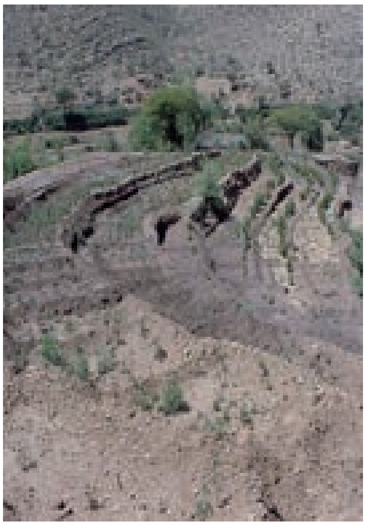
Key references: The Jesuit Centre for Theological Reflection. 2010. Social Conditions Programme. http://www.mywage.org/zambia/main/minimum-wage/comparitive-minimum-wage. ■ Nissen-Petersen E. 2006. Water from small dams. A handbook for technicians, farmers and others on site investigations, designs, cost estimations, construction and maintenance of small earth dams ■ Morris P. H. 1991. Statement of Policy: Progress Review of the Drought Relief Dam Cons/ruction Project, Southern Province. Part 1 — Main Report. Irrigation and Land Husbandry Branch, Department of Agriculture, Chôma. ■ Sichingabula H.M. 1997. Problems of sedimentation in small dams in Zambia. Human Impact on Erosion and Sedimentation (Proceedings of the Rabat Symposium, April 1997. IAHS Publ. no. 245, 1997

RUNOFF AND FLOODWATER FARMING - ETHIOPIA

Runoff and floodwater farming is a traditionally practiced water harvesting system which helps overcome problems of soil moisture and crop failure in a hot, dry area with erratic rainfall and shallow, highly erodible soils: floodwater and runoff from ephemeral rivers, roads and hillsides is captured through temporary stone and earth embankments. A system of hand dug canals – consisting of a main diversion canal and secondary / tertiary canals – conveys and distributes the captured water to the cultivated fields in naturally flat or leveled areas. The total length of the canal system is 200 – 2,000 m. The harvested water is used for growing high value crops, vegetables and fruit trees. Irrigated fields are divided into rectangular basins bordered by ridges to maximise water storage and minimise erosion risk.

Runoff and floodwater management requires preparedness for immediate action by the farmers: When a flood is expected in the ephemeral river, farmers rush to the diversion site and start erecting the embankment across the bed of the stream. Similarly, each famer starts to maintain the canal which leads water to his field. A schedule defines the date and time each farmer is allocated his turn to irrigate. When the water reaches the field, it is spread either through flooding or distributed in furrows which are opened and closed using a local tool.

The ratio between catchment area and production area is 10:1 – 100:1 or greater. While the diversion canals / ditches and basins for tree planting are permanent structures, basins for annual crops are seasonal. Soil fertility is improved by additional measures such as composting and mulching. Maintenance, including repairs to breaks along the canal and water conveying ditches, is needed every season before the onset of rains.



SLM measure	Structural
SLM group	Rainwater Harvesting
Land use type	Annual crops, tree crops
Degradation addressed	Loss of water, aridity; Loss of topsoil through erosion by water
Stage of intervention	Mitigation
Tolerance to climate change	Increased tolerance to drought and seasonal variations; sensitive to extreme flood events

Establishment activities

1. Construction of diversion canals with lateral embankments, from runoff source to the fields. Embankments are stabilised with stones – if possible (hand dug during dry season).
2. Seed bed preparation before the water is diverted to the fields: construction of rectangular basins separated by small bunds (0.3 m high; 0.3 m wide).
3. Watering the field for better seed germination. The field is watered before the seeds are planted otherwise germination will be affected.

Main canal: 3-4 m wide, 0.5-0.75 m high
Secondary canal: 2-3 m wide, 0.5 m high
Tertiary canal: 0.5-1 m wide

Maintenance / recurrent activities

1. Runoff management. This is essentially the activity of spreading water to the field which includes cleaning the canals for directing water to the field.
2. Seed bed preparation (reconstruction of basins is done every season, before the water is diverted to the field).
3. Regular maintenance / repairing of runoff diversion canals: scouring, removing sediment / silt, repairing breaks in the embankment.

Labour requirements

For establishment: high (very labour-intensive structures)
For maintenance: medium to high

Knowledge requirements

For advisors: medium
For land users: medium

Photo 1: Main canal for diverting flood water from seasonal rivers to the field. Lateral embankments are stabilised with stones.
Photo 2 and 3: Cropland prepared for floodwater farming: basins allow controlled flooding of the fields. In the background the river bed from which the water is extracted.
(All photos by Daniel Danano)

Case study area: Dire Dawa, Ethiopia

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 295 person-days	253
Equipment: shovels, hoes	24
Agricultural inputs	106
TOTAL	**383**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 525 person-days	450
Equipment	64
Agricultural inputs: seeds	300
TOTAL	**814**
% of costs borne by land users	100%

Remarks: Establishment costs include the construction of diversion ditch, construction of blocks (irrigation basins); seeds and seedlings. Maintenance costs include the reconstruction of blocks / seedbed preparation; seeds and seedlings; weeding and cultivation; irrigation; harvest. Costs have been calculated assuming that 0.5 ha of the land is planted by fruit trees and 0.5 ha planted with vegetables. Daily wage cost of hired labor to implement SLM is 0.85 US$. All costs are met by the land users themselves.

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	very positive	very positive

Remarks: Net benefits are positive from the beginning due to rapid production increase.

Ecological conditions

- Climate: semi-arid (also suitable for arid areas)
- Average annual rainfall: 500-750 mm; erratic, not well distributed
- Soil parameters: good drainage, low organic matter
- Slope: flat to gentle (0-5%)
- Landform: footslopes and valley floors
- Altitude: 1,000-2000 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha
- Type of land users: better-off small-scale farmers
- Population density: 150 persons/km^2
- Land ownership: state
- Land use rights: private
- Market orientation: mainly commercial, partly mixed (90% of vegetables and fruits are sold)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased farm income (net benefit 1st year: 226 US$; from 4th year onwards: 711 US$)
+++ Increased crop yield (gross production value increases by 200% after 3 years and 400% after 10 years)
+++ Increased fodder production and increased fodder quality
+++ Increased wood production

Ecological benefits

+++ Increased soil moisture
+++ Increased infiltration
+++ Reduced runoff (from 50% to 5% of annual rainfall)
+++ Reduced soil loss (from 60 to 6 t/ha)
+++ Increased soil fertility

Socio-cultural benefits

+++ Community strengthening
+++ Improved conservation / erosion knowledge

Off-site benefits

+++ Reduced downstream flooding
+++ Increased stream flow in dry season
+++ Reduced downstream siltation

Weaknesses ➜ and how to overcome

- Increased labour constraints: construction of diversion ditches, preparation of irrigation basin and spreading the runoff water and regular maintenance / reconstruction of structures is very labour intensive ➜ providing improved farm tools could improve efficiency of operation, organising farmers in groups for sharing labor would curtail labor problems; Placing permanent structures at the diversion head (concrete) and paving ditches to improve channel stability would reduce maintenance activities.
- Social inequity: mainly better-off farmers apply the technology (due to high costs) ➜ providing credit solves financial problems and facilitating market would motivate land users to get more engaged in the business.
- Loss of land (through conservation structures) ➜ is outweighed by the high production benefits.

Adoption

100% of land users that have applied the technology, have done it wholly voluntarily, without any incentives except technical guidance. There is enough local skill and support to expand the technology.

Main contributors: Daniel Danano, Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia; ethiocat@ethionet.et
Key references: Danano, D. 2008; (unpublished): Soil and Water Conservation Practices for Sustainable Land Management in Ethiopia. Ethiocat.

SMALLHOLDER IRRIGATION MANAGEMENT

Low-cost drip irrigation for vegetable production on a small plot in Niger. (William Critchley)

In a nutshell

Definition: A Smallholder Irrigation Management (SIM) unit is typically a plot covering an area less than 0.5 ha. SIM schemes may be managed either by an individual land user or by groups / communities.

The guiding principle of sustainable SIM is 'more crop per drop', in other words efficiency of water use. This can be achieved through more efficient (1) water collection and abstraction; (2) water storage; (3) distribution and; (4) water application in the field. Two main categories of SIM can be distinguished, traditional surface irrigation systems and recent micro-irrigation systems including drip irrigation. Micro-irrigation systems are commonly used for, and are very important in, the production of vegetables, fruits and flowers. More efficient water use can enhance production benefits remarkably. However, additional measures including soil fertility management, introduction of high value crops and appropriate pest and disease control are necessary for a substantial increase in production. As water resources in SSA are generally scarce and very unevenly distributed, any dream of widespread irrigation schemes is unrealistic. However, there is scope for improved irrigation management - making the most efficient use of precious water resources, especially for small-scale farming. Priority areas for SIM in SSA are in semi-arid and subhumid areas, where a small amount of irrigation water leads to a significant increase in yield - or at least a reduction in crop failure. Often there are possible synergies to be made by basing such schemes on water collected through rainwater harvesting. Therefore, SIM builds on the principles of supplementary irrigation, with rainfall as the principle source of water, and supplementary irrigation helping during dry spells and extending the growing period.

Applicability: SIM is most applicable to arid, semi-arid and subhumid areas. In water-scarce regions, the amount of irrigation water is limited and irrigation competes with other water demands.

Resilience to climate variability: SIM systems can enhance the resilience to droughts and temperature increase. The storage of excess rainfall and the efficient use of irrigation are critical in view of growing water scarcity, rising temperatures and climatic variability.

Main benefits: This system can increase incomes of the farmers by producing more, and higher-value, crops. Helping land users to move from subsistence farming to producing cash crops contributes to poverty reduction, primarily by enhancing the productivity of both labour and land. Agricultural production risks can be reduced, and food security enhanced.

Adoption and upscaling: The major constraint to smallholder irrigation is the availability of water. Financing (high costs of equipment), and the lack of a functioning market system to sell products, are further constraints. Therefore it is important that access to financial services is provided to land users. Land user group organisations can be a means to pool land users and resources and develop irrigation schemes.

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	na
Improving non wood forest production	na
Preserving biodiversity	na
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)	0.15 (+/- 0.012)*
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	na
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 management (Pretty et al., 2006)*

Origin and spread

Origin: Traditional SIM systems in SSA are mainly based on gravity systems using mountain streams. Spate irrigation is another traditional system, with a long history in the Horn of Africa. In the 1970s -1980s there was much investment in large-scale irrigation projects to intensify agriculture: these often ended in failure, because of either poor governance, or lack of maintenance, or both. In the 1980s investments in irrigation turned to a more integrated approach by financing small-scale irrigation with little or no government support. The use of drip irrigation systems has accelerated over the last decades with the mass production of plastic pipes. Initially it was a capital-intensive system. Recent innovations have helped to make drip irrigation more affordable to smallholders.
Mainly applied in: Burundi, Burkina Faso, Chad, Gambia, Guinea, Kenya, Mali, Niger, Nigeria, Senegal, Sierra Leone, Somalia, Tanzania, Zimbabwe

Spread of Smallholder Irrigation Management in SSA.

Principles and types

'More crop per drop' can be achieved through more efficient use of water:
(1) Efficient water abstraction, storage and distribution: SIM needs emphasis on efficient water storage, abstraction and distribution to the field. Water sources for irrigation can be rivers, lakes, groundwater, or water collected through rainwater harvesting systems (see RWH group). The water can be either abstracted through pumps or wells, or it can be gravity-fed. Treadle pumps, which are food-operated water lifting devices, have been very successfully introduced in SSA for the production of vegetables. More efficient water distribution can be achieved through the usage of pipelines instead of open water channels.
(2) Efficient water application in the field: In a SIM-system the water is used efficiently by applying appropriate quantities at strategic times, principally through providing supplementary irrigation water at particular growth stages. Excessive flooding can be harmful, as it may lead to nutrient leaching, as well as inducing greater evaporation and salinisation. The application of too little water is also wasteful, since it will fail to provide the desired benefits. Under the 'deficit irrigation method' crops are exposed to different levels of water stress resulting in enhanced root development - and thereby substantial saving of water can be achieved while maximum yields can be almost attained.
a) Micro-irrigation techniques are promising systems for increased water use efficiency. Within micro-irrigation, a small volume of water is applied at frequent intervals to the spot where the roots are concentrated. Micro-irrigation techniques are gaining popularity among small-scale farmers, especially those systems using water harvested in tanks and small ponds. The most common micro-irrigation system is drip irrigation.
In a **drip irrigation system**, water flows under pressure through a filter into drip pipes, with emitters located at variable spacings. Water is discharged directly onto the soil near the plants. Drip lines should be placed close to the plants to avoid salt accumulation in the root zone, and to minimise water loss. Fertilizer and nutrients can be applied easily, and more precisely, through the system.
b) Surface irrigation is the application of water by gravity flow to the surface of the field. Either the entire field is flooded, or the water is led into basins, or fed into furrows, or strips of land (borders). Surface irrigation is the main traditional irrigation method and still plays a significant role in SSA. An example is:
Spate irrigation: Floodwater diversion or spate irrigation techniques divert the water from its natural course. Storm-floods are harvested from rainfall-rich highlands, and diverted into levelled basins in the dry lowlands. Floodwater is channelled through a network of different channels. Collection areas may range from anything between a few hectares to over 25,000 ha. The schemes are expensive to construct and difficult to maintain due to frequent bund breakages during floods. Spate irrigation is mainly applied in Ethiopia, Eritrea, Kenya, Senegal, Somalia and Sudan.
Informal irrigation can be defined as the irrigation sector established purely by land users without public funding (often synonymously with smallholder irrigation). Informal irrigation is widespread in urban and peri-urban agriculture, especially in West Africa. It is common in market gardening of cash crops. Intensive irrigation relies mainly on watering cans, due to its low investments costs and precise water application, yet it is labour intensive. The value of urban agriculture and informal irrigation is still underestimated in SSA.

Top: Water distribution for irrigation, Kenya. (Hanspeter Liniger)
Middle: Large private vegetable producer using watering cans for irrigation, Senegal. (Christoph Studer)
Bottom: Detail of a drip irrigation system: water from the pipe is being emitted directly onto the soil close to the plant, Niger. (William Critchley)

Applicability

Land degradation addressed

Water degradation: aridification – decrease of average soil moisture content, overuse / over-abstraction of surface and groundwater / aquifer level due to inefficient water use and too high demand on irrigation water
Physical soil deterioration: waterlogging, sealing and crusting through inappropriate irrigation management
Chemical soil deterioration: salinisation of soil through inappropriate irrigation management and through bad quality of irrigation water
Unsuitable for areas prone to salinisation where salts cannot be washed out by drainage.

Land use

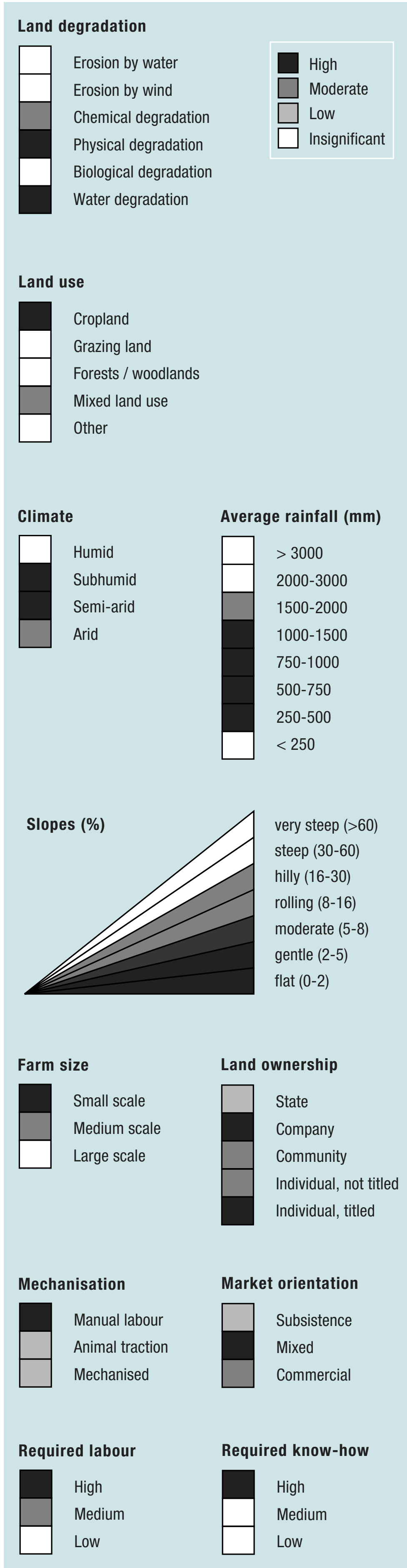
Mainly used on cropland and mixed land and in homegardens for food and cash crops (vegetables, fruit trees, etc.), rice, cotton, etc.
Sometimes used for establishment of tree plantations.
Micro-irrigation system mainly used for vegetables, fruits and cash crops or for tree seedlings and establishment of trees.
Spate irrigation is used mainly for cereal crops.

Ecological conditions

Climate: Mainly for semi-arid and subhumid areas, partly for arid areas. Smallholder irrigation systems are valid options in almost all types of agro-ecological zones. They are naturally most relevant in areas where water is a constraint to crop production, and where water resources are limited, very variable or overused: thus in semi-arid to subhumid zones. Drip irrigation systems are very suitable for water-scarce areas. In arid areas with annual rainfall of less than 500 mm, irrigation management is mainly related to permanent rivers, based on water harvesting methods, or withdrawals from groundwater.
Terrain and landscape: Spate irrigation requires a highland catchment area which supplies runoff in seasonal or ephemeral rivers. Drip irrigation can irrigate sloping land and even quite steep slopes.
Soils: No restrictions, apart from soils with high sodium (Na) content (sodic soils); needs good management on heavy clays due to risk of waterlogging. Drip irrigation can reduce or eliminate runoff and deep percolation, making it possible to irrigate difficult soils – e.g. crusting or porous soils, through frequent and controlled application of water.

Socio-economic conditions

Farming system and level of mechanisation: Traditional irrigation systems are mainly applied on small-scale farms. Modern irrigation systems were used originally on large-scale farms. The newly popularised system of drip irrigation, for example, is now also affordable and suitable for small-scale farming due to the development of smaller units and kits for smaller areas, tended by hand. Smallholder irrigation systems are mainly maintained with manual labour.
Market orientation: SIM can be used for subsistence and small-scale farming. Irrigation can help farmers to move from solely subsistence to a mixed subsistence / commercial system.
Land ownership and land use / water rights: SIM-systems are normally privately owned by the land users or land user groups, therefore secure rights and full control over water are essential for the users. Additional permits for the use of scarce water resources may be needed.
Skill / knowledge requirements: Needs high level of knowledge for the establishment, and also for the maintenance, of the system (especially micro-irrigation systems). Timing and amount of water application requires considerable skill.
Labour requirements: Depending on the system, the labour requirements are medium to high; a spate irrigation system needs higher labour inputs for establishment than micro-irrigation. The maintenance of a drip irrigation system can be very demanding, but the labour days needed for watering can be significantly reduced through the implementation of drip irrigation, compared to watering with cans.



Economics

Establishment and maintenance costs

Establishment costs for SIM-systems vary considerably. Drip irrigation systems carry relatively high investment costs. Some traditional systems are (or were) high in initial labour – where for example intricate networks of channels brought water down from highland streams. Maintenance of the latter has almost always been carried out with no external support. If the costs for a drip irrigation system are worked out per hectare then the prices appear high. Yet it is the low incremental cost that allows land users to start on a small area (e.g. for horticultural production). The costs for small-scale drip kits have decreased dramatically which makes them now affordable for small-scale users. Even so it still requires initial investment and hence access to micro-credit: this means it is not a possibility for the poorest of land users. Land user groups provide an opportunity for joint investment in the equipment.

SIM-system	Establishment costs
Drip irrigation: Bucket system (for home gardens) Drum kit irrigation system Farm kit drip irrigation	5 US$ for 50m² ➜ 2,000 US$ per ha 10 US$ for 40 m² ➜ 2,500 US$ per ha 25 US$ for 125 m² ➜ 2,000 US$ per ha 424 US$ with 1,000 litre tank, for 2,500 plants per one-eight acre (= 500 m²) 150–240 US$ for 1,000 m² ➜ 1,500 – 2,400 US$ per ha
Treadle pump	50-120 US$ per pump (for about 0.4 ha)
Spate irrigation systems	1,000 US$/ha

(Sources: FAO, 2001; GTZ, 2001; Grid, 2008)

Maintenance costs for SIM cannot be neglected: drip irrigation systems, especially, need careful maintenance. However, the implementation of a drip irrigation system in place of watering with cans lessens the labour input, reduces the water used and therefore the fuel costs. An example based on drip irrigation introduced in an African Market Garden system (AMG: see case study) has shown a reduction in workload from 240 man hours when irrigating with watering cans compared to 90 man hours with drip irrigation in the AMG system.

Production benefits

	Yield without SLM (kg/m²)	Yield with SLM (kg/m²)	Yield gain (%)
	Traditional irrigation	AMG* system	
Lettuce (Niger)	1.14	1.95	+ 70%
Onion (Ghana)	1.21	1.65	+ 36%

**AMG: African Market Garden system based on drip irrigation and crop species selection (Woltering, et al., 2009).*

Comment: The figures presented above show the higher crop yield for the AMG system compared to the traditional system with watering cans. Beside the improved irrigation system the crop varieties selected also influence the yield.

Benefit-Cost ratio

Irrigation system	short term	long term	quantitative
Drip irrigation	+	+++	AMG* (50 m²), Burkina Faso: Return to labour: 12.6 US$/day Return to land: 1.7 US$/m²
Bucket kit	+	+++	Income / cost per bucket kit, Kenya: 26-40/15 US$
Spate irrigation	++	+++	
Overall	+/++	+++	

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive;
**AMG: African Market Garden system based on drip irrigation and crop species selection (Source: Mati, 2005; Woltering, et al., 2009)*

Comment: The AMG system clearly shows the profitability of drip irrigation, which is around double that of traditional irrigated gardens. The returns to labour are about three times higher for the AMG than for the traditional system.

Example: *A simple bucket system costing US$ 10, allowing the irrigation of 40 m², represents an investment of US$ 2,500 per ha, which, depreciated over 2-3 years, results in annual depreciation costs of US$ 833 – 1,250 per ha. In comparison, some gravity-based communal schemes providing water for an irrigation area of 100 ha with high initial investment costs can be depreciated over 5 years at a rate of US$ 400/ha. Despite the large difference in investment costs per ha, the small units are on a par with the larger schemes with respect to the financial income they are able to generate (GTZ, 2006).*

Example: Zambia
In Zambia, treadle pumps could significantly increase incomes of small-scale land users. With the former used bucket irrigation system the income achieved was about 125 US$ per 0.25 ha of land, whereas with treadle pumps the income increased to 850-1,700 US$. This was attributed not only to increased crop yields, but also to the greater area of land irrigated. Cropping intensity rose in some cases by 300% with an associated increase in crop varieties. Because of the better water availability land users were more willing to invest in new crops (FAO, 2001).

Example: African Market Gardens in the North of Benin
Studies conducted through ICRISAT and partner organisations in West Africa have clearly shown the high profitability of African Market Gardens (AMG). The profitability of AMG is around double that of vegetable gardens irrigated with traditional methods. Returns to labour are more than three times higher for AMG and the investment can be paid back in little more than one year. The payback period can even be shorter if the investments are made through a land users / commune group. (Woltering, et al., 2009)

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	+++ informal irrigation in urban areas helps to diversity livelihoods and diets of the poor dwellers +++ higher crop yields ++ enhanced productivity of labour and land ++ increased diversity of cropping	++ reduced risk of crop failure	+++ improved food and water security
Economic	+++ increased income and new income streams + reduced labour (through reduction of weeds, because no watering between plants and less time needed for watering)	++ stimulation of economic growth ++ new labour opportunities for landless labourers + less damage to off-site infra-structure	+++ improved livelihood and well-being
Ecological	++ through more efficient water use reduced pressure on water resources ++ allows to produce crops in the off-season if water storage available + micro-irrigation: reduced salinisation hazard: through reduced evaporation and salt accumulation on soil surface + reduced soil erosion (by water / wind) + improved soil cover + increased soil fertility + biodiversity enhancement + improved micro-climate	++ increased water efficiency and reduced pressure on water resources	
Socio-cultural	++ strong gender component, as marketing of vegetables is the domain of women	+ increased awareness for environmental 'health' + attractive landscape	+ protecting national heritage

	Constraints	How to overcome
Production	• Lack of reliable water supply • Land users tend to use more water than needed by using a micro-irrigation system, since water can be applied more easily	➜ storage facilities (but has additional cost) ➜ needs good training of the land users
Economic	• Lack of market access and incentives for agricultural intensification • Lack of market for low cost irrigation material • High investment costs especially a problem for poor land users • Requires a high level of technical knowledge also for maintenance of the system	➜ promoting markets for smallholder irrigation systems ➜ access to credits and financial support to improve the ability to invest in smallholder irrigation systems
Ecological	• Abstraction / overuse of surface water and non-renewable ground and / or fossil water • Waterlogging and salinisation • If dependant on water harvesting or surface water during dry years / periods, water supply for irrigation can be threatened • Over-irrigation facilitates the development of diseases, weed growth and nutrient leaching Drip irrigation: • Salt accumulation at root zone (especially in areas with rainfall <100 mm) • Only a fraction of root zone is wetted, is more susceptible, and depends on the continuous operation of the system	➜ use of improved rainwater harvesting systems to collect and store additional irrigation water ➜ good crop rotation, appropriate irrigation practices, balance supply and demand of water ➜ needs good technical knowledge and appropriate maintenance of the system ➜ regular leaching of salts and drainage for removal of salts is necessary
Socio-cultural	– Over-abstraction of surface and groundwater resources can lead to a decline of river flows and groundwater table and endangering supply of drinking water – Conflicts over water	➜ specialists providing technical and economic information are needed ➜ proper planning and regional assessment of water resources as well as restricted allocation of irrigation water

References and supporting information:

Andersson, L. 2005. Low-Cost Drip irrigation – On farm implementation in South Africa. Master Thesis, Master of Science Programme, Environmental Engineering, Lulea University of Technology.
Community spate irrigation. 2009. http://www.spate-irrigation.org/spate/spatehome.htm, accessed on 28 September 2009.
FAO. 1988. Irrigation Water Management: Irrigation Methods. Irrigation Water Management, Training Manuals – 5. Prepared jointly by C. Brouwer and K. Prins, M. Kay, M. Heibloem.
FAO. 1997. Small-scale irrigation for arid zones. http://www.fao.org/docrep/W3094E/w3094e00.htm
FAO. 2001, Smallholder irrigation technology: prospects for sub-Saharan Africa. International Programme for Technology and Research in Irrigation and Drainage Knowledge Synthesis Report No. 3 - March 2001 Melvyn Kay FAO/IPTRID Consultant.
FAO. 2008. Water and Rural Poverty - Interventions for Improving Livelihoods in Sub-Saharan Africa.
Grid. 2008. International Programme for Technology and Research in Irrigation and Drainage (IPTRI), Issue 28, February 2008.

Adoption and upscaling

Adoption rate

SSA shows one of the lowest degrees of investment in irrigation among developing regions, and recent surveys do not show any sign of change, the annual increase in irrigation being slightly more than 1% between 1995 –2005.

Upscaling

The adoption of small-scale irrigation systems will also be determined by the capacity of land users to take risks in the uptake and investments with a new technology. Therefore the following aspects are crucial:

Reliable water supply: The access to reliable supply of water is often the major constraint to irrigation.

Profitability: The benefit-cost ratio must make it worthwhile for land users to invest in irrigation. For poor land users the high investment cost and the payback time pose a major obstacle.

Access to financial services: The financing and managing of irrigation systems need to be market-driven and are to a large degree the responsibility of smallholders. The self-financing capacity of farmers needs to be strengthened and credit must be easy accessible to smallholders. Land user groups / community organisations can be an opportunity for poor land users to receive credit and to make the initial investment.

Access to markets and infrastructure: Functioning markets and market access is a prerequisite for the success of SIM. Irrigation can help subsistence land users to become more market-oriented.

Market for low-cost drip irrigation systems: Even though a market very often exists for equipment generally, low-cost drip irrigation systems may be hard to obtain. Therefore, setting up a working supply chain and ensuring sufficient manufacturing capacity is essential.

Technical support and capacity development: The utilisation of the full potential of irrigation production needs adequate training and technical support for the land users also for appropriate water application and maintenance of the system. Competent specialists providing technical and economic information are needed.

Policy: Usually a Ministry of Agriculture is separate from a Ministry of Water, which often leads to administrative confusion and administrative hurdles. The water and agricultural sector must be coordinated.

If an irrigation system is used in common, the number of users sharing the infrastructure should be low. Operational simplicity is a major criterion for the success of small-scale community-based irrigation schemes.

Comment: The dream of many land users in SSA to increase production and income with irrigation is limited by the availability of water. Already today, scarce water resources are often overused. Therefore, the main aim should be to improve water use efficiency and to develop more decentralised smaller irrigation systems without causing land or water degradation.

Incentives for adoption

For SIM to be used by individuals these ideally should not be subsidised but should be self-financed by land users. For that reason, the access to micro-credit must be ensured. Yet, SIM techniques are still only accessible to land users who can afford to buy them or to access micro-credit. Therefore poorest land users need appropriate financial and technical support for the establishment of a SIM system.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	+++
Training and education	++
Land tenure, secure land use rights	+++
Access to markets	+++
Research	++
Infrastructure	++

Example: Kenya

In the study conducted by Kulecho and Weatherhead (2006) NGOs were asked what they considered as the main problems for smallholder irrigation in Kenya. The systems used were mainly drip, furrow and sprinkler systems. The results showed that the highest number of responses were related to the problem of crop marketing, low-cost drip irrigation maintenance, followed by water supply problems. The report clearly showed that farmers need adequate technical support, reliable water supplies, and affordable access to markets if they are to maximise the economic and poverty-reducing benefits of low-cost drip systems.

Example: Burkina Faso and Niger

ICRISAT has introduced the African Market Garden (AMG) system as a commercial irrigation and production system in Niger. There was little follow-up and in most cases non-educated land users were left on their own to operate the systems, which resulted in zero maintenance. Only 4 years after the implementation 20% of the systems were still found operational. The producers who abandoned the systems found that there were no clear savings in labour and water. Based on these experiences a new project started in Burkina Faso. This time only the wealthier small-scale farmers were approached and they paid 70% of the investments. Most of the systems are still operational. It demonstrates that the more educated and the wealthier a producer is, the more likely he / she is to adopt small-scale drip irrigation (Woltering, et al., 2009).

References and supporting information (continued):

GTZ. 2006. Financing Small-scale Irrigation in Sub-Saharan Africa. Grimm J., M. Richter. Volume 1: Desk Study, December 2006. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH, Commissioned by The World Bank .

IWMI. 2007. Recognising Informal Irrigation in Urban and Peri-Urban West Africa. Water Policy Briefing, Issue 26.

Pretty, J. N., A. D. Noble, D. Bossio, J. Dixon, R. E. Hine, F. W. T. Penning de Vries, and J. I. L. 2006. Resource-conserving Agriculture Increases Yields in Developing Countries. Environmental Science & Technology, Vol. 40, No. 4.

Kulecho,I.K. and K. Weatherhead. 2008. Issues of irrigation of horticultural crops by smallholder farmers in Kenya. Irrig Drainage Syst (2006) 20:259–266

Mati, B. M. 2005. Overview of water and soil nutrient management under smallholder rainfed agriculture in East Africa. Working Paper 105. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Mati, B. M. 2008. Capacity Development for Smallholder Irrigation in Kenya. IRRIGATION AND DRAINAGE. Irrig. and Drain. 57: 332–340 (2008)

Postel, S., P. Polak, F. Gonzales, and J. Keller. 2001. Drip Irrigation for Small Farmers - A New Initiative to Alleviate Hunger and Poverty. International Water Resources Association. Water International, Volume 26, Number 1, Pages 3–13, March 2001

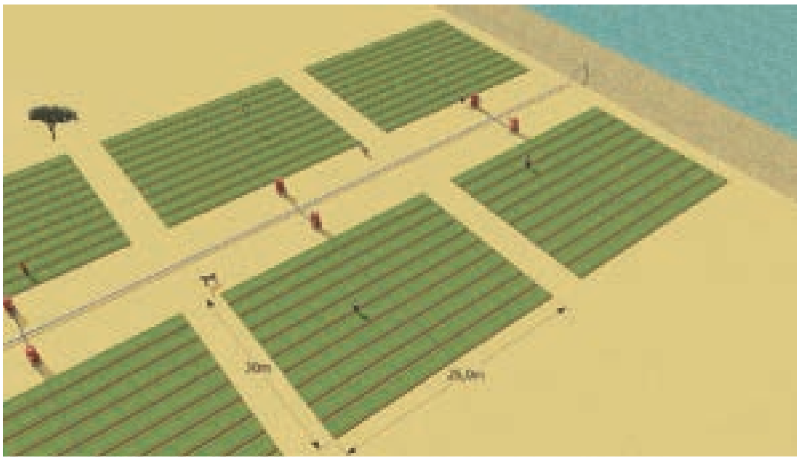
Woltering, L., D. Pasternak, and J. Ndjeunga. 2009. The African Market Garden: Development of an Integrated Horticultural Production System for Smallholder Producers in West Africa. Submitted to Irrigation and Drainage.

AFRICAN MARKET GARDENS - SENEGAL

The African Market Garden (AMG) is a horticultural production system based on low-pressure drip irrigation. According to the level of experience, market orientation or social structure of the land users, four different AMG models have been developed. This case study focuses on the 'Cluster System' which is suitable for an organised group of independent vegetable producers sharing a common water delivery system.

From a central source, water is distributed through a pipe network to a cluster of plots. Each farmer operates a 1,000 m^2 unit, and each is equipped with an elevated 200 litre barrel and a standard irrigation kit, including a tap, filter and thick-tube drip laterals. Minimal size of an AMG unit should be 500 m^2. Affordable high-quality material is used and the design and operation is simple. The barrel also serves as a fertilizer tank. A float ensures a constant pressure head. Water supply is calculated by the time needed for delivery of the daily water dosage, or through the use of water dosing valves. Producers have individual control of water use. Since the AMG requires only 1 meter pressure for operation, it can draw on low-capacity renewable energy sources such as elevated dams, solar pumps or reservoirs. To supply an area of 50,000 m^2 with 8 mm/day in the hot season a 400 m^3-reservoir is required. The crops are planted on elevated beds. Water mixed with urea as fertilizer is applied daily. Drip irrigation improves growing conditions for crops while at the same time saving labor, water and other inputs.

AMG is promoted as a holistic management package, integrating all aspects of production, post-harvest and marketing in one system. This includes the use of improved vegetable varieties, improved crop husbandry, integrated pest management, as well as improved storage, processing and marketing of products, and improved access to inputs.



SLM measure	Agronomic
SLM group	Smallholder Irrigation Management
Land use type	Annual crops: vegetables; Tree crops: fruit trees
Degradation addressed	na
Stage of intervention	Prevention
Tolerance to climate change	AMG especially suitable for seasons with high evapotranspiration demand, because AMG permits daily irrigation that eases water stress

Establishment activities

1. Build concrete reservoir.
2. Drill borehole (110 mm diameter; 12 m deep, hand drilled).
3. Install motor pump and tubes to connect well with reservoir.
4. Install drip kit with tap, filter and drip laterals (8-16 mm in diameter).
5. Establish a fence to protect the garden.

Maintenance / recurrent activities

1. Prepare elevated beds with a basic dressing of 4 kg/m^2 manure and 0.1 kg/m^2 NPK fertilizer biannually.
2. Add urea to irrigation water (concentration: 50-100 ppm N).
3. Operate water supply system.

Labour requirements

For establishment: high
For maintenance: low

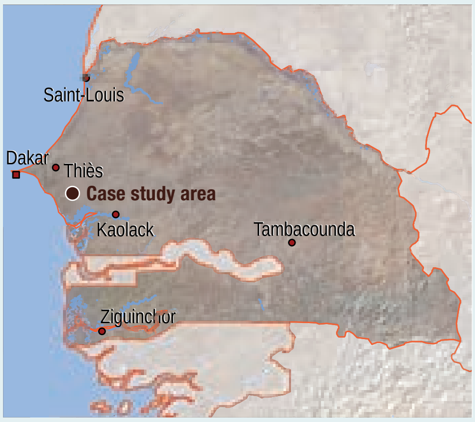
Knowledge requirements

For advisors: high
For land users: high

Remark: Installation of the system requires basic knowledge on engineering for the sizing of the PVC distribution network.

Photo 1: AMG system with elevated barrels for irrigation of cash crops (okra) through drip laterals. (ICRISAT)
Technical drawing: Cluster system with several AMG plots connected to a central water source - in this case a small elevated dam. (ICRISAT)

Case study area: Ngoyé Ndioffogor and Mbassis Tatadem, Senegal



Establishment inputs and costs per unit

Inputs	Costs (US$)
Drip system	300
Oil drum (200 l)	56
Well / borehole	16
Motor pump (3 hp)	34
Farming tools	65
Fence	25
PVC connections	79
TOTAL	**575**

Maintenance inputs and costs per unit and year

Inputs	Costs (US$)
Labour, fuel and agricultural inputs	510
TOTAL	**510**

Remarks: A unit corresponds to the area irrigated by one producer (= 500 m^2). Establishment costs include labour inputs (2 US$ per person-day). Annual maintenance costs include labour, fuel and agricultural inputs (e.g. fertilizer, seeds; based on ICRISAT recommended rates). For a 1,000 m^2-unit prices are doubled (except for tools and fence).

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	very positive
Maintenance	very positive	very positive

Remarks: Payback period is only 6 months. Net income per farmer after all deduction is about US$ 1,000 per year. The profitability of the AMG is around double that of vegetable gardens irrigated with traditional methods.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 400-500 mm
- Soil parameters: sandy soils, low fertility and organic matter content
- Slope: flat (0-2%)
- Landform: plains
- Altitude: no data

Socio-economic conditions

- Size of land per household: no data
- Type of land user: small to medium-scale, land user groups, poor to average level of wealth
- Land ownership: individual (titled)
- Land use rights: individual - secure land use rights are a precondition
- Level of mechanisation: manual labour / mechanised
- Market orientation: commercial
- AMG is suitable for urban / periurban areas where producers have access to credit, markets, technical support
- Strong organisation in groups is important for the maintenance of the system and for access to training / backstopping

Production / economic benefits

+++ Reduced production costs: costs for drip irrigated gardens are 50% lower than for traditional irrigated gardens due to savings in labour, water and consequently in fuel

+++ Reduced workload: total workload for AMG is 11.5 man-days compared to 30 man-days in traditional irrigation system

+++ Increased income due to doubled profits from vegetable production (compared to traditional irrigation methods)

Ecological benefits

+++ Improved water availability / reduced pressure on water resources

+++ Reduced evaporation / effective use of water due to accurate and equal distribution of water at optimal rates

+++ Effective application of fertilizer with the water

Socio-cultural benefits

+++ Improved nutrition and food security through year-round availability of quality vegetables and fruits

+++ Improved knowledge on irrigation techniques / horticulture

+++ Improved organisation (farmer associations, user groups, etc.)

Weaknesses ➜ and how to overcome

- Irrigated vegetable production is a capital intensive undertaking ➜ sharing infrastructure, land and water through producer groups can cut investment costs by 60% per unit area. Set-up and operation costs further decrease if producer groups can use communally owned infrastructure and / or alternative energy sources (e.g. elevated dams, solar pumps, artesian well).
- The AMG system is not suitable for farmers with limited access to knowledge, marketing and services ➜ improve access to markets and training programs (for extensionists and farmers); guarantee technical assistance during 2-3 years; target the system to educated producers who make a living out of vegetable production. Set up AMG service and demonstration centres offering credit, farm inputs, marketing support, training and technical advice.

Adoption

AMG is spreading fast in Senegal and Burkina Faso. Cost reduction (e.g. alternative energy sources), collective action and intensive training / backstopping are very important provisions for successful adoption. Upscaling of AMG in dry West Africa will depend on access to technology, inputs, knowledge and organisation, and a conducive institutional environment.

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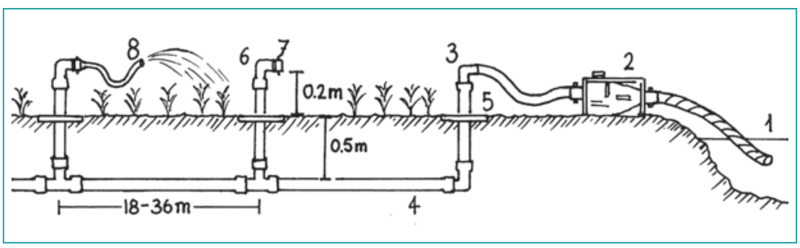
Key references: Woltering L., D. Pasternak and J. Ndjeunga. 2009. The African Market Garden: Development of an Integrated Horticultural Production System for Smallholder Producers in West Africa – Draft Submitted to Irrigation and Drainage 21-10-2009 ■ ICRISAT. 2009. The African Market Garden - Advanced Horticulture for the Poor (Flyer).

LOW-PRESSURE IRRIGATION SYSTEM 'CALIFORNIAN' - SENEGAL

The low pressure pipe distribution system called 'Californian' has proven to be a very efficient irrigation system for smallholder farmers group in Africa. The principle of the Californian system is to convey water to the crops through fixed underground rigid PVC pipes (40–75 mm diameter). The pipe network is buried at 0.50 m depth to avoid deterioration by UV radiation and agricultural practices. Risers with hydrants are fixed to those rigid pipes at regular distance (18-36 m). To each riser a 14 m long flexible hose is attached which can be dragged around to irrigate the individual plots and crops. The installation of the pipe network can be made locally by plumbers. Water is supplied through a pump (manual, pedal or small motor) from a well, a reservoir or a river. From the intake water is conveyed to the highest point of the plot which allows the conveyance to the field's most distant point (irrespective of topographical conditions - upslope or downslope).

The system is remarkably efficient in sandy or salty soils. It is adapted to small–scale farming especially for vegetable crops, rice and tree crops and is suitable for areas ranging between 0.25 - 1 ha; one riser irrigates an area of 500-1000 m^2. The system as such does not require maintenance. In case of deterioration of pipes or fittings, the farmer can easily fix the problem himself or with the assistance of a local plumber. The estimated life expectancy for the Californian system is 6-10 years in West African conditions. Ideal conditions for transfer / adoption of the technology include: (1) availability of shallow aquifers, and other water sources; (2) occurrence of sandy soils and sandy clay soils; (3) clearly defined land legislation and tenure; (4) access to markets and to microfinance institutions.



SLM measure	Agronomic
SLM group	Smallholder Irrigation Management
Land use type	Annual cropping
Degradation addressed	na
Stage of intervention	Prevention
Tolerance to climate change	High tolerance as long as water source is not depleted

Establishment activities

1. Layout of pipe network by putting stakes along the line to indicate the orientation of the canal to be dug.
2. Excavate network of canals (0.2 m wide, 0.5 m deep; straight and regular). In sandy soil the interval between risers is 30 m x 18 m or 36 m x 18 m (intervals are multiples of 6 m = PVC pipe unit length). Density of risers is 10 -15 risers/ha.
3. Install the pipes into the open canals, fittings are assembled by sticking.
4. Install hydrants composed by a 0.2 m high riser, a PVC elbow and a locally made flow control device (plug); the risers are anchored in the soil through a small concrete slab.
5. Put the pipe under flow condition to verify the water tightness of the system.
6. Bury the canals.
7. Protect risers from sun.

Maintenance / recurrent activities

1. Before starting to pump it is recommended to let open one of the hydrants in order to avoid excessive pressure and blasting of pipes.
2. In case of deterioration of the pipes or fittings, land users can easily fix the problem themselves or request the intervention of a local plumber.

Labour requirements

For establishment: medium
For maintenance: low

Knowledge requirements

For advisors: high
For land users: high

Remark: Technical assistance needed for design, installation and operation of the system; installation of pipes is quick and easy; no need for topographical survey.

Photo 1: Hand pump for supply of irrigation water;
Photo 2: Pipes for the distribution of irrigation water are buried in 0.5 m deep canals;
Photo 3: Growing onions on an irrigated plot (All photos by Sourakata Bangoura)
Technical drawing: Dimensions and main components of the low-pressure irrigation system: (1) water source; (2) manual or motor pump; (3) input hydrant; (4) rigid PVC pipes; (5) small concrete slab; (6) elbow; (7) plug; (8) flexible hose for irrigation.

Case study area: Diourbel, Senegal

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	50
Equipment/tools	no data
Construction material	1333
TOTAL	**1383**
% of costs borne by land users	0%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour, equipment, construction material	no data
TOTAL	**no data**

Remarks: If soil is not sandy labour input for establishment increases. Hand or treadle pumps are provided by the project. Motor pumps (with pump capacity 2 HP) increase costs for establishment and maintenance (fuel) but reduce labour inputs for operation.

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	positive	positive

Remarks: The estimated life expectancy for the Californian system is 6-10 years in the West African conditions.

Adoption

Totally 468 farmers (64% of them women) have adopted the technology. Inputs were paid by project. There is high demand for the technology. Full participation of stakeholders in the whole project process and the involvement of local leaders, local NGOs and private companies are prerequisites for successful implementation.

Ecological conditions

- Climate: semi-arid; sudano-sahelian, 9 months dry period: Oct.-June
- Average annual rainfall: 450 mm
- Soil parameters: sandy soils, with low organic matter content, low fertility, good drainage (tropical ferralitic soils)
- Slope: flat or gentle (0-5%)
- Landform: plains
- Altitude: 25 m a.s.l.
- Availability of shallow aquifers, and other water sources is crucial; sandy soils and sandy-clay soils are suitable.

Socio-economic conditions

- Size of land per household: 0.5 ha
- Type of land user: poor small-scale farmers, implemented individually or within farmer groups
- Population density: no data
- Land ownership: mostly individual
- Land use rights: mostly individual
- Level of mechanisation: mostly manual labour and animal traction
- Market orientation: mixed (subsistence and commercial)
- Strong local leadership, long term land use rights and external funding or access to microfinance institutions are preconditions.

Production / economic benefits

+++ Increased crop yield (in combination with improved agricultural inputs (fertilizer, pesticides, seeds)
+++ Increased production area (from 0.1 to 2 ha per farmer group)
+++ Reduced risk of production failure
+++ Increased drinking / household water availability (from < 10 to 20 liters/person-days)
+++ Increased irrigation water availability
+++ Increased farm income and diversification of income sources
++ Increased product diversification

Ecological benefits

+++ Increased water quantity
+++ Reduced hazard towards adverse events (droughts)
+++ Increased plant diversity
+++ Increased soil moisture
++ Increased water quality
++ Reduced surface runoff
++ Reduced salinity
++ Improved soil cover and increased biomass

Socio-cultural benefits

+++ Improved cultural opportunities (pilgrimage to Mecca, marriages, etc.)
+++ Community institution strengthening
+++ Conflict mitigation (group management of irrigation facilities)
+++ Improved food security / self-sufficiency
++ Improved situation of socially and economically disadvantaged groups
++ Improved health

Weaknesses

- Initial investment cost of construction material and equipments.
- Breakage of riser pipes.
- Scarcity of surface water resources, poor water quality (salinity), low water discharge from the shallow wells and boreholes limit the applicability of the system.
- Lack of farmers knowledge on irrigation techniques and lack of qualified personnel for training and supervision hinder successful implementation.

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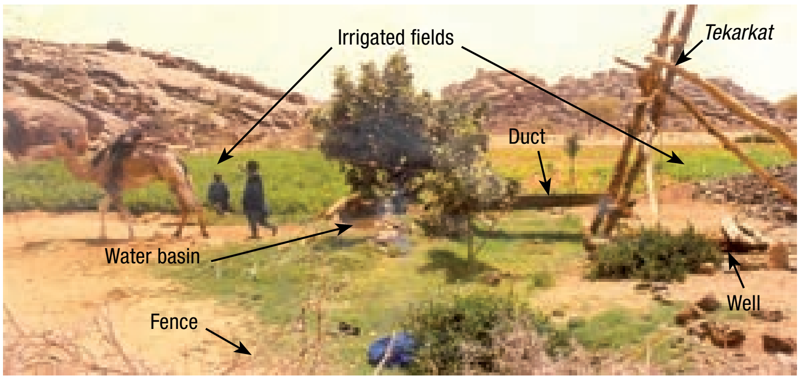
IRRIGATED OASIS GARDENS - NIGER

In the Oasis of Timia in the Aïr, small irrigated gardens (< 0.3 ha) have been used for over a century, producing dates and tree crops (figs, citrus, cherries, etc.) for sale and cereals for consumption (wheat, maize and pearl millet). With the onion boom in the 1990s, the establishment of new gardens grew dramatically. The new gardens cover a bigger area (0.5 - 1 ha) and focus on cash crops - mainly onions, but also potatoes and garlic. Gardens are fenced using branches from acacia trees. The water supply system in most cases is based on traditional wells with an animal-drawn scoop. The wells are less than 20 meters deep and generally built without a casing. Local experts were trained by GTZ project staff in well construction and maintenance. Modern motor pumps have recently become common and are used in new gardens. Water is conveyed to the plots through a hand-dug network of distribution channels. The channels are lined with clay and stones to minimise water loss through infiltration, evaporation, or breaching. Irrigating a whole garden takes about two hours.
There are two cropping seasons per year: the rainy season (June-September) with staple crops such as maize and millet; and the dry / cold season (October-February) with wheat-barley associations and cash crops such as onions, garlic, tomatoes and vegetables. Fruit trees covering up to a fifth of the gardens; one section of the garden is reserved for keeping small ruminants. Agricultural residues are used as fodder and manure produced by livestock ensures fertility of gardens in combination with inorganic fertilizers. Traditional techniques (local plants, ash, etc.) are used for pest management. Seed production and selection is done strictly locally.



SLM measure	Structural and vegetative
SLM group	Smallholder Irrigation Management
Land use type	Annual cropping, Tree cropping
Degradation addressed	Chemical and biological degradation of soil; Soil erosion by water and wind
Stage of intervention	Rehabilitation and mitigation
Tolerance to climate change	Technology is sensitive to drought, temperature increase, floods and storms

Establishment activities

1. Identify and demarcate of a free area to be converted into a garden. Fence area with acacia branches and living hedge.
2. Establish a traditional or cement well, max. 2 m wide and 15-20 m deep (contract with local well builder) in the middle of the field.
3. Installation of traditional water conveyance system (*Tekarkat*): wooden poles hold a pulley which conducts a rope with a scoop for extraction of water from the well. The system is powered by a dromedary. A 5 m duct (palm stem or iron sheet) conducts the water to a small reservoir.
4. Mark and dig irrigation canal system and basins for crop cultivation (8 m^2): Main canal and secondary canals (perpendicular to main canal) are reinforced with clay or stones.
5. Purchase inputs (local market): seeds, seedlings, fertilizer, tools.
6. Plant fruit trees.

Activities 1. and 4. are done collectively. All activities are carried out by manual labour.

Maintenance / recurrent activities

1. Maintenance of fence: replace missing branches; plant new tree seedlings to reinforce the living hedge (biannually).
2. Irrigation (daily).
3. Maintenance of *Tekarkat* and canal system: control (and replace) poles; periodic weeding, cleaning, repair leaks and improve lining with clay/stones (biannually, after harvest).
4. Field preparation and application of organic manure (beginning of each cropping season).
5. Maintenance of well: cleaning (hot season), reinforce walls with cement (if needed).
6. Feeding draught animal using natural grassland and crop residues.

Labour requirements

For establishment: medium to high
For maintenance: medium to high

Knowledge requirements

For advisors: medium to high
For land users: low (indigenous knowledge)

Photo 1: Components of an irrigated oasis garden with a traditional *Tekarkat* water supply system. The dromedary pulls up the water filled scoop.
Photo 2: *Tekarkat* established in an oasis North of Tahoua.
Photo 3: Irrigated gardens in Timia. (All photos by Abdoulaye Sambo Soumaila)

Case study area: Timia oasis, Aïr, Niger

Establishment inputs and costs per 0.5 ha

Inputs	Costs (US$)
Labour: 90 person-days	180
Land (opportunity costs)	400
Equipment: traditional well and *tekarkat*	500
camel / dromedary	400
Other equipment:	200
Agricultural inputs: seedlings (50)	200
TOTAL	**1880**
% of costs borne by land users	100%

Maintenance inputs and costs per 0.5 ha per year

Inputs	Costs (US$)
Labor: 104 person-days	208
Equipment: traditional well and *tekarkat*	100
camel (fodder, health)	1460
Other equipment:	100
Agricultural inputs: seedlings, organic fertilizer	240
TOTAL	**2108**
% of costs borne by land users	100%

Remarks: Cost calculation is based on local land prices and traditional irrigation systems. Maintenance costs include also fodder (for draught animal) and organic manure.

Benefit-cost ratio

Inputs	short term	long term
Establishment	very positive	vey positive
Maintenance	very positive	very positive

Remarks: The technology serves a double purpose: food security and income generation.

Ecological conditions
- Climate: arid
- Average annual rainfall: <120 mm
- Soil parameters: sandy soils, with usually good drainage, medium water storage capacity, medium soil fertility and soil organic matter; and low soil depth
- Slope: mostly flat (0-2%) in oasis
- Landform: mainly mountains, valley floors
- Altitude: 800 m a.s.l.

Socio-economic conditions
- Size of land per household: <1 ha
- Type of land users: individuals / families; mainly poor land users
- Population density: 10,000 persons/km^2 (oasis)
- Land ownership: mostly individual, untitled
- Land use rights: individual, communal (unorganised)
- Market orientation: mostly subsistence (self-supply), partly mixed (subsistence and commercial)
- The land user can be (1) the owner of the garden; (2) a family member managing the family-owned garden; (3) a paid labourer; (4) a usufructuary

Production / economic benefits
+++ Increased crop yield, fodder and animal production
+++ Increased fodder quality and animal diversity
+++ Increased farm income

Ecological benefits
+++ Improved soil cover
+++ Reduced wind velocity and soil loss
+++ Increased soil fertility
(+++Increased biomass / above ground carbon)
++ Reduced fire risk

Socio-cultural benefits
+++ Conflict mitigation
+++ Community institution strengthening through mutual aid in technology implementation
+++ Improved cultural opportunities
+++ Improved food security

Off-site benefits
++ Reduced damage on public / private infrastructure
+++ Reduced wind transported sediments

Weaknesses ➜ and how to overcome
- High implementation costs ➜ establish national financial support systems for acquisition of garden area by very poor people.
- High maintenance costs ➜ promote efficient irrigation technologies that reduce maintenance costs (such as drip irrigation).
- Uncontrolled spread of the technology resulting in an overexploitation of groundwater and over-production of e.g. onions ➜ increase water use efficiency; regulate market and promote agro-industrial food processing.
- High dependency on climatic factors influencing the recharge of the groundwater level ➜ exploitation of deep water resources through artesian wells and introduction of adapted drip irrigation technologies.

Adoption
The gardens are traditional with a high trend of spontaneous adoption. The technology was an answer to the successive droughts in the 1970ies and 1980ies which have caused heavy livestock losses in the region. Pastoralists adopted the technology to diversify their livelihoods and minimise risk. Since the 1990ies, 700 new irrigated gardens were established in Timia (as compared to 100 gardens).

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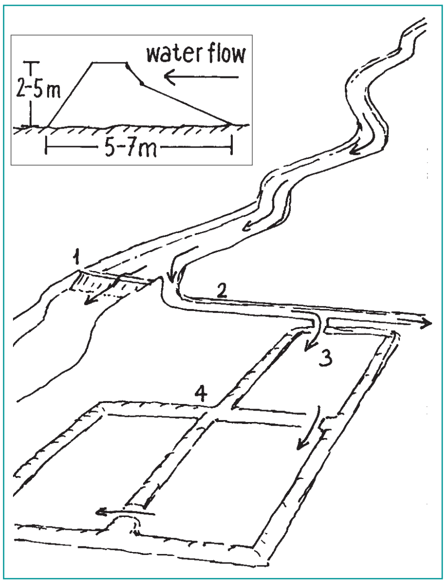
Key references: Suchantke, J. and A. S. Soumaila. 2001. Etude cadre pour le programme NIGETIP IV, KfW, Niamey, Niger ■ Soumaila, A. S., 2005. Rapport du symposium international sur le développement des filières agropastorales en Afrique organisé par GREAD. ■ UCMA. 2005, 2007, 2008, 2009. Rapports annuels de commercialisation ■ PPEAP. 2006. Rapport final d'évaluation du projet de promotion des exportations agropastorales ■ Ministère du développement agricole. 2008, 2009. Données statistiques sur la production maraichère.

SPATE IRRIGATION - ERITREA

Spate irrigation has a long history in Eritrea and still forms the livelihood base for rural communities in arid lowlands of the country. It is a traditional water diversion and spreading technique under which seasonal floods of short duration – springing from the rainfall-rich highlands – are diverted from ephemeral rivers (wadis) to irrigate cascades of leveled and bunded fields in the coastal plains. The diversion structures include the following elements: (1) the '*agim*', a temporary 3-4 m high river diversion structure on the low-flow side of the wadi, made from brushwood, tree trunks, earth, stones and / or boulders, erected to divert a large part of the flow during a spate flow to adjacent agricultural fields; (2) a primary, and several secondary distribution canals; unlined, bordered by earthen embankments; convey and spread the floodwater to the irrigable fields; (3) the fields, rectangular shaped, of about 1–2 ha, separated by earthen bunds. Floodwater is distributed from field to field: when a field is completely flooded (to a depth of about 0.5 m), water is conveyed to the immediate downstream field by breaching one of the bunds. This process continues until all the water is used up. Arable fields need to be flooded several times.
The water soaks deep into the soil profile (up to 2.4 m) and provides moisture sufficient for two or even three harvests: crop growth is entirely dependent on the residual soil moisture. The main crop grown is sorghum; maize is the next most important. Sedimentation is as important as water management: With each flood, soil is built up by depositing rich sediment on the fields. Due to the force of the floods, the diversion structures are frequently damaged and / or washed away. Reconstruction and maintenance are labour-intensive and require collective community action. Elaborate local regulations, organisation and cooperation at the community level are prerequisites for successful management of spate irrigation systems.



SLM measure	Structural
SLM group	Smallholder Irrigation Management
Land use type	Annual cropping
Degradation addressed	na
Stage of intervention	na
Tolerance to climate change	Tolerant to climatic extremes (adapted to unpredictable heavy floods)

Establishment activities

1. Construction of diversion structure (*agim*).
2. Construction of main distribution canal.
3. Construction of secondary distribution canals.
4. Leveling of fields.
5. Establish embankments around fields and within fields.

All activities are carried out by manual labour and animal traction, before the highland rainy season.

Maintenance / recurrent activities

1. Reconstruction / repair of diversion structures (2-4 times/year; collective community action).
2. Annual desilting / repair of distribution canals.
3. Annual raising of bund heights due to silting up of fields.
4. Flood fields (community action, during highland rainy season: July-September). Most likely a field receives 3 irrigation turns, on a bi-weekly interval between any 2 turns.
5. Soil tillage (15 cm deep; using oxen-drawn plough) to break capillary uplift of soil water and to create evaporation barrier (end of the flooding season).
6. Sowing (10 days after last flooding; Mid September).

Labour requirements

For establishment: high
For maintenance: high

Knowledge requirements

For advisors: high
For land users: high

Photo 1: Social organisation and community action are prerequisites for spate irrigation systems: construction of an *agim* in a dry river bed. (IFAD)
Photo 2: Fertile sediments and spate irrigation result in high sorghum yields. (IFAD)
Technical drawing: Cross section of an agim (top left); Components of a traditional spate irrigation system: (1) agim; (2) main distribution canal; (3) irrigated fields; (4) earthen embankments. Arrows indicate the water flow. (Mats Gurtner)

Case study area: Wadi Laba, Sheeb area, Eastern lowlands, Eritrea

Establishment inputs and costs per unit

Inputs	Costs (US$)
Labour: 12 person-days	no data
Equipment / tools: 4 camel-days, 10 pairs-of-ox-days, scouring and tillage implements, shovels	no data
Agricultural inputs: none	no data
Construction material: tree trunks, brush-wood, stones, boulders, earth	no data
TOTAL	**60**
% of costs borne by land users	100%

Maintenance inputs and costs per unit* and year

Inputs	Costs (US$)
Labour	no data
Equipment: camels, oxen, scouring and tillage implements	no data
Agricultural inputs: none	no data
Construction material: tree trunks, brush-wood, stones, boulders, earth	no data
TOTAL	**48-96**
% of costs borne by land users	100%

* unit = 10 m long *agim* (1 m high, 3 m wide), constructed with mixed material (stones, earth, brushwood)

Remarks: Data on labour inputs for construction / maintenance of canals and field bunds are not included, therefore not included in the tables above. Costs for *agim* reconstruction are 40% of establishment. Total maintenance costs depend on the number of reconstructions during normal spate season (2-4 times). The yearly cost (establishment and maintenance) reaches US$ 60-156.

Benefit-cost ratio

Inputs	short term	long term
Establishment	no data	no data
Maintenance	no data	no data

Ecological conditions

- Climate: arid (hot, high evapotranspiration)
- Average annual rainfall: < 200 mm
- Soil parameters: very deep and fertile soil (alluvial silts), formed by annual sedimentation; well drained, soil texture: loams to silt loams
- Slope: flat (0-2%)
- Landform: plains (alluvial plains of the coastal area)
- Altitude: 200 m a.s.l.
- The alluvial plains are cut through by wadis discharging into the Red Sea. The spates account for 65% of the annual flow volume. 75% of the irrigated land in Sheeb is watered by the main wadi. Floodwater is unpredictable in timing and volume, and has high destructive potential.

Socio-economic conditions

- Size of land per household: no data
- Type of land user: small-scale, poor to very poor land users; water management carried out communally, crop management individually
- Population density: low
- Land ownership: state
- Land use rights: individual
- Level of mechanisation: manual labour and animal traction

Production / economic benefits

+++ Increased crop yield
+++ Increased fodder production (residues are fed to livestock)
+++ Increased production area (without irrigation, agricultural production is not possible)
+++ Increased water availability
+++ Increased farm income

Ecological benefits

+++ Improved harvesting / collection of water
+++ Increased soil moisture
+++ Increased soil fertility

Socio-cultural benefits

+++ Improved food security
+++ High level of cooperation and organisation on community level

Weaknesses ➜ and how to overcome

- Highly labour-intensive and time consuming maintenance; water diversion structures are frequently breached / washed away by heavy floods; canals are obstructed through deposition of boulders, gravel and coarse sediments ➜ yearly repair / reconstruction is required.
- Great demand for wood: huge numbers of trees are annually needed for (re-) constructing diversion structures.
- Irrigation efficiency is only about 20% because of the difficulty of controlling large amounts of water in a short period of time (and often at night) and because water is lost by percolation, seepage and evaporation ➜ to overcome all 3 problems, recommendations focus on building permanent flood diversion and distribution structures which: (1) withstand the force of heavy floods and divert the water effectively; (2) eliminate the need to cut trees; (3) reduce human and animal labour inputs; (4) increase productivity. Lining the main canals with cements would reduce water loss by percolation and seepage. Proper leveling of basin fields helps to distribute the floodwater uniformly.

Adoption

Spate irrigation is an indigenous technology, originally introduced from Yemen. Spontaneous spread takes place throughout the lowlands. Current spate irrigation area in Eritrea is 16,000 ha. Potential area is estimated at 60,000–90,000 ha.

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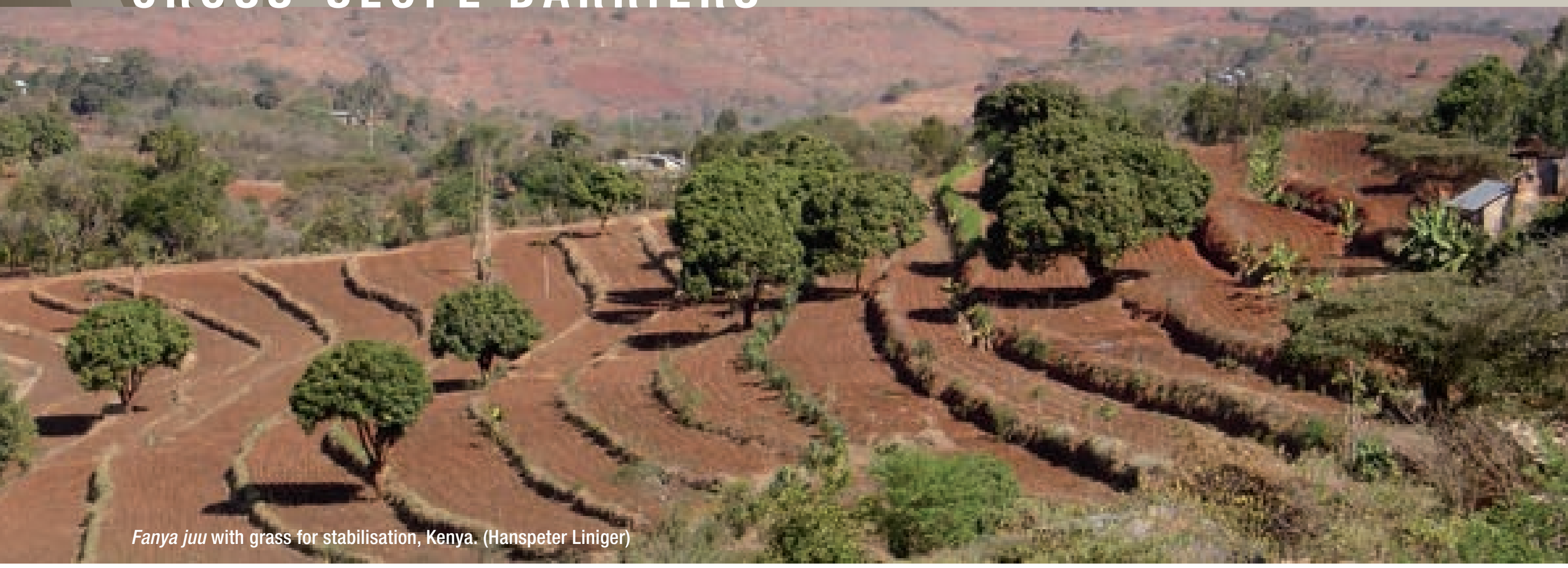
Key references: Abraham Mehari H, Van Steenbergen F, Verheijen O, Van Aarst S:Spate Irrigation, Livelihood Improvement and Adaptation to Climate Variability and Change; ■ Mehretab Tesfai Stroosnijder L:The Eritrean spate irrigation system ■ Abraham Mehari, Depeweg, H, Schultz B (2005): Hydraulic Performance Evaluation of The Wadi Laba Spate Irrigation System in Eritrea, in Irrigation and Drainage. 54: 389–406; online: Wiley InterScience (www.interscience.wiley.com). ■ Berhane Haile G, Van Steenbergen F: Agricultural Water Management in Ephemeral Rivers: Community Management in Spate Irrigation in Eritrea; in African Water Journal ■ Berhane Haile G: Community Spate Irrigation in Bada, Eritrea ■ Mehretab Tesfai, Stroosnijder L (2000): The Eritrean spate irrigation system; on-line: linkinghub.elsevier.com/retrieve/pii/S0378377400001153

CROSS-SLOPE BARRIERS



Fanya juu with grass for stabilisation, Kenya. (Hanspeter Liniger)

In a nutshell

Definition: Cross-slope barriers are measures on sloping lands in the form of earth or soil bunds, stone lines, and / or vegetative strips for reducing runoff velocity and soil loss, thereby contributing to soil, water and nutrient conservation. This is achieved by reducing steepness and / or length of slope. Terraces are not usually constructed per se, but rather develop gradually behind earth bunds, vegetative strips (usually grass) or stone barriers, due to soil movement from the upper to the lower part of the terrace. Erosion between the barriers helps to achieve the levelling of the terrace bed. While cross-slope barriers are primarily intended to reduce soil erosion, they also enable / ease cultivation between the barriers, which are usually sited along contours. However, in high rainfall areas they may be graded at 0.5 – 2.0% across the slope to allow safe discharge of excess surface water along the barriers to reach watercourses. Some common technologies used by smallholder farmers include contour bunds, *fanya juu* and *fanya chini* terraces, stone lines and vegetative barriers. Bench terraces can be the eventual result – though in some circumstances may be constructed through excavation and shaping.
To ensure sustained fertility of the land it is necessary to employ soil fertility management measures such as composting, green manures, cover crop, etc. (see group on Integrated Soil Fertility Management).
Applicability: Applicable from gentle to steep slopes. Suitable for the whole range of arid to humid areas; in subhumid and humid areas cross-slope barriers are used for protection against soil erosion, whereas in semi-arid areas they are employed for in-situ water conservation and even water harvesting purposes.
Resilience to climate variability: Terraces and vegetative strips can, to a certain extent, cope with extreme rainfall events.
Main benefits: Improved water management through reduced soil erosion by water in subhumid areas, increased water infiltration and storage in semi-arid areas - hence helping to maintain soil fertility, increase crop yields and food security.
Adoption and upscaling: Depending on the type of measure, very often the investment costs for establishment exceed the short term benefits. Due to these high initial costs, incentives to compensate land users for part of the establishment investments may be needed. However, land users and communities should be able to maintain the system without any external support.

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	na
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)	0.5-1.0*
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	+

** based on expert estimation for a duration of the first 10-20 years of changed land use management*

Origin and spread

Origin: Terracing steep lands in Africa is an indigenous technology. The same is true of earth bunds, stone lines and vegetative strips. New methods have evolved over the years in response to increasing population and land pressure. Under colonial regimes, large areas of communal lands were compulsorily terraced in the 1950s (e.g. in Kenya, Malawi and Zambia) through the construction of ridges or bunds. Often rejected immediately after independence such techniques made a come-back in the 1970s having been improved and promoted through projects / programmes. *Fanya juu* terraces first developed in the 1950s and are currently spreading throughout East Africa. The period of rapid spread occurred during the 1970s to 1980s with the advent of the National SWC Programme in Kenya. In the West African Sahel, contour stone lines (and vegetative barriers) have been promoted successfully since the 1980s, as water harvesting structures.

Mainly applied in: Terracing systems in steep areas throughout Africa; Stone lines on low slopes mainly West Africa (Burkina Faso, Mali, Niger); Earth bunds / ridges mainly in East Africa (Ethiopia, Kenya) and Southern Africa (Malawi, Zambia, Zimbabwe, etc.), *Fanya juu* mainly in East Africa (Kenya; also Ethiopia, Tanzania, Uganda); vegetative strips throughout Africa especially in the more humid zones.

Principles and types

Bench terraces are commonly developed on steep slopes as a result of constructing cross-slope barriers, and then erosion (water and tillage) progressively causing the bed to level. A bench terrace is defined by a flat or slightly backward or forward-sloping bed. Stone-faced terrace risers are characteristic of areas where stone is available (e.g. the Konso terraces in Ethiopia), otherwise the earth risers are protected by grass. Due to the heavy labour input they are usually constructed to support production of high-value crops such as irrigated vegetables and coffee. The design of the benches is usually calculated by a formula that relates their size and spacing to the slope. Bench terraces are rarely excavated and constructed directly, as this is very expensive.

Earth bunds (sometimes referred to as 'ridges' in Southern Africa) are soil conservation structures that involve construction of an earthen bund along the contour by excavating a channel and creating a small ridge on the downhill side. Usually the earth used to build the bund is taken from both above and below the structure. They are often reinforced by vegetative cover to stabilise the construction. Bunds are gradually built up by annual maintenance and adding soil to the bund.

Fanya juu ('do upwards' in Kiswahili) terraces are made by digging ditches and trenches along the contour and throwing the soil uphill to form an embankment. A small ledge or 'berm' is left between the ditch and the bund to prevent soil sliding back. In semi-arid areas they are normally constructed to harvest and conserve rainfall, whereas in subhumid zones they may be laterally graded to safely discharge excess runoff. The embankments (risers) are often stabilised with fodder grasses. *Fanya juu* terraces can develop into bench terraces.

In a ***Fanya chini*** system ('do downwards' in Kiswahili) soil is piled below a contour trench. These are used to conserve soil and divert water and can be used up to a slope of 35%. *Fanya chini* involve less labour than *Fanya juu*, but they do not lead to the formation of a bench terrace over time as quickly as the former.

Stone lines and bunds: In areas where stones are plentiful, stone lines are used to create bunds either as a soil conservation measure (on slopes) or for rainwater harvesting (on plains in semi-arid regions). Stones are arranged in lines across the slope to form walls. Where these are used for rainwater harvesting, the permeable walls slow down the runoff, filter it, and spread the water over the field, thus enhancing water infiltration and reducing soil erosion. Furthermore, the lines trap fertile soil sediment from the external catchment.

Vegetative strips are the least costly or labour-demanding type of cross-slope barriers. Such strips are a popular and easy way to terrace land, especially in areas with relatively good rainfall. The spacing of the strips depends on the slope of the land. On gentle sloping land, the strips are given a wide spacing (20-30 m), while on steep land the spacing may be as little as 10-15 m. Vegetative strips can also provide fodder for livestock if palatable varieties of grass (or densely spaced bushes) are used.

Top: Konso Terraces in Ethiopia. (Rima Mekdaschi Studer)
Top middle: *Fanya juu* terrace with napier grass, Kenya. (Hanspeter Liniger)
Bottom middle: Vegetative strips along contour line for reducing surface runoff and erosion, Kenya. (Christoph Studer)
Bottom: Stone lines catching run-off water and fertile soil sediments, Niger. (Hanspeter Liniger)

Applicability

Land degradation addressed

Soil erosion by water: mainly loss of topsoil / surface erosion, partly gully erosion / gullying
Physical soil deterioration: runoff can contribute to crusting and soil sealing
Water degradation: sedimentation and pollution of water downstream, partly aridification

Land use

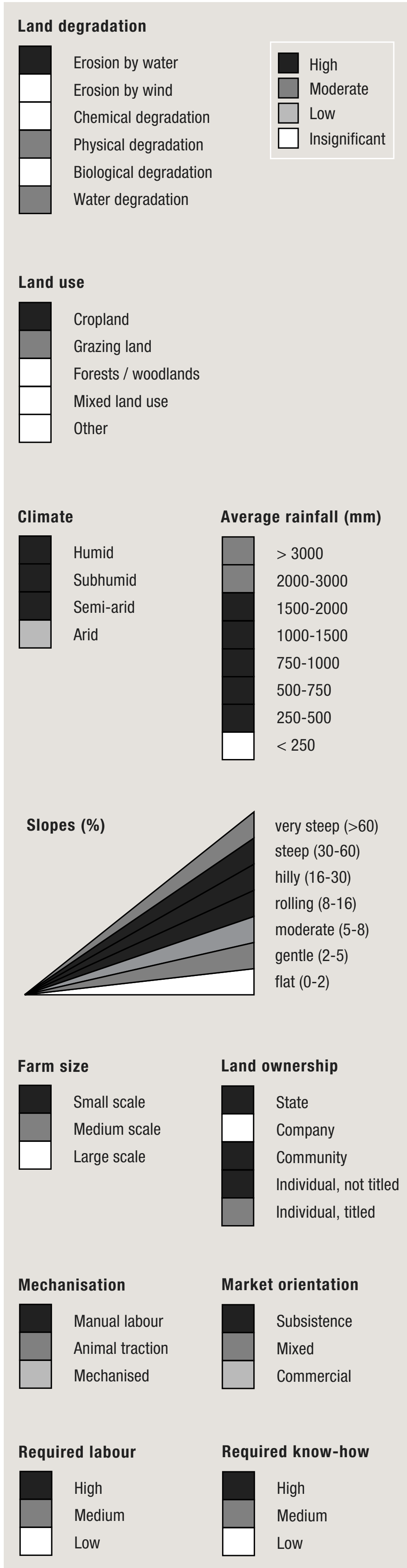
Mainly on annual cropland and / or partly on mixed land with tree and shrub cropping.
Partly on intensive grazing fodder production: rarely on grazing land.

Ecological conditions

Climate: Mainly in subhumid and semi-arid, partly in humid and arid areas. In subhumid to humid areas mainly for protection against soil erosion, whereas in semi-arid areas mainly for water conservation purposes.
Earth bunds are not suitable for very wet areas unless graded; Vegetative strips are most effective in moist areas and least effective in dry areas; *Fanya juu* terraces are not suitable in dry areas unless used for rainwater harvesting.
Terrain and landscape: Bench terraces: moderate to very steep slopes; Earth bunds: gentle to moderate slopes; Stone bunds: gentle to steep slopes; *Fanya juu* terraces: moderate to steep slopes (up to 50%); *Fanya chini* terraces: moderate to hilly slopes (up to 35%); Vegetative strips: gentle to steep slopes.
Soils: Not suitable for very shallow and sandy soils – bench terraces must not be built on shallow soils (to avoid risk of landslides).

Socio-economic conditions

Farming system and level of mechanisation: Mainly animal traction (oxen, with plough) and manual labour (hand tools, on steeper slopes where oxen can not be used, etc.), very often a combination of animal traction and manual labour; only partly mechanised (e.g. for transportation of stones)
Market orientation: Mainly subsistence (self-supply), partly mixed and partly commercial / market.
Land tenure and land use / water rights: Secure individual land use rights are needed, otherwise the land users are not willing to invest in structural conservation measures. Land tenure is often formally state- or communal-(village) property and individually not-titled.
Skill / knowledge requirements: A high level of know-how is required for the establishment and the maintenance of terraces and bunds.
Planting and construction of vegetative strips is relatively simple and can be done by local land users with minimum investment and with local equipment.
Labour requirements: The establishment of terraces and bunds requires high input; sometimes outside labour needs to be hired for the construction of the terraces or the bunds. *Fanya juu* terraces are associated with hand construction, and are well suited to small-scale farms. In Kenya they are often established through self-help groups.
Maintenance can usually be done by individuals and is very important for all kind of terraces and bunds. Earth structures often need considerable maintenance - building up and reshaping the structure every year and stabilising through vegetative cover.
Vegetative strips often require less establishment work compared to terraces and bunds. Maintenance work is also very important e.g. grass strips require trimming and gap-filling to keep them dense.



Economics

Establishment and Maintenance costs

	Establishment costs (US$/ha)			Maintenance costs (US$/ha)		
Costs	Terraces	*Fanya juu*	Veg. strips	Terraces	*Fanya juu*	Veg. strips
Labour cost PDays*	High 150-1200 150-600	High 40-600 40-300	Medium-high 7-80 7-40	Medium 10-300 10-150	Low 10-60 10-30	Low 0-30 0-15
Equipment	Low-medium 10-50	Low-medium 20-60	Low 10-50	Low 0-20	Low 0-10	Low 0-10
Material inputs	Medium-high 50-300	Low-medium 10-80	Medium 20-100	Low 0-50	Low 0-15	Low 0-10
Total	**210-1350**	**70 – 740**	**37-230**	**10-370**	**10-85**	**0-50**

**PD: Person days (labour is valued as 1-2 US$ per day), (Source: WOCAT, 2009)*

Comment: Very often the high establishment costs related to labour for the construction of terraces are the main obstacle for establishment. The construction costs depend on the slope of the area (number of barriers needed), the distance to the material (e.g. stones), the level of mechanisation and labour costs. The construction of vegetative strips requires least working days and can provide a cost-saving alternative to terracing. The equipment needed does not differ a lot between the three measures.

Production benefits

	Yield without SLM (t/ha)	Yield with SLM (t/ha)	Yield gain %
Maize, Kenya	2.1 – 3.4	2.3 – 3.7 (grass strips) 3.1 – 4.5 (*fanya juu*)	10-45%
Beans, Tanzania	1.5 – 1.8	2 (grass strips) 2.8 (*fanya juu*) 2.1 – 2.7 (bench terraces)	10-85%
Sorghum, Ethiopia 15% slope 25% slope 35% slope	Non-terraced 0.96 0.67 0.43	Terraced (stone bunds) 2.18 1.83 1.7	 127% 173% 297%

(Sources: Mwangi et al., 2001; Tenge et al., 2005; Alemayehu et al., 2006)

Comment: With increasing slope the difference in sorghum yields between terraced and non-terraced lands increases. Terraces result in remarkably higher yields on steep slopes compared with non-terracing.

Benefit-Cost ratio

	short term	long term	quantitative
Bench terraces	– –	++	Internal rate of return, Tanzania: 19%
Bunds	–	++	
Stone lines	–	++	
Fanya juu	–	++	14%
Vegetative strips	+/–	++	6%
Overall	–	++	

– – negative;– slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive
(Sources: Tenge et al., 2005 and WOCAT, 2009)

Comment: The internal rate of return as shown above suggest that, farmers who are able to invest in bench terraces, will be able to recover their investment faster than from the *fanya juu* and grass strips. However, the short term benefit-cost ratio for cross-slope barriers is mostly negative due to high investment costs. It can take up to 2 years until the barriers lead to a positive return. The profitability of barriers also depends on the opportunity costs for labour. For land users with an off-farm income the establishment of cross-slope barriers is often financially not attractive.

Examples: Burkina Faso
The analysis of different structural conservation measures in Burkina Faso, has shown shown that the construction of stone lines generally leads to the highest establishment costs (140-400 US$/ha), the construction of earth bunds is slightly cheaper (95-200 US$/ha), whereas vegetation barriers show relatively low establishment costs if local grasses are used (approx. 60-70 US$/ha) (Spaan, 2003).

Example: Tanzania
A study in the West Usambara Highlands has shown significant increase in the crop yield for maize and beans by implementing bench terraces, fanya juu or grass strips (see production benefits). However, the results clearly showed that cross-slope barriers alone may not significantly increase crop yields unless these are followed by other practices such as manure and fertilizer. Grass strips and / or the introduction of grass on the risers, can lead to an additional increase in yield which can be either used as fodder for livestock or it can be sold (Tenge et al., 2005).

Example: Burkina Faso
A cost-benefit analysis for stone lines in the region of Kaya shows that, from the farmer's point of view, the implementation of stone lines alone is only profitable if a lorry is provided for the transport of stones. If the farmer has to pay the transport himself the net present value of stone lines is negative. The benefits (20% yield increase in wet years and 30% yield increase in dry years) are not high enough to compensate for the costs of transport and construction. Thus profitability of stone lines depends closely on transport and distance to the source of the stones (Kempkes, 1994).

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	++ increased crop yield (long term) ++ increased grass / fodder production (through grass strips and / or grass on risers) can be used for livestock, sold, as mulch or to thatch roofs + increased wood production	++ reduced risk and loss of production + access to clean dinking water	+++ improved food and water security
Economic	++ increased farm income (long term)	++ less damage to off-site infra-structure + stimulation of economic growth	+++ improved livelihood and well-being
Ecological	+++ reduced soil loss (mainly in subhumid areas) ++ increased soil moisture (mainly in semi-arid areas) ++ reduced soil erosion (by wind / water) ++ increased infiltration rates ++ decrease in runoff velocity and control of dispersed runoff + improved soil cover + increase in soil fertility (long term) + biodiversity enhancement + improved micro-climate	++ reduced degradation and sedimentation ++ improved water quality + increased water availability + intact ecosystem	++ increased resilience to climate change ++ reduced degradation and desertification incidence and intensity ++ enhanced biodiversity
Socio-cultural	++ improved conservation / erosion knowledge + community institution strengthening	++ increased awareness for environmental 'health' ++ attractive landscape	++ protecting national heritage

	Constraints	How to overcome
Production	• Loss of land for production due to risers of terraces, ditches for *Fanya juu* / chini, vegetative strips, etc. • The constructions can easily be damaged by cattle interference • Planting of vegetative strips falls in the period with highest agricultural activity • If not adequately managed soil and water conservation function can be lost or can even be accelerated • Competition for water and nutrients in the case of vegetative barriers	➜ integrating and incorporating vegetative measures in the system, widen the spacing between bunds, make bund area productive (e.g. grass on terraces for livestock), increase productivity of fod-der trees on bunds, etc. ➜ controlled grazing management of the terraces ➜ needs good capacity building and training for appropriate manage-ment of the measures
Economic	• High investments costs, usually exceeding short term benefits • Shortage of labour, especially for the construction; very high labour input is needed. Some cross-slope barriers can also lead to high maintenance requirement, e.g. soil bunds. • Shortage of construction material and hand tools • Lack of market infrastructure	➜ credits and financial incentives for initial investments should be easily accessible to land users ➜ establishment with labour-sharing groups, financial incentives or credit facilities or phasing the establishment over several years to overcome. For maintenance less support is needed but land users should be organised (individually or in groups) to undertake main-tenance and repairs
Ecological	• Possible waterlogging before bund / embankment • Uneven flood water distribution, breakages of terraces • Rodent and other pests hiding in the vegetation • Competition of vegetative strips + bunds with crop • Unprotected bunds, which have not been planted with grass, are prone to erosion	➜ additional measures such as vegetation / mulch cover ➜ maintenance and adjustments of the barriers ➜ provision of appropriate measures, provision of rodent and pest controlling mechanisms ➜ trimming of vegetation during crop growing period ➜ additional measures such as vegetation / mulch cover to reduce runoff
Socio-cultural	• Often traditional system, but not properly maintained, especially when populations move away from rural areas	➜ incentives for 'renovation' of traditional structures (e.g. Konso ter-races in Ethiopia)

Adoption and upscaling

Adoption rate

The labour requirement can be a major constraint to the adoption of cross-slope barrier technologies. Vegetative strips have the lowest labour requirements leading to higher adoption. However, establishment of these very often coincides with the labour peak of the normal agricultural activities.

The loss of land and temporal yield decline in the short term are the main obstacles, especially for small-scale farmers, to adoption of structural measures such as terraces or bunds, even though long term benefits are likely.

High investment costs and the uncertain benefits in the short term further hinder the adoption and upscaling of this group of measures.

Upscaling

For adoption, a substantial yield gain is essential to overcome the high investment costs and the loss of agricultural productive land. Land users need to be well informed in terms of yields and / or monetary values which can be gained through the implementation of cross-slope barriers.

Awareness raising: Land users need to recognise the multiple resource losses due to runoff and erosion on sloping land.

Clear **land use rights** are needed for investments to be made in structural measures.

Access to knowledge must be ensured for land users; training of land users is essential to establish knowledge and technical skill about appropriate establishment and also maintenance.

Micro-credit for financial investments: The self-financing capacity of farmers needs to be strengthened and credits must be easily accessible also for small-scale land users.

Access to material inputs and markets is necessary for establishment of cross-slope barriers.

Incentives for adoption

The construction of cross-slope barriers usually requires considerable labour but material inputs also, and hence the investment costs often exceed the short term benefits. Therefore it is crucial that land users have access to micro-credit to enhance self-financing. Incentives should only be given if there is no other possibility of establishing cross-slope barriers. Two reasons to justify the provision of incentives are: (1) the costs are only slowly recuperated by on-site benefits; (2) part of the benefits are obtained by people downstream. Possible options for incentives can be transport facilities for stones (for example) or subsidies on inputs such as seedlings for the vegetative strips. Payment for ecosystem services (PES) is another incentive that specifically addresses the benefits of downstream users. Maintenance work should be conducted without any external support.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	++
Training and education	++
Land tenure, secure land use rights	++
Access to markets	+
Research	++
Infrastructure	+
Conflicts of interest	+

Example: Kenya

During the colonial period in Kenya, in the 1950s, bench terracing used to be forced on local people, and after independence in 1963, many terraces were destroyed or neglected. After the soil conservation extension campaigns of the 1970s-1980s, bench terraces were adopted by farmers living on steep mountain slopes of Central and Eastern Provinces, especially on farms where coffee was grown (Mburat, 2006).

Example: Tanzania

Despite decades of efforts to promote cross-slope barriers in the West Usambara Highlands in Tanzania, there is still minimal adoption by land users. Among the major reasons for this could be that land users do not recognise the losses caused by runoff and soil erosion, that the recommended measures are not effective enough or not financially attractive. Furthermore, the establishment period competes with other activities for scarce labour resources and equipment. It is crucial that land users are well informed about costs and benefits of implementing the measures in order to achieve greater motivation to implement cross-slope barriers (Tenge et al., 2005).

References and supporting information:

Alemayehu M., F. Yohannes, and P. Dubale. 2006. Effect of Indigenous Stone Bunding (KAB) on Crop Yield at Mesobit-Gedeba, North Shoa, Ethiopia. Land Degrad. Develop. 17: 45–54 (2006).

Amsalu, A. and J. de Graaff. 2007. Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed. Ecological Economics, 61 (2007) 294-302.

Bodnar, F. 2005. Monitoring for impact: evaluating 20 years of soil and water conservation in southern Mali.

IWMI. 2009. http://www.iwmi.cgiar.org/africa/west/projects/Adoption%20Technology/Soil&WaterConservation/56-ImprovedStoneTerracing.htm, accessed on 15 September 2009.

IWMI. 2009. http://www.iwmi.cgiar.org/africa/west/projects/Adoption%20Technology/RainWaterHarvesting/50-Fanya%20juu.htm, accessed on 15 September 2009.

Kempkes, M. 1994. Analyse financière des cordons pierreux: cas d'étude de Tagalla, province du Sanmatenga au Burkina Faso; rapport des étudiants 44a Antenne Sahélienne, Ouagadougou.

Mati B. M. 2005. Overview of water and soil nutrient management under smallholder rainfed agriculture in East Africa. Working Paper 105. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Mwangi J.N., T.O. Mboya and Kihumba. 2001. Improved Maize Production in Central Kenya with Adoption of Soil and Water Conservation Measures. Seventh Eastern and Southern Africa Regional Maize Conference, 11th-15th February, 2001. pp. 299-300.

Spaan, W.P. 2003. Consuming the savings: water conservation in a vegetative barrier system at the Central Plateau in Burkina Faso., Wageningen University and Research Centre, Wageningen.

Tenge, A.J., J. De Graaff, J.P. Hella. 2005. Financial efficiency of major soil and water conservation measures in West Usambara highlands, Tanzania. Applied Geography 25, 348-366.

UNEP. 1998. Sourcebook of Alternative Technologies for Freshwater Augumentation in Africa. Newsletter and Technical Publications.http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-8a/fanya.asp, accessed on 28.10.2009.

WOCAT. 2009. WOCAT databases on SLM technologies and SLM approaches. www.wocat.net, accessed on 15 September 2009.

ALOE VERA LIFE BARRIERS - CAPE VERDE

Aloe vera is a drought tolerant, fleshy plant which is planted in the form of live barriers to recuperate degraded slopes on the Cape Verde Islands. The plants are closely planted along the contour to build an efficient barrier for retention of eroded sediments and surface runoff. The hedgerows stabilise the soil, and increase soil humidity by improving infiltration and soil structure. Soil is accumulating behind the *Aloe* strips and slope angle is considerably reduced over time. Groundwater is recharged indirectly. Soil cover is improved, and thus evaporation reduced.

Implementation is relatively simple. The contour lines are demarcated using line- or water-levels. Seedlings are planted at a distance of 30-50 cm between plants; Spacing between the rows varies between 6–10 m according to the slope. The technology is applied in subhumid and semi-arid areas, on steep slopes with shallow soils, sparse vegetative cover and high soil erosion rates. These areas are generally used by poor subsistence farmers for rainfed agriculture with crops such as maize and beans, which are considered inappropriate for such slopes. On slopes steeper than 30% the live barriers are often combined with stone walls (width 40-50 cm; height 80-90 cm). The plants stabilise the stone risers, making this combined technology one of the most efficient measures for soil erosion control on Cape Verde.

Aloe vera is well adapted to the local biophysical conditions and to the prevailing land use system: it can be used with any crop and is available to all farmers; establishment and transport is simple, its leaves are not palatable to livestock, the plant is extremely resistant to water stress and grows in any bioclimatic zone on the island. Furthermore, *Aloe vera* is known for its multiple uses in traditional medicine.

SLM measure	Vegetative
SLM group	Cross-Slope Barriers
Land use type	Annual cropping (maize, beans)
Degradation addressed	Soil erosion by water
Stage of intervention	Mitigation and rehabilitation
Tolerance to climate change	Tolerant; *Aloe vera* is resistant to water stress, and establishes well in different climatic zones

Establishment activities

1. Demarcation of contour lines, using line or water levels; spacing between barriers is minimum 6 meters (early June).
2. Collection of *Aloe vera* plants; *Aloe vera* is growing naturally in abundant quantity on the upper slopes, in depressions / hollows, in arid as well as in more humid zones.
3. Planting of *Aloe vera* seedlings, one next to the other, or at a spacing of 30-50 cm between plants; (end of June) manually, using hoe / pickaxe.
4. From the second year on the gaps between the plants are plugged by naturally expanding *Aloe vera* plants.

Maintenance / recurrent activities

1. Vegetative control: removal of *Aloe vera* plants that are invading cropland (maize, peas) between the life barriers.
2. Replanting of *Aloe vera* to fill gaps in life barriers (very rare; survival rate is over 95%).

Labour requirements

For establishment: medium
For maintenance: low

Knowledge requirements

For advisors: low
For land users: low

Photo 1: Well established *Aloe vera* life barriers on steep slopes. (Jacques Tavares)
Photo 2 and 3: Detailed view of *Aloe vera* life barriers; soil is accumulating on the upper side of the barriers. (Jacques Tavares)
Photo 4: *Aloe vera* life barriers are often combined with stone walls to enhance the erosion control on steep slopes. (Hanspeter Liniger)

Case study area: Santiago, Cape Verde

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 65 person-days	215
Equipment: levels, hoes, shovels	13
Agricultural inputs: 5,000 plants	0
TOTAL	**228**
% of costs borne by land users	0%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 1 person-day	3
Equipment	0
Agricultural inputs	0
TOTAL	**3**
% of costs borne by land users	100%

Remarks: Labour inputs for implementation are rewarded by project: Individuals of poor communities receive a salary of 3 US$ per day. Plants are collected locally. Establishment costs do not include labour-intensive construction of stone risers (supportive measure). Maintenance costs are borne by land users.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly negative	very positive
Maintenance	neutral / balanced	very positive

Remarks: Maintenance is not costly, it's simply vegetative control and punctual replanting.

Ecological conditions

- Climate: mainly semi-arid, partly subhumid
- Average annual rainfall: mainly 500-750 mm, >800 mm in wetter areas
- Soil parameters: mainly shallow loamy soils, with medium fertility and low-medium organic matter content; drainage is medium while water storage capacity is high to very high
- Slope: steep (30-60%), partly less
- Landform: mountain slopes and ridges
- Altitude: mainly 500-1,000 m a.s.l., partly 100-500 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha (poor), 2-5 ha (better-off)
- Type of land user: small-scale, poor; partly medium-scale, better-off
- Population density: 100-200 persons/km^2
- Land ownership: individual (titled) and communal (Diocese)
- Land use rights: mainly leased, partly individual or hereditary
- Level of mechanisation: mainly manual, few farms are mechanised
- Market orientation: mainly subsistence, few mixed (subsistence and commercial)

Production / economic benefits

++ Reduced risk of production failure
+ Increased crop yield
+ Increased fodder production
+ Increased production area

Ecological benefits

+++ Improved harvesting / collection of surface runoff
+++ Reduced surface runoff
++ Improved soil cover
++ Increased biomass / above ground carbon
+ Increased soil moisture
+ Increased water quality
+ Increased water quantity

Socio-cultural benefits

+++ Improved conservation / erosion knowledge
+ Conflict mitigation
+ Improved food security / self-sufficiency
+ *Aloe vera* is used in traditional medicine / personal hygiene: pills against anaemia, diabetes and digestion problems; bactericide for wound treatment

Off-site benefits

+++ Recharge groundwater table / aquifer

Weaknesses ➜ and how to overcome

- Reduction of the production area, which is occupied by strips of *Aloe vera* ➜ annual vegetative control within cultivated area and by cutting *Aloe vera* plants growing outside the life barriers.

Adoption

Most of the land users have implemented the technology by receiving financial incentives (payments). Totally 380 land users have adopted the technology; the area treated with *Aloe vera* life barriers is 71.5 km^2. There is a small trend towards spontaneous adoption.

Main contributors: Jacques Tavares and Larissa Varela, Instituto Nacional de Investigação e Desenvolvimento Agrário (INIDA), Praia, Cape Verde; inida@inida.gov.cv
Key references: WOCAT. 2010. WOCAT database on SLM technologies. www.wocat.net. DESIRE-project. 2010. http://www.desire-project.eu/

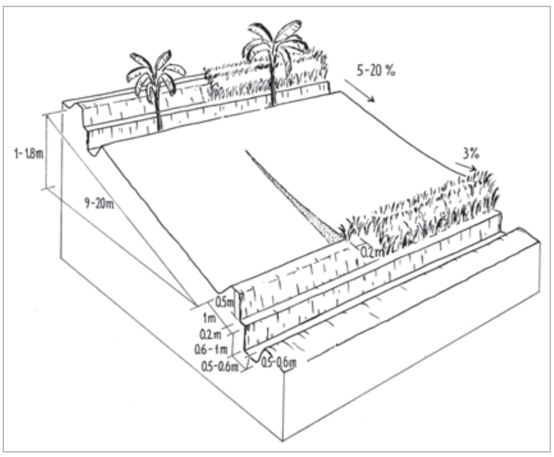
GRASSED *FANYA JUU* TERRACES - KENYA

A *fanya juu* terrace is made by digging a trench and throwing the soil uphill to form an embankment. A berm prevents the embankment soil from sliding back into the trench. On the embankment a grass strip is established, serving a triple purpose: it stabilises the earth structure through its roots, it enhances siltation of eroded soil particles, and it is used as a fodder source for livestock. Often napier (*Pennisetum purpureum*), or makarikari (*Panicum coloratum* var. *makarikariensis*) are used in the drier zones.

In semi-arid areas the structures are laid out along the contour to maximise water retention, whereas in subhumid zones they are laterally graded to discharge excess runoff. Spacing of terraces ranges from 9 - 20 m, according to slope and soil depth. On a 15% slope with a moderately deep soil, the spacing is 12 m between the structures and the vertical interval around 1.7 m.

The purpose of the *fanya juu* is to reduce loss of soil and water, and thereby to improve conditions for plant growth. The embankment impounds runoff water, eroded soil and nutrients. As a consequence of water and tillage erosion, sediment accumulates behind the bund, making it necessary to periodically build up the embankment (by throwing silted material from the trench upslope). In this way *fanya juu* terraces gradually develop into forward sloping terraces. Grass strips require trimming to keep them dense.

Fanya juu terraces are associated with hand construction, and are well suited to small-scale farms. *Fanya juu* is applicable where soils are too shallow for level bench terracing and on moderately steep slopes (e.g. < 20%), they are not suitable for stony soils.



SLM measure	Structural combined with vegetative
SLM group	Cross-Slope Barriers
Land use type	Cropland: annual crops
Degradation addressed	Loss of topsoil (water erosion); Soil moisture problem
Stage of intervention	Mitigation
Tolerance to climate change	Tolerant to climatic extremes (e.g. rain storms); Water conservation effect increases resilience to periods of water stress

Establishment activities

1. Layout (alignment and spacing) of terraces: (a) on the contour in dry areas; (b) on a slight grade in more humid areas, using 'line levels'.
2. Loosen soil for excavation (forked hoe, ox-drawn plough).
3. Dig a ditch / trench and throw the soil upwards to form a bund, leaving a berm of 15-30 cm in between (using hoes and shovels).
4. Levelling and compacting bund.
5. Digging planting holes for grass.
6. Creating splits of planting materials (*Makarikari* or Napier grass).
7. Manuring and planting of grasses.

All activities are done manually before the rainy seasons start (March and October) except planting of grasses, at the onset of rains. Duration of establishment: usually within one year.

Maintenance / recurrent activities

1. Desilting the trench and throwing silt upslope.
2. Repairing breaches in embankment where necessary.
3. Building up embankment annually.
4. Cutting grass to keep low and non-competitive, and provide fodder for livestock.
5. Maintaining grass strips weed-free and dense.

Labour requirements

For establishment: high
For maintenance: low to medium

Knowledge requirements

For advisors: moderate
For land users: low

Photo 1: Napier grass strip on the upper part of a *Fanya juu* bund; maize trash was deposited in the ditch below after harvest. (Hanspeter Liniger)
Photo 2 : *Fanya juu* terraces with well established grass strips in a semiarid area have developed over time into bench terraces. (Hanspeter Liniger)
Technical drawing: Schematic representation of *fanya juu* terraces with dimensions of structures; initial stage (left) and mature stage with well established grass strip and soil accumulating on the upper side of the embankment (right). (Mats Gurtner)

Case study area: Eastern Province, Kenya

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 90 person-days	270
Equipment / tools	20
Agricultural inputs: compost, manure	30
Grass establishment	60
TOTAL	**380**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 10 person-days	30
Equipment	
Agricultural inputs: compost	
TOTAL	**30**
% of costs borne by land users	100%

Remarks: These calculations are based on a 15% slope with 830 running metres of terraces per hectare with typical dimensions and spacing (see technical drawing).

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly negative	positive
Maintenance	positive	very positive

Remarks: As the terrace is built up gradually over the years, establishment costs can be limited.

Ecological conditions

- Climate: subhumid, semi-arid
- Average annual rainfall: 500-1,000 mm
- Soil parameter: moderately deep, loamy soils, with medium soil fertility, low to medium organic matter content; medium water storage capacity, medium to good drainage
- Slope: mainly moderate-rolling (5-16%); partly hilly
- Landform: hillslopes and footslopes
- Altitude: 500-1,500 m a.s.l.

Socio-economic conditions

- Size of land per household: mainly < 1ha, partly 1-2 ha, some 2-5 ha
- Type of land user: small-scale, average level of wealth to poor land users
- Population density: 100-200 km^2
- Land ownership: individual titled and individual not titled
- Land use rights: individual
- Market orientation: subsistence and mixed (subsistence and commercial)
- Level of mechanisation: mainly animal traction, partly manual labour

Production / economic benefits

++ Increased crop yield (25%)
++ Increased fodder production and fodder quality
+ Increased farm income

Ecological benefits

++ Increased soil moisture (semi-arid)
++ Increased efficiency of excess water drainage (subhumid)
++ Reduced soil loss
++ Increased soil fertility (in the long term)
++ Improved soil cover

Socio-cultural benefits

++ Improved conservation / erosion knowledge
++ Community institution strengthening

Off-site benefits

++ Reduced downstream siltation
+ Increased stream flow in dry season
+ Reduced downstream flooding

Weaknesses ➜ and how to overcome

- Loss of cropping area for terrace bund ➜ site-specific implementation: only where *fanya juu* terraces are absolutely needed, i.e. where agronomic (e.g. mulching, contour ploughing) and vegetative measures are not sufficient in retaining / diverting runoff; use the bund for production of valuable fodder / fruit (trees).
- High amounts of labour involved for initial construction ➜ spread labour over several years and work in groups.
- Risk of breakages and therefore increased erosion ➜ accurate layout and good compaction of bund.
- Competition between fodder grass and crop ➜ keep grass trimmed / harvest for livestock feed.

Adoption

Fanya Juu is a wide-spread technology – covering approx. 3,000 km^2 in the case study area – with high degree of spontaneous adoption throughout East Africa, and further afield also. The terraces first came into prominence in the 1950s, but the period of rapid spread occurred during the 1970s and 1980s with the advent of the National Soil and Water Conservation Programme.

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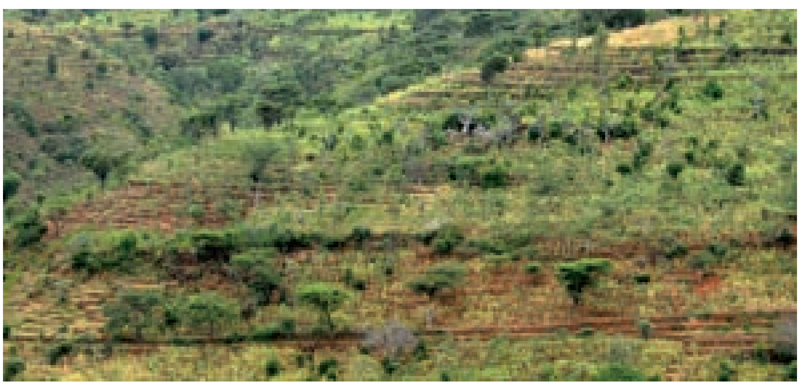
Key references: Thomas D (Editor) 1997: Soil and water conservation manual for Kenya. Soil and Water Conservation Branch, Nairobi ■ WOCAT 2004, WOCAT Database on SLM Technologies; www.wocat.net

KONSO BENCH TERRACE - ETHIOPIA

The traditional Konso Bench Terraces are established by building up stone embankments along the contour and gradually levelling the land in between risers. Levelling is done actively and by siltation processes. Stone walls have to be enhanced periodically. The appearance of the technology evolves over time from stone embankments to bench terraces. The stone walls are supported on the downslope side by trees and / or legumes including coffee, pigeon pea, etc. The purpose of the structures is to break the slope length and reduce run-off concentration thereby controlling erosion, increasing water stored in soil and harvesting eroded sediments.
Terraces have a long tradition in the area, and farmers are specialists in construction of stone walls. The first step during terrace establishment is to dig foundation up to 30 cm. Then stone walls are gradually built up to an impressive height of 1.5 - 2 m above the ground. The technology is very labour intensive: Establishment takes 5 years and bi-annual maintenance is required. However, it is worth the effort, since without terracing crop production would not be thinkable in a marginal area characterised by shortage and high variability of rainfall, shallow, stony soils on steep slopes, high levels of soil erosion and (thus) frequent food shortages.
Social systems for labour-sharing and voluntary assistance have evolved to manage heavy labour inputs. Multiple cropping is practised for risk aversion. Growing leguminous crops helps to further improve soil fertility. Additional water harvesting measures are needed to further raise yields.



SLM measure	Structural combined with vegetative
SLM group	Cross-Slope Barriers
Land use type	Annual cropping
Degradation addressed	Soil erosion; Fertility decline; Aridification / soil moisture problem
Stage of intervention	Rehabilitation and mitigation
Tolerance to climate change	Tolerant to climatic extremes (e.g. rain storms). Water conservation effect increases resilience to periods of water stress

Establishment activities

1. Survey / layout.
2. Collecting stones.
3. Digging foundation (0.3 m deep; 0.3 m wide).
4. Establish stone wall (0.7 m high).
5. Land levelling.
6. Option: plant trees on the upper part of the stone riser.

All activities carried out by manual labour, using water level, poles, scoop hoe, spade. All activities carried out in the dry season.

Maintenance / recurrent activities

1. Stabilising terraces / enhancing walls by putting additional stones.
2. Repairing broken terraces and replanting of vegetative material.
3. Include inter-terrace management measures.

All activities carried out by manual labour, using crowbar, hammer,
hoe, spade (1-2 times a year).

Labour requirements

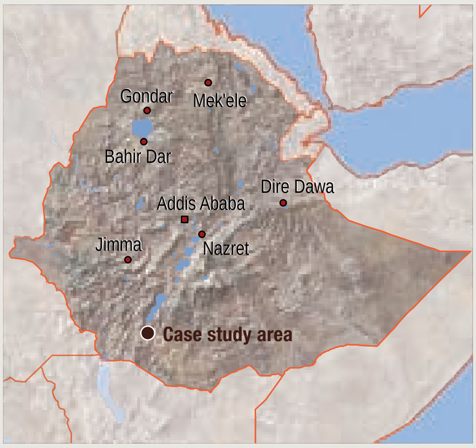
For establishment: very high
For maintenance: high

Knowledge requirements

For advisors: moderate
For land users: moderate

Photo 1 and 2: Meticulously built terrace risers reaching a height of 1.5 – 2 meters; frequent maintenance is needed to enhance risers and repair breaches.
Photo 3: Bench terraces with maize, cassava and sunflowers.
Photo 4: Overview of a terraced hillside with annual crops and trees. (All photos by Hanspeter Liniger)

Case study area: Konso; Ethiopia



Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 1,650 person-days)	1,650
Equipment	70
Agricultural inputs: seeds and manure	40
Construction material: stones	300
TOTAL	**2,060**

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 25-30% person-days of establishment	500
Equipment	0
Agricultural inputs	40
TOTAL	**540**

Remarks: Duration of establishment phase is 5 years. Land users maintain the terrace at least twice a year, mainly while preparing the land for crops. Labour inputs for maintenance are usually 25-30% of construction. Daily wage of hired labour is about US$ 1; material costs include collection and sizing of stones.

Benefit-cost ratio

Inputs	short term	long term
Establishment	negative	slightly positive
Maintenance	slightly positive	positive

Remarks: The profit is very marginal but without the terraces no harvest is expected. The land users continue to invest on the terraces as long as they can make a living from the land this way.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 500-750 mm
- Soil parameters: low to very low fertility, low soil organic matter, good drainage
- Slope: moderate – hilly (5-30%)
- Landform: hillslopes and footslopes, ridges
- Altitude: 1,500 - 2,500 m a.s.l.

Socio-economic conditions

- Size of land per household: 0.5-1.5 ha
- Type of land user: poor / better-off small-scale farmers; in groups or individually
- Population density: 50-100 persons/km^2
- Land ownership: state
- Land use rights: individual
- Market orientation: mostly subsistence
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased crop yields: sorghum yield raised by 50% (from 0.4 t/ha to 0.6 t/ha)
++ Increased farm income

Ecological benefits

+++ Reduced soil loss (>50%)
+++ Reduced runoff (60%)
++ Increased infiltration and increased soil moisture
++ Increased soil organic matter (sediment harvesting)

Socio-cultural benefits

+ Social organisation: establishment of community organisations and strengthening of groups
+ Maintenance of cultural heritage

Off-site benefits

++ Reduced downstream siltation
+ Reduced downstream flooding

Weaknesses ➜ and how to overcome

- The terraces require very frequent maintenance which makes the technology highly labour-demanding ➜ use bigger stones for construction; avoid free grazing (animals damage the structures).

Adoption

The technology is wide-spread in the case study area, covering approx. 1200 km^2. 90% of land users have implemented the terraces without receiving any external support other than technical guidance.

Main contributors: Firew Desta, Bureau of Agriculture, Southern Nation, Nationalities and Peoples Region (SNNPR), Awassa, Ethiopia. ■ Daniel Danano, Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia; ethiocat@ethionet.et
Key references: Danano D. 2008 (unpublished). Soil and Water Conservation Practices for Sustainable Land Management in Ethiopia. Ethiocat. ■ WOCAT. 2002. WOCAT database on SLM technologies. www.wocat.net.


High diversity in an agroforestry system, Ethiopia. (Hanspeter Liniger)

In a nutshell

Definition: 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. 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-storey cropping, relay cropping, intercropping, multiple cropping, bush and tree fallows, parkland systems, homegardens etc.; many of them 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 multi-functionality. There is no clear boundary between AF and forestry, nor between AF and agriculture.
Applicability: On subhumid 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 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 biologically. 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.

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	+++

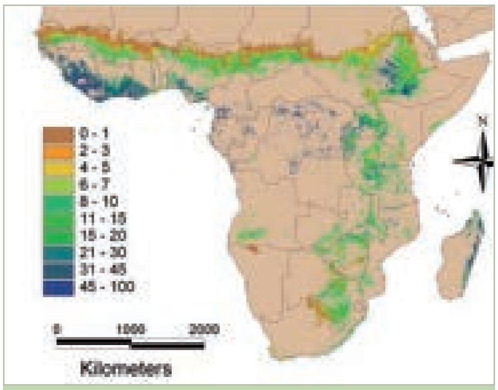
Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year)	0.3 - 6.5*
C Sequestration: above ground	++
C Sequestration: below ground	++

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	++

** for a duration of the first 20-30 years of changed land use management, depending on the selected tree species (Source: Nair et al., 2009)*

Origin and spread

Origin: AF encompasses many traditional land-use systems such as home gardens, boundary tree planting, shifting cultivation and bush fallow systems, contour cropping. AF is traditional and was 'rediscovered' in 1978 when the name 'agroforestry' was coined. Since then it has been promoted by projects and through land user's initiative. Alley cropping was conceived in the late 1970s by research to eliminate the need for a fallow period in the humid and subhumid tropics to replenish soil fertility.
Mainly applied in: Burkina Faso, Ethiopia, Guinea, Kenya, Lesotho, Malawi, Mozambique, Nigeria, Niger, South Africa, Tanzania, Togo, Uganda, Zambia, Zimbabwe: however all countries in SSA practise one form or another of AF. What differs is the extent, and the forms of AF practiced in these countries.



Tree cover on agricultural land in SSA
(Source: Zomer et al., 2009)

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 (through acting as windbreaks). Parklands are found primarily in the semi-arid and subhumid zones of West Africa. *Faidherbia albida* / cereal systems are predominating throughout the Sahelian zone (e.g. 5 million ha in Niger) and in some parts of East Africa. For many local populations these systems are very important for food security, income generation and environmental protection.
Multistorey systems are defined as existing or planted stands of trees or shrubs that are managed as an upperstorey of woody plants and one to several understoreys 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) protect soils and provide a favourable micro-climate; (c) improve soil quality by increasing utilisation and cycling of nutrients and maintaining or increasing soil organic matter and (d) increase carbon storage in plant biomass and soil. The Chagga homegardens of Tanzania, which integrate more than 100 plant species, provide a classic example of a multistorey AF system.
Fodder banks: Trees and shrubs with palatable leaves and / or pods are attractive to farmers as feed supplements for their livestock because they require little or no cash for inputs: they can be grown on boundaries as trees (often pollarded to reduce competition) or as hedges. They effectively do not compete for land as they are grown along boundaries, pathways - and along the contour to curb soil erosion. Managing fodder shrubs requires multiple skills including raising seedlings in a nursery, pruning trees, and feeding the leaves. 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, litter fall and nitrogen fixation. Improved fallows are one of the most promising agroforestry technologies in the subhumid and humid tropics and have shown great potential for adoption in southern and eastern Africa in recent years.
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.

Top: Off-season onion gardens (background) in a parkland system, Burkina Faso. (Christoph Studer)
Middle: Intercropping of 4 different plant species, Rwanda. (Hanspeter Liniger)
Bottom: Agroforestry with grevilla trees, coffee, tea on steep mountain slopes, Kenya. (Hanspeter Linigier)

Applicability

Land degradation addressed

Chemical soil deterioration: declining soil fertility and organic matter content (due to continuous cropping and few inputs)
Erosion by water and wind: loss of fertile topsoil
Physical soil deterioration: compaction, sealing and crusting
Water degradation: namely high water losses by non-productive surface evaporation, extreme heavy events causing runoff and erosion

Land use

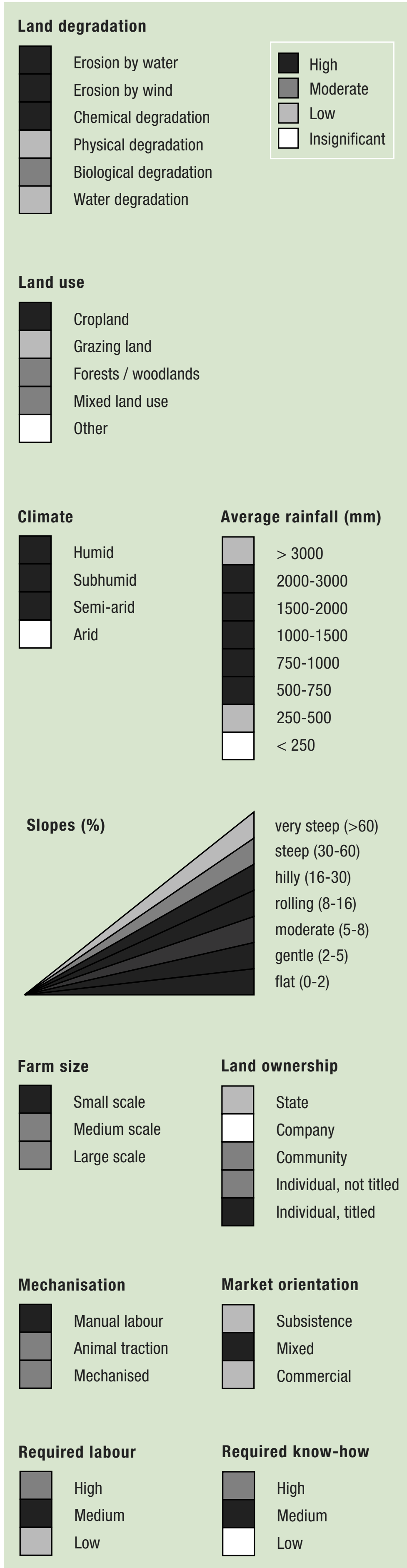
AF is suitable for all types of cropping systems where woody and non-woody species can be mixed. It is suitable for dry areas suffering from strong winds and wind erosion and low soil fertility (parkland systems, alley cropping and / or shelterbelts). Multistorey systems are suitable for areas with excessive rainfall causing erosion by water, soil compaction, expensive inputs especially fertilizers, pest and diseases.
Unsuitable for dry areas in situations where a lack of land (small farming units) makes AF systems such as parklands and improved fallows unsuitable. In more humid regions AF can be practiced on very small land parcels (e.g. Chagga homegardens; other multistorey systems). Unclear land and tree use rights are not favourable for the establishment of AF systems.

Ecological conditions

Climate: AF systems can be found in all kind of environments. Systems with low tree densities are more suitable in low rainfall areas and high density systems in high rainfall areas. AF in its diversity is suitable for a wide range of climates and AEZs. Parklands are not confined to specific AEZs and occur in various latitudes, but primarily in the semi-arid and subhumid zones of West Africa and in some parts of East Africa. Multistorey systems are more applicable in subhumid to humid environments or under irrigated systems, due to water requirements. Alley cropping and improved fallow have a wide range of applicability from semi-arid to humid.
Terrain and landscape: Suitable for all landforms and slopes: plains / plateaus as well as slopes and valley bottoms. Not suitable for high altitudes (higher than 2,000 – 2,500 m a.s.l) due to lower temperatures, negative impact of shade and a shorter growing season. AF is viable on steep land which otherwise is too steep for cropping: here AF can help building up terraces if trees are planted along the terrace risers.
Soils: No major limitations, AF is suitable for a wide range of soils. AF system can restore the soil fertility, where other land use systems have mined (depleted) soil nutrients.

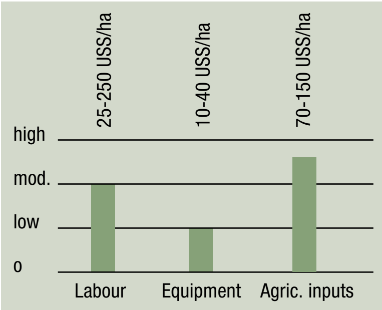
Socio-economic conditions

Farming system and level of mechanisation: Mainly applied on small-scale farms. However, it can be applied to all farm scales and conducted under different level of mechanisation (where trees are planted at low densities). In many countries women are the main actors in home gardening and food is mainly produced for subsistence.
Market orientation: Mainly applied in mixed systems (subsistence with some commercial). Can be applied in subsistence or commercial systems; access to markets is important to sell surplus production and for availability of inputs.
Land ownership and land use / water rights: Mostly applied on areas with individual land use rights and where land users have the rights to the trees they plant and tend. Communally owned land often lacks security of tenure and hence renders land users reluctant to practise and invest in agroforestry. Local regulations for the use of trees and crops are needed.
Skill / knowledge requirements: Medium to high and often part of a tradition, however selection of species suitable for different environments and purposes, as well as to minimise competition, needs know-how.
Labour requirements: Very variable, can be high for establishment – unless a system of protecting natural regeneration is used - but low for maintenance though some input needed for pollarding and pruning to reduce competition.

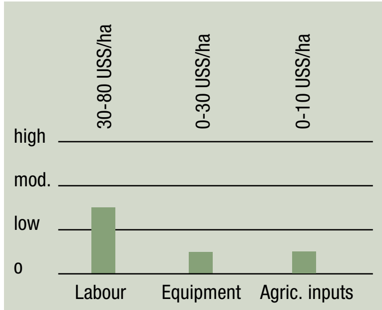


Economics

Establishment costs



Maintenance costs



Based on case studies from Ethiopia, Kenya and Togo (Source: WOCAT, 2009)

Establishment costs for agroforestry systems can vary a lot. Labour and agricultural inputs (seeds, seedlings, etc.) affect the establishment costs especially when linked to rainwater harvesting systems in drier areas.
Maintenance costs are relatively low.

Production benefits

	Yield without SLM (t/ha)	Yield with SLM (t/ha)	Yield gain (%)
Maize (Malawi)	0.7	1.5-2.0	110-190%

(Source: Malawi Agroforestry Extension Project; in Woodfine, 2009)

Comments: Crop yields can increase under an agroforestry system, however, AF does not lead in every case to an increase in crop production; depending on the type of system, the aggregate yield may improve as the products gained from the trees / shrubs compensate for any loss of crop yield.

Benefit-Cost ratio

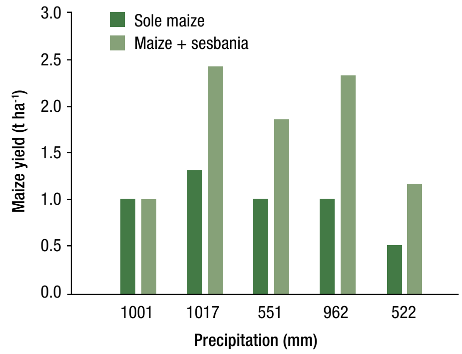
AF systems	short term	long term	quantitative
Parkland systems	–/+	+/++	No data available
Multistorey	+/++	+/++	
Alley cropping	+	++	
Improved fallow	++	+++	
Overall	+	++	

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive
(Source: WOCAT, 2009)

Comments: Available benefit-cost analyses all point to the economic profitability of integrating trees within crop fields (particularly multipurpose tree species). Analyses have mostly only taken direct use values into account, because indirect use values, such as environmental functions, and non-use values such as cultural and religious functions are more difficult to evaluate. Furthermore, benefit-cost estimates are complicated by the many sources of annual variation in factors governing tree and crop production and tree-crop interactions.

Impact over different temporal scales is an issue that is especially relevant to agroforestry. Low-income land users more readily adopt agroforestry practices with short term benefits such as short term improved fallows (enriched with N-fixing bush / tree species) and multistorey systems.

Example: Malawi
Modeled maize grain yields in improved fallow rotations in Makoka, Malawi as a function of growing season precipitation.



(Source: Chirwa, 2003 in Verchot et al., 2007)

Example: Kitui district, Kenya
Within a study conducted in Kitui district, Kenya it was determined whether growing Melia volkensii trees in croplands was cost effective or not. The value of timber products gained with that of the 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 has occured 50% of the time. 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% during average years and US$ 22 or 180% with the assumption of 50% crop failure due to drought. (In this district of Kenya, on average six of the 16 cropping seasons have failed) (Ong et al., 1999 in Verchot et al., 2007).

Example: 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 depending on whether they used shrubs as a substitute, or as supplement, and depending on where they are located. 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).

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	+++ crop diversification ++ higher combined yields (trees, crops and livestock) ++ provide products year around	+++ reduced risk and loss of production ++ access to clean drinking water ++ reliable fuel wood supply	+++ improved food and water security
Economic	++ generate additional cash income	+++ less damage to off-site infrastructure + creation of employment + stimulation of economic growth	+++ improved livelihood and well-being
Ecological	+++ improved soil cover +++ reduced soil erosion (by water / wind) +++ favourable changes in micro-climatic conditions (e.g. shade trees (can reduce temperature extremes by approximately 5°C, windbreaks) ++ improve soil fertility and biological activity ++ improve organic carbon content (above and below ground) ++ more effective use of available water ++ enhanced biodiversity and soil life ++ improve soil structure + biocontrol of pests and diseases	+++ reduced degradation and sedimentation ++ increased water availability ++ improved water quality ++ intact ecosystem	+++ increased resilience to climate change +++ enhanced biodiversity ++ arresting and reversing land degradation
Socio-cultural	++ improved conservation / erosion knowledge ++ multipurpose tree, meeting various needs ++ reduces pressure on forests + community institution strengthening + social services (as boundary markers) + aesthetic value	++ increased awareness for environmental health ++ reduced conflicts due to reduced negative off-site impacts ++ attractive landscape ++ reduced deforestation	+++ protecting natural and national resources for the next generations (heritage)

	Constraints	How to overcome
Production	• Systems produce multiple products under specific conditions: some single products can suffer due to competition	➜ minimise competition and emphasise the overall production
Economic	• Labour and time consuming • High input demand • Reduced flexibility to changing markets related to tree products	➜ participation of all family members ➜ maximum use of locally available inputs: including indigenous tree seedbanks
Ecological	• Competition between trees (parkland, windbreaks, alley cropping) and crops for light, water and nutrients • Interception of rain by canopy • Loss of land for non-woody crops • Depleting groundwater (when scarce groundwater) • Dry periods result in low seedling survival rates • Timber susceptible to pest attack	➜ species selection and canopy management for reducing above and below ground competition (e.g. pruning of tree branches, periodic root pruning) ➜ with water harvesting and moisture management techniques, the technology could spread to lower rainfall areas ➜ increase the productivity of land per unit area, regular pruning of woody bush and trees esp. during the crop growing period ➜ species selection ➜ supplement with water harvesting and moisture management techniques ➜ species selection, integrated pest management, breeding of more pest tolerant varieties
Socio-cultural	• Forest policies hindering planting, use and ownership of trees • Physical and social barriers to smallholder participation in markets • The overall lack of information at all levels on markets for agroforestry products • Seedling availability and survival low	➜ e.g. charcoal policy reform and rights to trees; contract fuelwood schemes ➜ novel market information systems (e.g. per cell phones); facilitating and capacity building of farmer and farm forest associations ➜ collaboration between the private sector, research and extension ➜ small-scale nursery enterprises encourage local seed collection

Adoption and upscaling

Adoption rate

The complex management requirements of agroforestry (AF) may limit its adoption. Agroforestry systems, such as improved fallows, found widespread acceptance and adoption by smallholder farmers in Southern Africa (e.g. Zambia). In regions such as the highlands of East Africa, AF systems have spread with very little or no support from the outside, as land users value trees for multiple purposes and have strong motivation to plant and maintain good tree cover. 'Fertilizer tree species' (making nutrients available from deeper soil layers) tend to be adopted to a greater extent by the poorest families in the villages, which is unusual for agricultural innovations. Recently, with improved rainfall, secured rights to trees and project support, there has been a massive increase in parkland systems in the West African Sahel.

Upscaling

Parklands, for example, were developed by farmers over many generations to diversify production for subsistence, and for income generation, as well as to minimise environmental risks related to the high climatic variability in the region. This knowledge and tradition needs to be tapped and built upon in order to upscale AF. Understanding the system and how it works in different environments is also crucial. A knowledge system is needed that documents experiences and facilitates exchange between practitioners and scientists from different countries, and stimulates better understanding of the processes behind upscaling. Land users need more information and training to be able to adopt and implement AF systems suitable for their specific environmental conditions, as compared to other agricultural activities. This limits the spread of some AF techniques. Extension strategies, including field schools, exchange visits and farmer training, are effective ways of disseminating information.

Incentives for adoption

Both ecological and social factors are simultaneously important in motivating land users to grow trees on their farms. Land users as observed do accept yield losses provided the new intervention results in a clear return on investment. In the traditional parklands of West Africa, dense shading by shea nut trees (*Vitellaria paradoxa*) and *néré* (*Parkia biglobosa*), which reduce millet yield by 50–80% are used because of the high economic returns from marketable tree products. Markets for multipurpose tree products are crucial for the adoption of AF on a scale to have meaningful economic, social and environmental impacts. Land tenure reforms and established systems of payment for ecosystems services (PES) will encourage land ownership and stimulate the development of plantations (both forest and AF parklands). A stronger AF focus in agricultural policy and extension services and the promotion of markets and improved processing of AF products will encourage the adoption. Incentives provided are often in relation to building up tree nurseries at the village level.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	+
Training and education	++
Land tenure, secure land use rights	++
Access to markets (niche markets and high value products)	++
Research	++
Infrastructure	+

Example: Kenya, Uganda, Rwanda, and northern Tanzania

The spread of fodder shrubs in East Africa has been substantial. By 2006, about 10 years after the dissemination began, 224 organisations across Kenya, Uganda, Rwanda, and northern Tanzania were promoting fodder shrubs, and over 200,000 farmers had planted them, even though the number of shrubs per farm was still well below the number needed to feed a single dairy cow. The reason for the still rather low number of shrubs is that many farmers adopt incrementally - they first want to see how it performs, and many farmers 'partially adopt' applying several different strategies for providing fodder supplements to ensure better risk management. Due to the information-intensive nature of the technology, it does not spread easily on its own and thus requires outside facilitation. Considerable investments are required to reach other dairy farmers and sustain the uptake process (Franzel and Wambugu, 2007).

References and supporting information:

Bekele-Tesemma, A. (ed). 2007. Profitable agroforestry innovations for eastern Africa: experience from 10 agroclimatic zones of Ethiopia, India, Kenya, Tanzania and Uganda. World Agroforestry Centre (ICRAF), Eastern Africa Region.

Boffa, J. M. 1999. Agroforestry parklands in sub-Saharan Africa. Conservation Guide 34. FAO. http://www.fao.org/docrep/005/x3940e/X3940E10.htm#ch7.4

Chirwa, P.W. 2003. Tree and crop productivity in Gliricidia/Maize/Pigeonpea cropping systems in southern Malawi, Ph.D dissertation, University of Nottingham.

Critchley, W. forthcoming. More People, More Trees. Practical Action Publications.

FAO. 2005. Realising the economic benefits of agroforestry: experiences, lessons and challenges. State Of The World's Forests, P. 88-97.

Franzel S. and C. Wambugu. 2007. The Uptake of Fodder Shrubs among Smallholders in East Africa: Key Elements that Facilitate Widespread Adoption. In Hare, M.D. and K. Wongpichet (eds). 2007. Forages: A pathway to prosperity for smallholder farmers. Proceedings of an International Symposium, Faculty of Agriculture, Ubon Ratchathani University, Thailand, 203-222.

Leakey, R.R.B., Z. Tchoundjeu, K. Schreckenberg, S. Shackleton and C. Shackleton. 2005. Agroforestry Tree Products (AFTPs): Targeting Poverty Reduction and Enhanced Livelihoods. International Journal of Agricultural Sustainability 3: 1-23.

Nair, P. K. R B., M. Kumar and V.D. Nair. 2009. Agroforestry as a strategy for carbon sequestration. J. Plant Nutr. Soil Sci. 2009, 172, 10–23.

Sinclair, F. L. 1999. A general classification of agroforestry practice. Agroforestry Systems 46: 161–180.

Sood, K. K. and C. P. Mitchell. 2009. Identifying important biophysical and social determinants of on-farm tree growing in subsistence-based traditional agroforestry systems Agroforest Syst (2009) 75:175–187.

Verchot, L. V., M. Van Noordwijk, S. Kandji, T. Tomich, C. Ong, A. Albrecht, J. Mackensen, C. Bantilan, K. V. Anupama and C. Palm. 2007. Climate change: linking adaptation and mitigation through agroforestry. Mitig Adapt Strat Glob Change 12: 901–918.

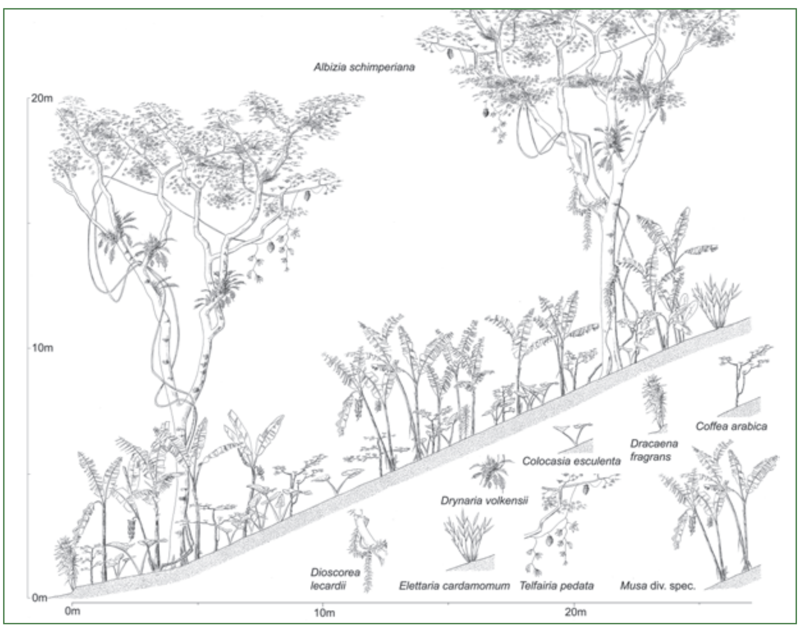
WOCAT, 2009. WOCAT database on SLM technologies and SLM approaches. www.wocat.net, accessed on 15 September 2009.

Woodfine, A. 2009. Using sustainable land management practices to adapt to and mitigate climate change in sub-Saharan Africa: resource guide version 1.0. TerrAfrica. www.terrafrica.org

Zomer, R., A. Trabucco, R. Coe and F. Place. 2009. Trees on Farm: Analysis of Global Extent and Geographical Patterns of Agroforestry. ICRAF Working Paper no. 89. Nairobi, Kenya: World Agroforestry Centre. 60pp.

CHAGGA HOMEGARDENS - TANZANIA

The Chagga homegardens are traditional, densely planted 'banana forests' with a scattered upper tree layer. The complex multicropping system evolved over several centuries through a gradual transformation of the natural forest on the footslopes of Kilimanjaro. A Chagga homegarden has an average size of 0.68 ha and integrates numerous multipurpose trees and shrubs with food crops, and stall-fed animals, without a specific spatial arrangement. However, vertically, the following 4 stories / canopies can be distinguished: (1) food crops: taro, beans, vegetables and fodder herbs / grasses; (2) coffee: 500-1,400 plants/ha; (3) banana: primary crop; 50% cover; 330-1,200 clumps/ha; and (4) trees, such as *Cordia abyssinica*, *Albizia schimperiana* and *Grevillea robusta*. The trees provide shade for coffee, act as live fences, provide medicines, firewood, fodder, mulching material, bee forage; and some have pesticidal properties (e.g. *Rauwolfia caffra*).
This multilayer system maximises the use of limited land in a highly populated area, making sustained production possible with a minimum of external inputs, minimises risk (less production failure, increased resistance against droughts and pests) and ensures at the same time environmental protection. The large species diversity provides both subsistence and cash crops.
Parts of the homegarden area are irrigated and drained by a network of over 1,000 canals and furrows tapping runoff from the montane forest. However, many systems are now in disrepair. Starting in the 1930s when coffee took more space from the food production, it became necessary to expand food production to the lowlands. Today, the Chagga highland homegarden works only in combination with a lowland field where maize, millet, beans, sunflower and groundnuts are grown to ensure food security.



SLM measure	Management and vegetative
SLM group	Agroforestry
Land use type	Mixed (Agroforestry)
Degradation addressed	Nutrient depletion; Loss of topsoil
Stage of intervention	Prevention
Tolerance to climate change	Tolerant to climatic extremes: the system has a high buffer capacity (micro-climate, biodiversity, irrigation)

Establishment activities

1. Transforming the native forest: trees that provided fodder, fuel, fruits, medicines, shade, timber, bee forage, anti-pest properties are retained while the less useful species are eliminated.
2. Introduction of new fruit and timber tree species, such as avocado, mango, *Grevillea robusta*, *Persea americana.*
3. Planting crop species (banana, coffee, taro, beans, vegetables).
4. Establishment of irrigation / drainage channels.
5. Terracing or building of bunds in steep places.

Spatial arrangement of components is irregular and appears haphazard with the trees / shrubs and food crops intimately mixed.

Maintenance / recurrent activities

1. Planting, tending and harvesting of bananas, taro, yams (all year round).
2. Opening up the canopy to ensure better fruiting of the coffee.
3. Spacing out the banana stools.
4. Manuring crops (using dung from the stall-fed livestock and compost).
5. Lopping fodder trees / shrubs.
6. Pruning and spraying against coffee berry disease and leaf rust.
7. Maintaining irrigation furrows.
8. Coffee harvest (August-January).
9. Tending and milking the stall-fed cows (typically only one cow).
10. Mulching, terrace maintenance (soil erosion prevention in general).

All operations are performed manually.

Labour requirements

For establishment: medium
For maintenance: medium

Knowledge requirements

For advisors: medium to high
For land users: medium to high

Photo 1: Chagga homegardens with the snow-capped peak of Mt. Kilimanjaro in the background. (Hanspeter Liniger)
Profile: Typical chagga homegarden on a 45% slope at 1,400 m a.s.l. with 4 vegetation layers: open light upper canopy with *Albizia schimperiana* (up to 20 m high); upper shrub layer with banana (4-6 m); a lower shrub layer with coffee (1.5-2 m) and food crops such as taro (< 1.5 m) (Hemp A., Hemp C. 2009)

Case study area: Mt. Kilimanjaro Region, Tanzania

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	na
Equipment	na
Agricultural inputs	na
TOTAL	**na**

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour	300
Equipment (axes, hoes, pangas)	45
Agricultural inputs	100
TOTAL	**445**
% of costs borne by land users	100%

Remarks: Chagga homegardens are traditional systems which evolved over centuries through a gradual transformation of the natural forest into agroforestry gardens. Establishment of new gardens is not possible due to land shortage.

Benefit-cost ratio

Inputs	short term	long term
Establishment	na	na
Maintenance	positive	very positive

Adoption

Locally well adopted traditional land use system, covering an area of approximately 1,200 km^2; further spread at local level is not possible due to land shortage. Migration of young people to urban areas leads to labour shortages and disrupts intergenerational knowledge transmission, required for the successful management and perpetuation of the homegardens.

Ecological conditions

- Climate: subhumid (tropical montane; bimodal: long rains in March-May, short rains in Nov-Dec)
- Average annual rainfall: 1,000-2,000 mm (depending on slope orientation and altitude)
- Soil parameters: fertile volcanic soils with a high base saturation and cation exchange capacity
- Slopes: hilly to steep (16 - 60%)
- Landform: Mountain slopes, orientation south / south-east
- Altitude: 1,000-1,800 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha (2-3 separate plots)
- Type of land user: poor small-scale farmers
- Population density: 650 persons/km^2
- Land ownership: individual, traditional clan regulations (land cannot be sold to outsiders)
- Land use rights: individual
- Market orientation: mixed (subsistence and commercial)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Continuous and diversified production: 185 kg beans/ha; 410 kg coffee/ha; 400 bunches of banana/ha; ca. 30 kg honey/ha
+++ Reduced risk of crop failure
++ Increased fuelwood production 1.5-3 m^3/ha/year
++ Valuable gene pool (for breeding programmes to improve crop varieties for multistorey cropping systems)
++ Increased labour efficiency

Ecological benefits

+++ Improved continuous ground cover
+++ Improved micro-climate
+++ Improved soil conservation and reduced soil loss
+++ High biodiversity and genetic variability (over 500 plant species including 400 non-cultivated plants)
++ High pest resistance

Socio-cultural benefits

+++ Improved food security
+++ Improved health
+++ Preservation of traditional knowledge

Weaknesses ➜ and how to overcome

– Productivity of Chagga homegardens is not optimal ➜ (1) Replace the less productive trees / shrubs with fast growing nitrogen fixing species (2) improve animal husbandry (e.g. to increase lactation period); (3) improve apiculture; (4) introduce new crop varieties using the gene pool developed by natural and farmer selection; (5) use fertilisers; (6) improve coffee production: certified production (organic, fair trade) to fetch higher prices; (7) replace old coffee plants with new ones; (8) integrated pest management; (9) facilitate access to capital for farm investments; (10) improve erosion control (terraces and bunds); (11) include productive fruit trees; (12) improve advisory services.
– Water management causes nutrient loss in the gardens and water shortages on the lower slopes ➜ improve efficiency of furrows: Install pipes and surfacing by cement, protect river banks from cultivation.
– High demand of wood, low coffee prices and the introduction of sun-tolerant coffee varieties endanger the homegardens ➜ incentive-based tree planting in gardens to reduce the pressure on the forest.

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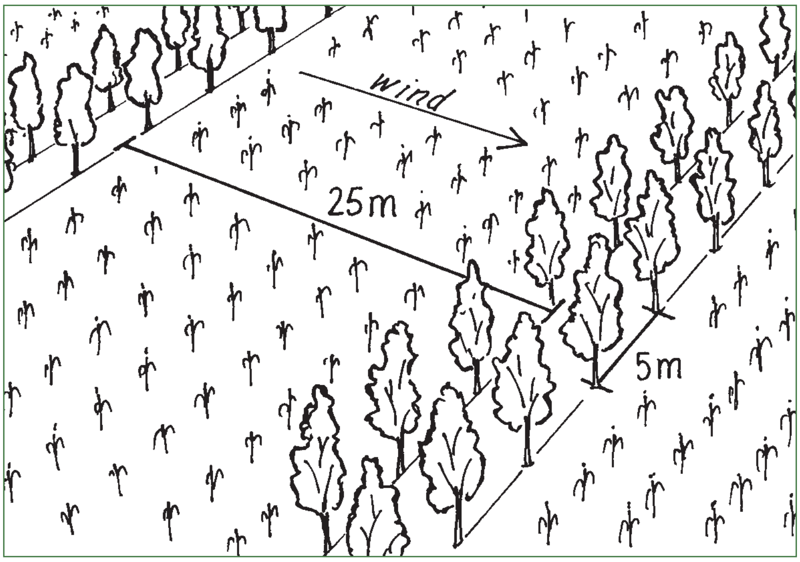
Key references: Hemp, A. (1999): An ethnobotanical study on Mt. Kilimanjaro. Ecotropica 5: 147-165. ■ Hemp, A. (2006): The banana forests of Kilimanjaro. Biodiversity and conservation of the agroforestry system of the Chagga Homegardens. Biodiversity and Conservation 15(4): 1193-1217. ■ Hemp, C. (2005): The Chagga Home Gardens – relict areas for endemic Saltatoria Species (Insecta: Orthoptera) on Mt. Kilimanjaro. Biological Conservatrion 125: 203-210. ■ Hemp, A., C. Lambrechts, and C. Hemp. (in press). Global trends and Africa. The case of Mt. Kilimanjaro. (UNEP, Nairobi). ■ Hemp, A., Hemp, C., Winter, C. (2009) Environment and worldview: The Chagga homegardens. In: Clack, T.A.R. (ed.) Culture, history and identity: Landscapes of inhabitation in the Mount Kilimanjar area, Tanzania. BAR International Series 1966, Archaeopress Oxford, pp. 235-303 ■ Fernandes E.C.M., Oktingati A., Maghembe J. 1985. The Chagga homegardens: a multistoried agroforestry cropping system on Mt. Kilimanjaro (Northern Tanzania) in Agroforestry Systems 2: 73-86.

SHELTERBELTS - TOGO

On the vast denuded plains of Pays Kabyé in northern Togo, barriers of leguminous trees (e.g. *Cassia siamea* or *spectabilis*; a medium sized tree growing between 10-20 m tall; *Albizzia procera*, *Leucaena leucocephala*) and shrubs (*Cajanus cajan, Erythrina variegate*) are established between fields cultivated with annual crops such as maize. The shelterbelts provide a good microclimate and protect the crops against the counterproductive effects of wind speed such as wind erosion, soil moisture loss through evaporation and physical damage to crops.

The shelterbelts' effectiveness depends on their permeability, their spacing and the direction of planting in relation to the wind direction: A proportion of 40-50% of holes (openings, void) in relation to the total surface of the shelterbelt is desirable, and establishment of tree rows perpendicularly to the main wind direction is most effective. In order to reduce lateral turbulence the windbreaks need to reach a length of minimum 10 times their height. Shelterbelts protect 15-25 times their height on the leeward and 1-2 their height on the windward side. If the area to be protected is large, several windbreaks need to be established.

The denser the shelterbelts are, the better the windbreaking effect, but the higher the competition with crops for nutrients, light and water. Frequent pruning helps to avoid too much competition and provides fuelwood. In case leguminous tree species are used, soil properties can be improved through nitrogen fixation and the provision of organic matter (leaves).



SLM measure	Vegetative
SLM group	Agroforestry
Land use type	Cropland / mixed land
Degradation addressed	Wind erosion, Aridification
Stage of intervention	Prevention and mitigation
Tolerance to climate change	No data

Establishment activities

1. Determine the area to be protected and alignment of shelterbelts (1,2, or 3 lines of trees per row); rows to be established perpendicular to main wind direction; spacing between rows: 20-25m).
2. Establish plant nursery.
3. Dig planting pits at a spacing of 2-3 meters.
4. Planting of seedlings (when conditions are favourable).
5. Regular irrigation of young tree seedlings after plantation.
6. Weeding.
7. Reduce density to a spacing 5 m between trees.

All activities carried out during rainy season, using hand tools such as hoe, machete and measuring tape. Establishment takes 36 months.

Maintenance / recurrent activities

1. Weeding (according to necessity / speed of regrowth).
2. Pruning to avoid shading effect on crops.

Labour requirements

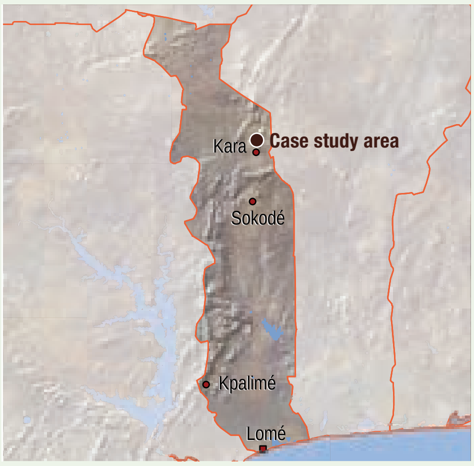
For establishment: high
For maintenance: moderate

Knowledge requirements

For advisors: high
For land users: moderate

Photo 1: A windbreak with two or three tree lines planted 5 m apart established between fields of annual crops. (Idrissou Bouraima)
Technical drawing: Spacing between windbreak rows is 20-25 m. The row of windbreak can be of a single tree line, of double tree lines, etc. depending on wind speed and scope of protection. The in between tree line spacing is 5 m. Plant density can range from 100 – 200 plants/ha depending on the number of tree lines planted within a windbreak. (Mats Gurtner)

Case study area: Tchitchao, Kara, Togo



Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	200
Equipment	86
Agricultural inputs	90
TOTAL	**376**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour	139
Equipment	
Agricultural Inputs	23
TOTAL	**162**
% of costs borne by land users	100%

Remarks: The monetary costs include the purchase of seeds, cuttings or nursery plants and labour for the preparation and planting. In certain circumstances, it is necessary to protect young trees against browsing and other damage.

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	positive
Maintenance	positive	very positive

Ecological conditions

- Climate: subhumid
- Average annual rainfall: 1,000-1,500 mm
- Soil parameters: medium to good drainage; shallow, sandy-loamy soils; medium soil organic matter
- Slope: gentle (2-5%)
- Landform: footslopes, plateaus / plains, hill slopes
- Altitude: 100-500 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha
- Type of land user: small-scale farmers, relatively rich (about 1.5% of land users). Windbreak technology is little known by most farmers
- Population density: 300 persons per km^2 in the region
- Land ownership: individual, titled
- Land use rights: individual
- Level of mechanisation: no data
- Market orientation: subsistence and commercial

Production / economic benefits

++ Increased income from agriculture
++ Increased wood production and forest products (fruits)
++ Increased crop yield

Ecological benefits

++ Reduced wind speed
++ Reduced loss of topsoil (through wind erosion)
++ Reduced loss of soil moisture (through evaporation)

Socio-cultural benefits

++ Increased conservation / erosion knowledge

Socio-cultural benefits

++ Reduced off-site deposition of wind sediments

Weaknesses ➜ and how to overcome

- Reduced area for cultivation of crops ➜ establish the minimum of shelterbelts necessary for optimal protection.
- Reduced crop yields alongside shelterbelts (competition for nutrients, light, water) ➜ avoid dense planting of trees and shrubs; frequently prune the trees.
- Shelterbelts provide habitat for vermins / pests (rats, insects) ➜ frequently hunt these animals.
- Increased labour inputs.

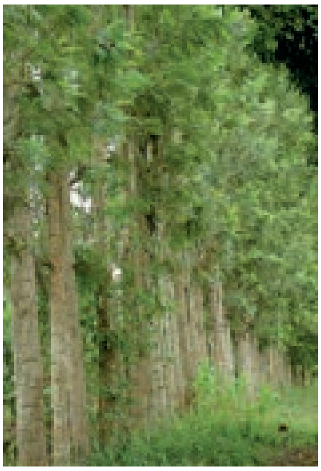
Adoption

100% of the families who have implemented shelterbelts in the case study area have done it without any external support apart from technical advice. However, there is no growing trend of spontaneous adoption in the region since the windbreak technology is little known by most farmers.

Main contributors: Mawussi Gbenonchi, Ecole Supérieure d'Agronomie, Université de Lomé (ESA UL), Lomé, Togo; gmawussi@gmail.com
Key references: Care International Togo. 1997. Agroforestry training and demonstrations in northern Togo. Final report to European Union B7-5040/93/21 ■ Louppe, D., H. Yossi. 1999. Les haies vives défensives en zones sèches et subhumides d'Afrique de l'Ouest. Atelier Jachères, Dakar. ■ Ariga, E. S., 1997. Availability and Role of Multipurpose Trees and Shrubs in Sustainable Agriculture in Kenya. Journal of Sustainable Agriculture 10:2/3, 25-35. ■ WOCAT. 2007. WOCAT database on SLM technologies. www.wocat.net

GREVILLEA AGROFORESTRY SYSTEM - KENYA

While *Grevillea robusta* (the 'silky oak', an Australian native) was originally introduced from India to East Africa as a shade tree for tea and coffee estates, it is now more commonly used in small-scale farming areas, especially in association with annual crops (maize / beans). There are three major forms of grevillea agroforestry systems: (1) planting along farm boundaries; (2) scattered grevillea trees on cropland - resembling open forests with multi-storey layers; (3) 'alley cropping' on terraces. Boundary planting is the most common form and is described in this case study.
Grevillea can be easily established and is relatively free of pests and diseases. The trees are managed through periodic pollarding – the pruning of side branches while maintaining the trunk – to reduce competition with crops. Competition is little in any case, and can be further reduced by digging a small trench around the trees, thus cutting the superficial roots.
Grevillea is planted for a number of purposes, including marking property boundaries, supplying fuelwood and building materials (pruning of side branches which rapidly regrow), providing shade and for ornamental value. Simultaneously it increases organic matter, provides mulching materials to improve ground cover, reduces wind speed, and encourages nutrient recycling due to its deep rooting. It can be planted over a wide range of agroecological zones and from sea level up to 2,000 metres. It is ideally suited to intensive areas of small-scale mixed farming. To effectively combat soil erosion problems on slopes, grevillea planting must be combined with additional measures such as *fanya juu* and bench terraces, grass strips and other vegetative and agronomic measures.



SLM measure	Vegetative
SLM group	Agroforestry
Land use type	Mixed (crops and trees)
Degradation addressed	Soil moisture problem; Fertility decline, reduced organic matter content; Loss of topsoil through water erosion
Stage of intervention	Mitigation
Tolerance to climate change	High tolerance to change of temperature and rainfall – Grevillea grows under a high range of climates

Establishment activities

1. Dig planting pits (before rainy seasons).
2. Purchase seedlings from nurseries or collection of wildings (naturally generated seedlings).
3. Plant seedlings (at onset of rains), initial spacing ca. 1 m, later thinned to 1.5 – 3 m.

Maintenance / recurrent activities

1. Weeding around seedlings when necessary (rainy season).
2. Pruning as necessary; pruned branches are dried and used for fuelwood (annually).
3. Pollarding (pruning of side branches; ensures large and straight tree trunks): annually, after crop harvest.
4. Root pruning: dig a trench (60 cm from tree, 25 cm deep) and cut the shallow roots to reduce competition with annual crops every four years.
5. Felling some trees to reduce density as they grow bigger (during dry season).
6. Replanting when trees are harvested for timber.

All activities carried out by manual labour using machetes (panga), hoes and handsaws.

Labour requirements

For establishment: moderate
For maintenance: moderate

Knowledge requirements

For advisors: moderate
For land users: low

Photo 1: Boundary planting of grevillea trees between smallholder plots used for cultivation of maize and beans.
Photo 2: Detailed view of a dense row of grevillea trees.
Photo 3: Scattered grevillea trees planted as a shade tree in a coffee plantation. (All photos by Hanspeter Liniger)

Case study area: Kiawanja, Nembure division, Embu, Kenya

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	25
Equipment	10
Agricultural inputs	125
TOTAL	**160**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour	65
Equipment	0
Agricultural inputs	25
TOTAL	**90**
% of costs borne by land users	100%

Remarks: Boundary planting is the basis of costing (assuming average plot size of 25 m by 25 m and an average spacing of 1 m between trees = 1,000 trees/ha). 1 person plants 50 trees in one day. The labour required for management (pruning and pollarding) of established trees is high. Seedling purchase price is also high, but this can be reduced by collecting wildings (seedlings growing in the wild) and establishing personal or group nurseries.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	very positive
Maintenance	slightly positive	very positive

Adoption

All land users of the catchment (totally 120 families) have accepted the technology spontaneously.

Ecological conditions

- Climate: subhumid
- Average annual rainfall: 1,000-1,500 mm
- Soil parameters: good drainage, deep well drained nitosols; soil organic matter mostly low and partly medium
- Slope: mostly rolling to hilly (8-30%), partly steeper
- Landform: ridges, mountain / hill slopes; also foot slopes / valleys
- Altitude: 1,000 – 1,500 m a.s.l.

Socio-economic conditions

- Size of land per household: mainly 1-2 ha, partly <1 ha
- Type of land user: mainly small-scale farmers
- Population density: > 500 persons/km^2
- Land ownership: individual titled
- Land use rights: individual
- Level of mechanisation: manual labour
- Market orientation: mixed (subsistence and commercial): marketed products include: grevillea timber, coffee, macademia nuts and milk

Production / economic benefits

+++ Increased wood production (for timber and fuelwood)
++ Increased farm income
+ Increased fodder production (leaves used as fodder during dry season)
+ Increased crop yield (through mulching and nutrient pumping)

Ecological benefits

+++ Reduced wind velocity (affecting crops / homesteads)
++ Improved soil cover (mulch and canopy cover)
++ Improved micro-climate
++ Increased soil fertility and organic matter (leaf litter, leaves used as cattle bedding; nutrient recycling)
++ Reduced soil loss
+ Increased soil moisture (mulching improves infiltration)
+ Biodiversity enhancement (bees, birds, etc.)

Socio-cultural benefits

++ Improved conservation / erosion knowledge (stakeholder interaction)
++ Improved housing (more timber available)

Off-site benefits

+++ Reduced deforestation (alternative source of fuel and timber)
++ Creation of employment (tree management and harvesting)
+ Reduced downstream flooding and siltation
+ Reduced river pollution (chemical contamination)
+ Increased stream flow in dry season

Weaknesses ➜ and how to overcome

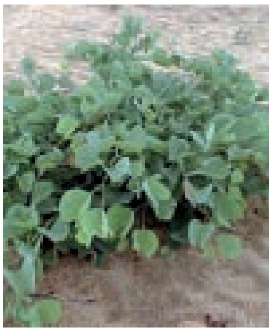
- Seedlings and wildings not always readily available ➜ encourage local seed collection and setting up of group tree nurseries.
- Timber is susceptible to pests attack (weevils) ➜ timber treatment with appropriate chemicals; breeding of pest tolerant varieties.
- Livestock can damage young seedlings ➜ protection by fencing.
- Dry periods result in low seedling survival rates: planting not possible in dry areas ➜ combine technology with water harvesting / moisture management techniques.
- Competition with crops ➜ regular pruning of side branches; dig a small trench around the trees, thus cutting the superficial roots.
- Limited efficiency of agroforestry system in combating soil erosion problems on slopes ➜ combine with agronomic and vegetative measures (e.g. contour ploughing, mulching, grass strips), and where necessary with structural measures (e.g. terraces, bunds and ditches).

Main contributors: John Munene Mwaniki, Ministry of Agriculture & Rural Development, Embu, Kenya; mwanikijm2002@yahoo.com. Ceris Jones, Agronomica, UK; ceris.a.jones@btopenworld.com

Key references: ICRAF. 1992. A selection of useful trees and shrubs in Kenya. ■ ICRAF, Nairobi. Guto et al (1998) PRA report, Kiawanja catchment, Nembure division, Embu District-Kenya. Ministry of Agriculture, Nembure division, Embu. ■ Harwood CE. 1989. Grevillea robusta: an annotated bibliography: ICRAF, Nairobi. ■ Rocheleau D., F. Weber and A . Field-Juma. 1988. Agroforestry in dryland Africa: ICRAF, Nairobi http://www.winrock.org/forestry/factpub/factsh/grevillea.htm. http://www.ces.uga.edu/pubcd/b949-w.html

FARMER MANAGED NATURAL REGENERATION - NIGER

Farmer Managed Natural Regeneration (FMNR) is the systematic regeneration of living and sprouting stumps of indigenous vegetation which used to be slashed and burned in traditional field preparation. The naturally occurring seedlings and / or sprouts are managed and protected by local farmers. Most suitable are species with deep roots that do not compete with crops and have good growth performance even during poor rainy seasons. In the case study area the three most valuable species – as perceived by land users – are *Faidherbia albida*; *Piliostigma reticulatum* and *Guiera senegalensis*.
The ideal density, when grown with cereal crops, is between 50 and 100 trees per hectare. For each stump, the tallest and straightest stems are selected and side branches removed to roughly half of the stem height. Excess shoots are then removed. Regular pruning of any unwanted new stems and side branches stimulates growth rates. Farmers are encouraged to leave 5 stems / shoots per tree, cutting one stem each year and letting another grow in its place. On removing a shoot, the cut leaves are left on the surface where they reduce erosion and are then eaten by termites, returning the nutrients to the soil. The remaining shoots continue to grow, providing a continuous supply of wood. From the first year, firewood is collected from trimmings. From the second year on, cut branches are thick enough to sell. A more intensive form of FMNR is to profit from every stump sprouting on the land. This option allows idle land to become a productive resource during an otherwise unproductive eight-month dry season.
FMNR is a simple, low-cost and multi-benefit method of re-vegetation, accessible to all farmers, and adapted to the needs of smallholders. It reduces dependency on external inputs, is easy to practice and provides multiple benefits to people, livestock, crops and the environment. Tree layout will need to be carefully considered if ploughs are used for cultivation.



SLM measure	Vegetative and management
SLM group	Agroforestry
Land use type	Mainly annual cropping
Degradation addressed	Deforestation; Wind erosion and sedimentation (increased wind speed, dust storms); Water deficiency; Sand dune movements
Stage of intervention	Mainly rehabilitation, partly mitigation
Tolerance to climate change	Tolerant to climatic extremes (e.g. droughts, temperature increase, rainfall decrease, etc.)

Establishment activities

1. Select 50 - 100 stumps per hectare for regrowth during the dry season.
2. Select the tallest and straightest stems and prune side branches to roughly half the height of the stem (using sharpened axe or machete and cutting upwards carefully).
3. Remove excess shoots, leave the cut leaves on the surface.
4. Prune any unwanted new stems and side branches (each 2-6 months).

All activities carried out manually.

Maintenance / recurrent activities

1. Cut one stem (per tree) each year and let another grow in its place.
2. Once the stems selected for growth are > 2 meters high, they can be pruned up to two thirds.
3. Prune any unwanted new stems and side branches (each 2-6 months).

All activities carried out manually.
Note: Farmers in different countries have developed a range of management practices which best suit their needs and thus differ from the present case study.

Labour requirements

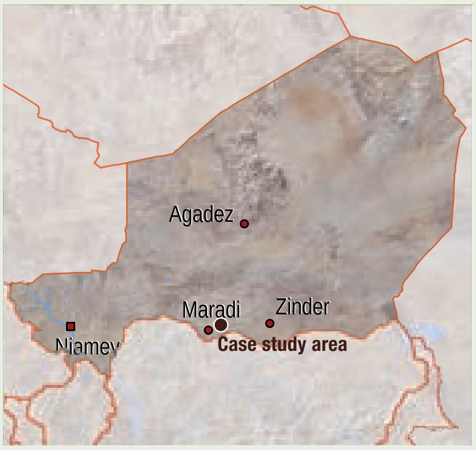
For establishment: low
For maintenance: low

Knowledge requirements

For advisors: medium
For land users: medium

Photo 1: Mature FMNR system in Maradi, with millet and a tree density of around 150 trees/ha.
Photo 2: New tree sprouts in front of the farmer, harvested wood in the background. Note the proximity of the crop (millet) to the tree without detrimental effect.
Photo 3: Re-sprouting tree stumps and roots: the basis of FMNR.
Photo 4: Typical FMNR farm after harvest of millet.
Photo 5: After just one year the numerous stems are growing vigorously and straight. Ideally, one or two are harvested from the clump each year, always leaving new regrowth to replace them. (All photos by Tony Rinaudo)

Case study area: Maradi, Niger



Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 2-3 person-days	6
Equipment / tools: see below	0
Agricultural inputs: none	0
TOTAL	**6**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 1-2 person-days	4
Equipment / tools: see below	0
Agricultural inputs: none	0
TOTAL	**4**
% of costs borne by land users	100%

Remarks: Main costs are in the form of labour. One man could prepare one hectare in 1–3 days, depending on tree density (labour is undertaken by the farm owner and rarely through paid labour). No inputs used; no extra tools needed, tools are available on-farm (hoe, axe, machete etc). Maintenance costs depend on tree density also and could require 1–2 days/year/ha.

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	positive	very positive

Remarks: Annual income from selling wood: US$ 140 (from the 6th year after implementation). By some estimates, total benefit per hectare (incl. wood sales, increased crop yield, increased livestock productivity, wild foods and medicines etc.) are in the order of US$ 200/ha, compared to an investment in labour US$ 10-15.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 150–500 mm (variable)
- Soil parameters: low fertility, very low soil depth, drainage and organic matter content
- Slope: mainly flat, partly undulating
- Landform: mainly plains
- Altitude: 200–300 m a.s.l.

Socio-economic conditions

- Size of land per household: 1–5 ha (average production area)
- Type of land user: small-scale; very poor and poor land users
- Population density: 11 persons/km²
- Land ownership: individual, generally untitled
- Land use rights: individual
- Level of mechanisation: mainly manual labour, partly animal traction
- Market orientation: mixed (subsistence and commercial)
- FMNR can be practiced by any farmer, even the poorest. No external

Production / economic benefits

+++ Increased wood production (production value increased by 57%)
+++ Increased income
+++ Increased crop production (at least doubled)
++ Reduced workload: no annual clearing / burning of trees
++ Increased livestock production (nutritious pods as fodder)

Ecological benefits

+++ Increased soil cover and increased biomass: increased tree density on farmland (from 30 to 45 trees/ha average)
+++ Windbreak effect: deposition of rich, wind blown silt; improved micro-climate
+++ Increased organic matter from leaf fall and trimmings
+++ Increased soil fertility (dung; livestock spends more time in fields with trees)
+++ Increased biodiversity; creation of habitat, food and shelter for predators of crop pests
+++ Increased drought-tolerance: regenerated trees are indigenous and generally have mature root systems

Socio-cultural benefits

++ Increased food security: edible leaves / fruits; bridge food shortages
+++ Improved quality of life: reduced wind speeds and dust; shade is available; barren landscape is returning to a natural savanna
+++ Increased disaster risk reduction: FMNR acts as an insurance policy

Off-site benefits

+++ Urban populations benefit from cheaper, sustained wood supply and reduced incidence of dust storms

Weaknesses ➜ and how to overcome

- Scarce presence of live tree stumps ➜ alternatively broadcast seeds of indigenous species (reduced short term benefits; high mortality rates).
- Cultural norms and values: 'a good farmer is a clean farmer' (= no trees) ➜ work with all stakeholders to change norms.
- Land (including trees) is treated as common property during dry season; damaging and removing trees on other people's land occurs ➜ create sense of ownership of trees: (1) encourage communities to develop rules that respect property; (2) local forestry authorities granting informal approval for farmers to be able to reap the benefits of their work.

Adoption

The technology has first been implemented in Maradi region, Niger in the early 1980's. Spread has been largely spontaneous, with minimal external assistance. The area covered today by trees from FMNR is estimated to be more than 50,000 km² in Niger.

Main contributors: Tony Rinaudo; World Vision, Melbourne; tonyrinaudo@worldvision.com.au; Dov Pasternak ICRISAT-WCA, Niamey, Niger; d.pasternak@icrisatne.ne
Key references: Rinaudo T (1999): Utilising the Underground Forest: Farmer Managed Natural Regeneration of Trees, in Dov Pasternak and Arnold Schlissel (Eds). Combating Desrtification with Plants. ■ Cunningham PJ and Abasse T (2005): Reforesting the Sahel: Farmer Managed Natural Regeneration; in Kalinganire A, Niang A and Kone A (2005). Domestication des especes agroforestieres au Sahel: situation actuelle et perspectives. ICRAF Working Paper, ICRAF, Nairobi. ■ Haglund E, Ndjeunga J, Snook L, and Pasternak D (2009): Assessing the Impacts of Farmer Managed Natural Regeneration in the Sahel: A Case Study of Maradi Region, Niger (Draft Version)

PARKLAND AGROFORESTRY SYSTEM - BURKINA FASO

Parklands are the traditional agroforestry systems of semi-arid West Africa or Sahel where naturally growing, valuable trees are protected and nurtured on cropping and grazing lands. For the rural people in the Sahel, parkland trees are multipurpose: they are a grocery shop, a pharmacy and a silo at the same time. People rely on many locally cherished species to provide food and nutritional security for both human and livestock populations and to protect and enrich soils. Important tree species are baobab (*Adansonia digitata*), tamarind (*Tamarindus indica*), *Faidherbia albida*, shea nut or *karité* (*Vitellaria paradoxa*, see photo 1 below) and *néré* (*Parkia biglobosa*).
Crop production can be increased below and around the trees (especially under *Faidherbida albida*) due to the favourable micro-climate, accumulation of soil organic matter through litter fall, prunings and root decay in the predominantly sandy and poor soils.
Parkland management practices include: assisted tree regeneration (see also Farmer Managed Natural Regeneration, Niger); Tree planting (mostly in vicinity of family compounds); Improved fallows (under which economically useful and fertility-improving trees are planted before cropping is discontinued) and fire protection. Farmers commonly apply silvicultural techniques to increase production of parkland trees. These include seedling protection and fencing, watering, and the selection of vigorous shoots. Pruning is done to improve productivity of trees, reduce shade and enhance understorey crop performance and to produce fuelwood and fodder. It stimulates leaf regrowth, causes an additional foliation peak during the rainy season and depresses pod production. Coppicing and pollarding represent a way of limiting competition with intercrops and providing wood and other tree products in species with good vegetative growth.

SLM measure	Vegetative
SLM group	Agroforestry
Land use type	Mixed (crops and trees)
Degradation addressed	Desertification problem; Fertility decline, reduced organic matter content; Loss of topsoil through water erosion
Stage of intervention	Mitigation
Tolerance to climate change	Increased tolerance through the use of indigenous species

Establishment activities

1. Retaining saplings from natural regeneration or wildings before rainy seasons.
2. Planting improved material (early stage).
3. Grafting for shortening juvenile phase and improving fruit quality (initiation stage).
4. Pruning to form erect canopy.
5. Protection from animals by dead or live fences.

Maintenance / recurrent activities

1. Weeding around seedlings when necessary (rainy season).
2. Pruning as necessary (pruned branches are dried and used for fuelwood): annually.
3. Pollarding (pruning of side branches to improve light for understorey crops.
4. Felling some trees to reduce density as they grow bigger (during dry season).

All activities carried out by manual labour using machetes (panga) or hoes.

Labour requirements

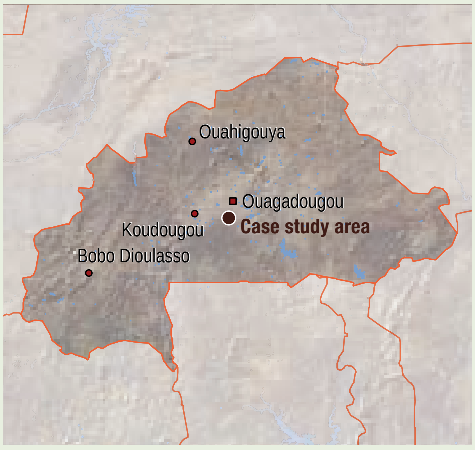
For establishment: moderate
For maintenance: high

Knowledge requirements

For advisors: moderate
For land users: low

Photo 1: *Karité* –millet parkland in Sapone, Burkina Faso. (Jules Bayala)
Photo 2: *Faidherbia albida* dominating a parkland system with pearl millet in Burkina Faso. (William Critchley)

Case study area: Saponé, Burkina Faso



Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	-
Equipment	-
Agricultural inputs	-
TOTAL	**no data**

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour	-
Equipment	-
Agricultural inputs	-
TOTAL	**no data**

Remarks: Data on costs is not available. However, costs for management of the land use system are low; only some pruning and trimming of trees is needed which is effectively 'harvesting' of fodder and wood.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	very positive
Maintenance	slightly positive	very positive

Remarks: Costs of establishment and maintenance in traditional parklands are difficult to quantify because trees usually arise through natural regeneration and then are 'nurtured'. Annual returns from the sale of *neré* products were estimated at 50-60 US$ (26% of farmers' income) and *karité* / shea nut activities can represent 20–60% of women's income in rural areas.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 720 mm (unimodal)
- Soil parameters: sandy loam, Regosols; low soil organic matter
- Slope: mostly flat
- Landform: plains
- Altitude: no data

Socio-economic conditions

- Size of land per household: 1-5 ha
- Type of land user: poor and better-off farmers (basically everyone who has land)
- Population density: 76 persons/km^2
- Land ownership: majority has ownership of the land, few borrow
- Land use rights: individual
- Level of mechanisation: manual labour
- Market orientation: mixed (subsistence and commercial)

Production / economic benefits

+++ Increased production from fruits
++ Increased farm income
\+ Increased fodder production (leaves used as fodder during dry season)
\+ Increased crop yield (through mulching and nutrient pumping)

Ecological benefits

+++ Reduced wind velocity (affecting crops / homesteads)
++ Improved soil cover (mulch and canopy cover)
++ Improved micro-climate
++ Increased soil fertility (leaf litter and nutrient recycling)
++ Reduced soil loss
\+ Increased soil moisture (mulching improves infiltration)
\+ Biodiversity enhancement (bees, birds, etc.)

Socio-cultural benefits

++ Improved conservation / erosion knowledge (stakeholder interaction)
++ Improved housing (more timber available)

Off-site benefits

+++ Reduced deforestation (alternative source of fuel and timber)
++ Creation of employment (tree management and harvesting)
\+ Reduced downstream flooding
\+ Reduced downstream siltation
\+ Increased stream flow in dry season

Weaknesses ➜ and how to overcome

- Seedlings and wildings not always readily available ➜ encourage local seed collection and setting up of group tree nurseries.
- Livestock sometimes damage the young seedlings ➜ protection by fencing.
- Dry periods result in low seedling survival rates: planting not possible in dry areas ➜ combine technology with fencing.
- Competition with crops ➜ regular pruning of side branches.
- Long period to fruiting ➜ use vegetative propagation of superior trees.

Adoption

Tens of millions of people live in the traditional parklands of Burkina Faso, Mali, Senegal and Niger. In Mali alone an estimated 3.6 million people practice parkland agroforestry with 40 trees per hectare.

Main contributors: Jules Bayala, CORAF; secoraf@coraf.org; www.coraf.org
Key references: Boffa,J.M. 1999. Agroforestry parklands in Sub-Saharan Africa. FAO Conservation guide no.34, Rome, 230pp. ■ Jonsson K, CK. Ong and JCW. Odongo . 1999. Influence of scattered nere and karite trees on microclimate, soil fertility and millet yield. Experimental Agriculture 35:39-53. ■ Bayala J., J. Balesdent, C. Marol, F. Zapata, Z. Teklehaimanot, SJ. Quedrago. 2006. Relative contribution of trees and crops to soil carbon content in a parkland system in Burkina Faso using natural 13C abundance. Nutrient Cycling in Agroecosystems 76:193-201.

INTEGRATED CROP-LIVESTOCK MANAGEMENT

Pegged small-stock on harvested cropland, Cape Verde. (Hanspeter Liniger)

In a nutshell

Definition: In Integrated Crop - Livestock Management (ICLM) crops and livestock interact to create synergies, making optimal use of resources. The waste products of one component serve as a resource for the other: manure from livestock is used to enhance crop production (improve soil fertility), whilst crop residues and by-products (grass weeds and processing waste) are supplementary feed for the animals. Grass – and prunings from agroforestry trees - grown on contour conservation barriers, as well as nitrogen-fixing legumes grown under conservation agriculture systems, are further potential sources of fodder. Livestock are integral to most African cropping systems: they provide traction and transport, as well as meat, milk and hides. Improvements to the livestock component of integrated systems include upgraded intensive pastures through shifting night enclosures (kraals / bomas), fodder planting / hay making, and stall feeding ('cut-and-carry'; 'zero grazing') in the more humid areas. Various factors influence the type and effectiveness of crop - livestock interactions, including socio-economic parametres (access to land, labour and capital) and ecological conditions (temperature and rainfall).

Applicability: Integrated crop - livestock systems are common in semi-arid and subhumid (and humid) areas as well as in tropical / temperate highlands. Given the growing demand for livestock products, the subhumid areas are predicted to the best potential to provide most of this increase. ICLM can be applied in many areas, but needs to be adapted and modified to prevailing conditions.

Resilience to climate variability: ICLM systems tend to be relatively well adapted to climatic variability because of their diversity and flexibility – especially when soil and water conservation / water harvesting and agroforestry are integrated into the overall system.

Main benefits: Well managed ICLM (a) increases crop yields; (b) improves soil biological activity and health; (c) builds up fertility through nutrient recycling, the planting of leguminous crops and trees; (d) reduces erosion; (e) intensifies land use, improving profits; and (f) improves livestock productivity and health. Including animals in farm systems increases sustainability and reduces reliance on external inputs. Carbon storage can be high: in one case from West Africa, soil receiving manure for five years had 1.18 t/ha more carbon present than soil treated with plant residues alone (Woodfine, 2009 and FAO, 2007). Nevertheless, the carbon budget of such systems is affected negatively by methane emitted by livestock. ICLM thus reduces poverty and malnutrition, and strengthens environmental sustainability.

Adoption and upscaling: Skillful organisation and management of animals and the land is needed. Rules and regulations have to be followed by all concerned, particularly with regard to exclusion of areas from grazing and in terms of animal health and nutrition. Specific skills can be taught, but much must be learnt through experience.

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	++

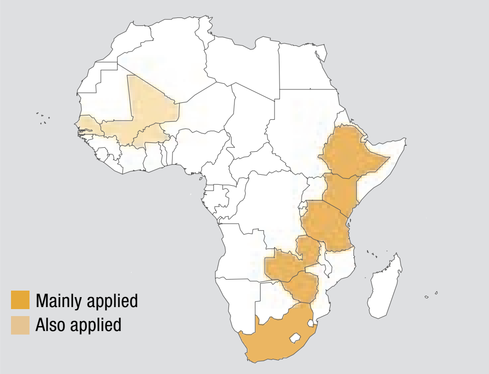
Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year) in silvo / agro-forestry systems	0.1- 0.8* up to 3*
C Sequestration: above ground	++
C Sequestration: below ground	++

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 management (Source: Woodfine, 2009)*

Origin and spread

Origin: Traditional agriculture in Africa was generally based on mixed crop-livestock systems, with pure livestock production predominating only when rainfall was too low and uncertain to support some form of crop production. Pure arable systems only developed when large-scale mechanised cereal farming was introduced, or where cash crops such as coffee, tea or sugar cane expanded. Animal disease may also have played a role in some areas. Today the re-discovery and modification of traditional techniques, including rotational land use / fallows, mixed cropping, grazing rules and regulations, in combination with agroforestry, improved fodder species, specific soil and water conservation measures (SWC) and more productive livestock breeds, make these systems stronger and more versatile.
Mainly applied in: Ethiopia, Kenya, South Africa, Tanzania, Zambia, Zimbabwe
Also applied in: Burkina Faso, Mali, Senegal



Integrated Crop-Livestock Management in SSA.

Principles and types

ICLM is evolving as a very viable and common farming system, allowing smallholder farmers to capitalise on the complementarity and synergies between crops and livestock for improved cycling of nutrients, efficient resource use, and safeguarding the environment. Some activities / measures in an integrated crop livestock system are:
Animals stall-fed (zero-grazing) has expanded significantly through the introduction in the more humid areas of (particularly) dairy cows. This has led to an all-round intensification of crop – livestock systems. Combined with vegetative SWC measures, based often on napier grass which is an excellent fodder, as well as agroforestry, and sometimes biogas plants, whole farming systems have been upgraded.
Harvesting and relocating nutrients: Crop residues are sometimes stored but most are left in the field after harvest, opportunistically grazed and often underutilised (and spoiled). Land users can paddock animals on cropland or otherwise collect (sometimes store and process) and spread manure on cropland to improve fertility and hence production. In agropastoral systems animals graze freely during the day and are in *kraals / bomas* (enclosures for cattle, goats and sheep) or on cropland during the night. The balance of feed that an animal consumes influences the properties of its gaseous emissions (especially methane, CH_4), and manure management is important in this context.
Dual-purpose crops (food-feed) enable farmers to increase unit area productivity with the same resources. Significant advances have already been made in the development and promotion of dual-purpose cowpeas in West Africa and maize in Kenya.
Addition or control of species involves improving grazing land through planting high-value species (e.g. grasses, multi-purpose shrubs / trees) for increased biomass production ('enrichment planting'), eradicating invasive species by selective cutting, while simultaneously encouraging natural regeneration of desirable local species. Under dry conditions, water harvesting techniques can be useful.
Haymaking allows the building up of reserves for the dry season from surplus in the wet. Storing fodder helps animals to survive during dry periods without having to overgraze the land. It is also a buffer in extreme drought when market prices for animals are very low. The conservation of fodder as hay or silage, however, has not been a common practice in small-scale farming systems in SSA due to lack of information on conserving fodder under tropical conditions, and the resilience of local breeds to harsh conditions and poor diets.
Production of forages, grasses and leguminous trees is often through being grown on bunds and intercropped with food or cash crops. Live fences can also serve the same purpose.
Enclosures: If pasture is severely degraded due to overgrazing then fencing (social as well as physical) is often the first step, followed by a period of several years of rest. After good regeneration and regrowth, cut-and-carry or controlled grazing (e.g. rotational grazing) leaving periods of recovery of the vegetation are the management systems that maintain the land's condition.
Animals for field work and transportation constitute an appropriate, affordable and sustainable technology that is used in most countries in SSA. Draft animals, notably cattle and donkeys, provide smallholder farmers with vital power for cultivation and transport. Animal traction can also be used for water-raising, milling, logging, land-leveling and road construction.

Top: Cow stall fed with crop residues, Kenya.
(Hanspeter Liniger)
Middle: Transportation of grass for stall feeding, Ethiopia.
(Hanspeter Liniger)
Bottom: Stall feeding of dairy cows, Uganda.
(William Critchley)

Applicability

Land degradation addressed

Chemical soil deterioration: fertility decline and reduced organic matter content
Biological degradation: reduction of vegetation cover and species composition / diversity decline, loss of fodder value
Poor animal health due to limited availability and quality of feed
Fire is a widely used management practice for vegetation clearance, growth stimulation and pest control. Rangeland and crop residue burning, besides emitting CO_2, reduces soil organic matter and nutrient levels.

Land use

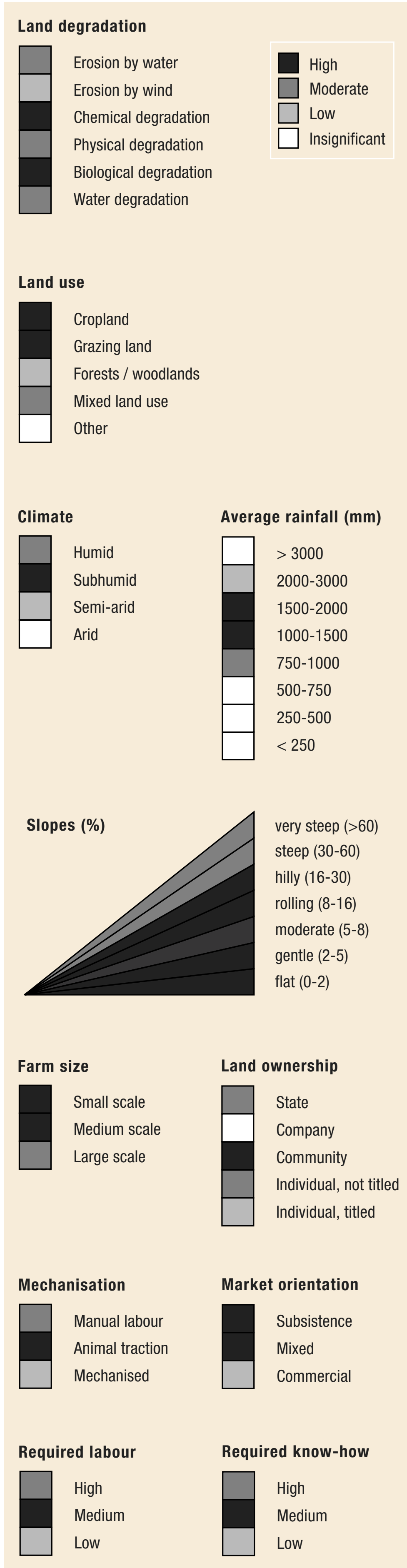
Mainly cropland and mixed land use
Also intensive grazing / fodder production (improved or planted pastures, etc.)

Ecological conditions

Climate: mainly subhumid to humid areas, partly in semi-arid, with rainfall mainly between 750-1,500 mm (though even higher also)
Terrain and landscape: no restrictions whole range from flat to hilly
Soils: no restriction

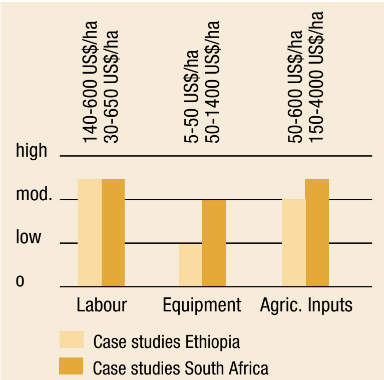
Socio-economic conditions

Farming system and level of mechanisation: Mainly on small-scale to medium-scale farms, mainly animal draught and manual labour, low level of mechanisation (few exceptions: replanting / reseeding).
Market orientation: Mainly subsistence and mixed, but also commercial (e.g. Kenya and South Africa).
Land ownership and land use / water rights: In most cases individual land use rights and communal (organised).
Skill / knowledge requirements: Compared to other SLM practices medium to high, depending on the ICLM management practices applied e.g. if a stall-fed dairy unit is introduced. Land users need to undergo training programmes to learn how to best apply technology, including conserving the land, improving grazing and controlling invasive species. Keeping animals well-fed, healthy and productive needs a high level of skill.
Labour requirements: Medium to high labour requirements for stall-fed livestock with cut-and-carry and high for rehabilitation of grazing land through addition of species with structural and vegetative measures (e.g. for water harvesting). In this case labour requirements are mainly for the establishment phase.

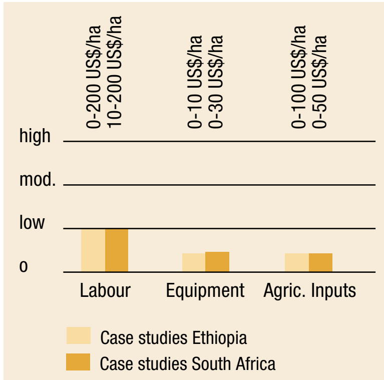


Economics

Established costs



Maintenance costs



(Source: WOCAT, 2009)

Labour costs in US$ are similar between ICLM technologies in Ethiopia and South Africa. In Ethiopia more manual and untrained labour, and in South Africa less but more qualified (therefore more expensive) labour is required.
Establishment costs can be relatively high for fencing materials, and increasing when reseeding / replanting, control of invasive species, water harvesting is added. Maintenance costs are generally low.
In the case of stall-fed livestock, initial costs are high both for purchase of animals and for buildings.
The costs per hectare for ICLM are relatively low compared to other SLM groups, however the generally lower productivity of grazing land compared to cropland, makes a comparison per hectare difficult.

Production benefits

Several studies carried out recently have clearly shown that integration of livestock with crops results in improvements of 50% (Ethiopian highlands) to over 100% (Zimbabwe) or more, in terms of farm productivity and income, compared to smallholders who only raise subsistence crops.
Approximately 25% of the agricultural domestic product in SSA is from livestock, not considering the contributions of animal traction or manure (Winrock International, 1992; in Pell, 1999). When traction and manure are included, livestock contribute 35% of the agricultural domestic product (Pell, 1999).

Benefit-Cost ratio

	short term	long term	quantitative
Fodder / crop / animal productivity	+	++/+++	No data available

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive

The value of manure and animal traction equals in East Africa the value of meat, and Sub-Saharan Africa as a whole has the potential to increase the total gross value of livestock products by about a third. As mixed crop-livestock systems expand, the relative importance of animal traction and manure will grow (Ogle 1996).

Output	West Africa	Central Africa	East Africa	South Africa	Sub-Saharan Africa
	Percent of gross value of output				
Animal traction	21	3	39	26	31
Manure	4	1	3	2	3
Meat	56	79	38	58	47
Milk	11	12	17	9	15
Eggs	8	5	3	5	4

Example: Senegal
The Rodale Institute Regenerative Agriculture Research Centre in Senegal has worked closely with 2,000 farmers in 59 groups to improve soil quality, integrate stall-fed livestock into crop systems, add legumes and green manures, improve the use of manures and rock phosphate, incorporate water harvesting systems and develop effective composting systems. The result has been a 75-195 percent improvement in millet yields – from 330 to 600-1,000 kg/ha, and in groundnut yields from 340 to 600-900 kg/ha. Yields are also less variable year to year, with consequent improvements in household food security – clearly contributing to CC adaptation (FAO 2007).

Example: Kenya
In the semi-arid highlands of Kenya, water loss by runoff was over 80% of the rainfall due to bare ground. The fodder production was mainly annual grasses and forbs of low value. In a rotational grazing system with a ground cover of more that 40%, runoff was reduced to zero. The cover was mainly from perennial grasses and the production was between 4-8 times higher than on the overgrazed land. Furthermore, it was recorded that under acacia trees high value perennial grasses were preserved even in the overgrazed areas (Liniger and Thomas, 1998).

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	+++ increased crop yield and quality +++ improved livestock nutrition and productivity ++ fodder production / quality increase ++ production diversification ++ providing energy through draft power and (sometimes) biogas	++ reduced risk and loss of production	+++ improved food and security
Economic	++ increased farm income + creation of job opportunities, spreading of labour + recycle resources, reduces need for chemical fertilizer (inputs)	++ stimulation of economic growth + diversification and rural employment creation + less damage to off-site infrastructure	+++ improved livelihood and well-being
Ecological	+++ increased soil fertility and organic matter (improved nutrient recycling) ++ improved soil cover ++ reduce soil erosion (by water / wind) ++ biodiversity enhancement ++ increase animal health + improved water availability + improved micro-climate	+ reduced degradation and sedimentation ++ intact ecosystem + increased water availability + increased water quality + reduced wind transported sediments	++ reduced degradation and desertification incidence and intensity ++ increased resilience to climate change ++ enhanced biodiversity
Socio-cultural	++ improved conservation / erosion knowledge ++ reduced workload (draft power) + improvement in household diets	+ increased awareness for environmental 'health' ++ attractive landscape ++ reduced rural-urban migration	+ protecting national heritage

	Constraints	How to overcome
Production	• Low nutritional value of crop residues • *Tsetse* fly in specific areas • Possibly more vulnerable to disturbances since livestock and crop production are interdependent	➜ supplement with fodder legumes, trees ➜ resistant breeds of livestock (stall-fed)
Economic	• 'Investment' costs can be rather high (e.g. fences, manure transport, seeds and seedlings) • Availability of inputs, e.g. labour and seeds, at times even tractors and implements • On larger scale fencing almost impossible	➜ establish credit and loan systems ➜ community mobilisation, self-help groups, government and project support and using family labour ➜ use thorn bush (encroachment) to make fence or social fencing
Ecological	• Competition for crop residues • Efficient use of biomass • Insufficient livestock and availability of animal manure • Burning of seed / seedlings by manure • Contamination of water by livestock • Increase of incidence by fire	➜ alternative sources e.g. other sources of animal feed ➜ keep animals in stalls; introduce cut-and-carry, initial reduction of stocking rates ➜ amend with green manure, N-fixing trees and / or supplement with chemical fertilizers ➜ modify and adapt mode of application ➜ introduce cut-and-carry, haymaking before grass is too tall and controlled grazing to reduce potential fuel material
Socio-cultural	• Insecurity of land tenure • Access to credit (e.g. veterinary services) • Possible dependence on experts concerning species selection (livestock and crop / feed) and planting methods • Lack of awareness and access to knowledge • More pressure on remaining grazing area (enclosures) • Rotational grazing can fail due to wrong timing • Weak governance and reluctance to observe the existing rules and regulations (lack of control) • Requires 'double' expertise (animal and crops)	➜ set appropriate land use policy ➜ credit schemes and land users associations ➜ create awareness ➜ use enclosures for cut and carry and hay making ➜ intelligent pasture management – knowing when to graze and when to rest ➜ install control and fining mechanism ➜ training and capacity building, strengthening advisory service

Adoption and upscaling

Adoption rate

The adoption rate depends on the specific ICLM system. Land users have basic traditional knowledge needed to integrate livestock and crop production, but because of their limited access to knowledge, assets and inputs – especially dairy cattle - relatively few adopt an upgraded integrated system.

Adoption of enclosures with cut-and-carry depends on availability of land for closure and availability of incentives. Spontaneous acceptance of this practice is relatively low and if it is practised then it is mainly with external support.

It is rare that the initiative is taken by the villages alone. The reasons are numerous inlcuding the decrease of production area, privatisation of land etc.

Upscaling

In semi-arid regions the transition in crop and livestock production from the current relatively extensive, low input/output production to more intensive, higher input/output production presents numerous challenges.

- participation of community right from the beginning, during planning to implementation, to ensure ownership
- availability of land and consensus of the community where the system can be introduced or applied
- secure land use rights and tenure
- need for training and capacity building in use of technology and its benefits
- need for training and support in animal husbandry
- requires change in mindset from 'focus on parts' towards 'the whole system'

Incentives for adoption

For regeneration of pastureland, where intensive structural measures are included, land users often rely on incentives (food-for-work or materials). If seedlings and seed are used, the community might need support to at least initiate their production (e.g. tree and seed nurseries). Where stall-fed dairy systems are put in place, it is common that projects supply an initial cow, and then they are 'repaid' with the first heifer calf.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	++
Training and education	++
Land tenure, secure land use rights	+++
Access to markets	++
Research	++
Participation (% involvement)	+++
Initial external support	++

References and supporting information :

FAO. 2009. Grasslands: enabling their potential to contribute to greenhouse gas mitigation. A submission by The Food and Agriculture Organisation of the United Nations1. Workshop held at FAO Rome 15 -17 April 2009.

FAO. 2007. TerrAfrica- A Vision paper for Sustainable Land Management in Sub-Saharan Africa. Food and Agriculture Organisation of the United Nations, Rome, Italy.

FAO. 2001. Mixed crop-livestock farming- a review of traditional technologies based on literature and field experience. FAO, Animal production and health papers 152 (http://www.fao.org/DOCREP/004/Y0501E/Y0501E00.HTM)

Gebremedhin, B., J. Pender, and T. Girmay. 2004. Collective action for grazing land management in crop-livestock mixed systems in the highlands of northern Ethiopia. Agricultural Systems 82 (2004) 272-290.

IFAD. 2009. Integrated-Livestock Farming Systems. Thematic paper 12-13 January 2009

Lenné, J. and D. Thomas. 2006. Integrating crop-livestock R & D in sub-Saharan Africa: option, imperative or impossible? Outlook on Agriculture, Volume 35, Number 3, pp. 167-175(9)

Liniger, H.P. and D.B. Thomas 1998: GRASS: Ground cover for the Restoration of the Arid and Semi-arid Soils. In: Advances in GeoEcology 31, 1167-1178, CATENA Verlag, Reiskirchen.

Ogle, B. 1996. Livestock Systems in Semi-Arid Sub-Saharan Africa, Integrated Farming in Human Development – Workshop Proceedings

Otte J. and V. Knips. 2005. Livestock Development for Sub-Saharan Africa. PPLPI Research Report Nr. 05-09. Food and Agriculture Organisation of the United Nations, Rome, Italy

Pell, A.N. 1999. Integrated crop-livestock management systems in sub Saharan Africa. Environment, Development and Sustainability 1: 337–348.

Powell, J. M., R. A. Pearson, and P. H. Hiernaux. 2004. Crop–Livestock Interactions in the West African Drylands. Agron. J. 96:469–483.

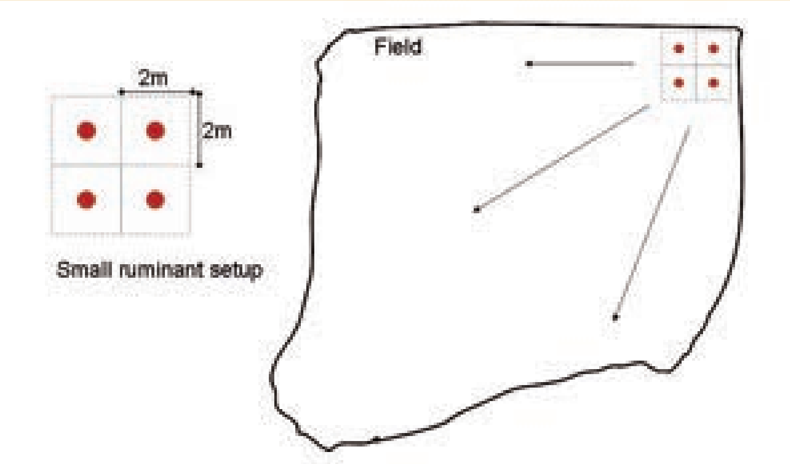
Van Keulen, H. and H. Schiere. 2004. Crop-Livestock Systems: Old Wine in New Bottles? In New Directions for a Diverse Planet. Proceedings of the 4th International Crop Science Congress, Brisbane, Australia, 26 September-October 2004. http://www.cropscience.org.au/icsc2004/symposia/2/1/211_vankeulenh.htm

WOCAT, 2009. WOCAT database on SLM technologies and SLM approaches. www.wocat.net, accessed on 15 September 2009

Woodfine, A. 2009. Using sustainable land management practices to adapt to and mitigate climate change in Sub-Saharan Africa: resource guide version 1.0. TerrAfrica. www.terrafrica.org.

NIGHT CORRALLING - NIGER

Night corralling of cattle, sheep and goats on cropland during the dry season (November-April) replenishes soil fertility of agricultural land depleted by continuous cropping. This technology is mainly applied in semi-arid and subhumid areas on sandy / loamy plains with low soil organic matter content, low soil pH, and with slopes below 5%. Adequate spacing of animals helps to homogenously distribute the manure on the field (see photo): in cattle this is ensured through tying the animals to poles, in sheep and goats a movable fence serving as night enclosure helps to save labour.
Corals and animals are moved to a new spot within the field every 4-5 nights to homogeneously manure fields. Ideal is a rate of 2.5 tonnes of faecal dry matter per hectare. The application of this amount results in superior grain yields (millet, sorghum) as compared to an unmanured field. High yield response is achieved in the cropping season directly following the corralling (year 1) and in the subsequent two to three years, in which no new deposit of faeces and urine, i.e. no further corralling, is needed.
While a 250 kg cow deposits about 1 kg of manure dry matter per night, 7 sheep or 7 goats are needed to produce this same amount. Thus, to cover 1 hectare of land with 2.5 tonnes of manure, a herd of 15 cattle would need to be corralled during 167 nights; alternatively 178 nights would be needed if 70 small ruminants were corralled. Since individual herds are often smaller than 15 cattle (or 70 small ruminants) and fields are larger than 1 hectare, it is recommended to organise corralling of fields within a community (village) of farmers and especially to revitalise the traditional corralling contracts ('*contrats de parcage*') with transhumant herders.



SLM measure	Management and agronomic
SLM group	Integrated Crop-Livestock Management
Land use type	Agropastoral and cropland
Degradation addressed	Loss of soil fertility (organic matter, nutrients, pH decline) due to continuous cropping
Stage of intervention	Rehabilitation
Tolerance to climate change	Technology not much affected by climatic extremes or changes

Establishment activities

1. Purchasing the poles.

Maintenance / recurrent activities

In year 1 (of a 3-years cycle):

1. Placing poles in the field at 2m x 2m spacing for small ruminants and at 4m x 4m spacing for cattle, starting at the field border (see technical drawing).
2. Attach individual animals (adult small ruminants, adults or calves if you work with cows) to the pole during night.
3. Shift the poles to an adjacent unmanured part of the field every 4 days in cattle, and every 5 days in small ruminants. To cover the whole field (1 ha) with manure:
   – with 15 cattle you will need a total of 167 nights of corralling;
   – with 70 small ruminants you will need 178 nights.

In year 2 and 3 (of a 3-years cycle):

4. Cultivate the field for 3 subsequent cropping seasons (year of application, plus year 2 and 3) without further corralling in year 2 and year 3.
5. Apply a new corralling treatment in year 4 (repeat maintenance steps 1-4).

Labour requirements

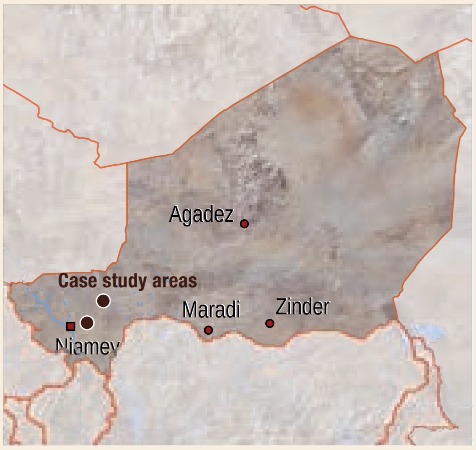
For establishment: low
For maintenance: low

Knowledge requirements

For advisors: moderate
For land users: moderate (spacing and timing of animal placement need to be respected)

Photo 1: Relatively homogenously manured field obtained through night corralling of cattle in south-western Niger. (Pierre Hiernaux)
Technical drawing: Corralling area of 4 sheep to poles (brown circles) during 5 nights (left) and principle of shifting corralling areas across a field of undefined size (right). (Eva Schlecht)

Case study area: Fakara region (near Niamey) and Chikal territory (near Filingué), Niger



Establishment inputs and costs per ha

Inputs (for 1 ha with 15 cattle)	Costs (US$)
Equipment: 15 poles (1 per animal)	15
TOTAL	**15**

Inputs (for 1 ha with 70 sheep)	Costs (US$)
Equipment: 70 poles (1 per animal)	70
TOTAL	**70**

Maintenance inputs and costs per ha per year

Inputs (for 1 ha with 15 cattle)	Costs (US$)
Labour: 1.3 person-days*	3
Equipment: 5 poles (replacement)	5
TOTAL	**8**

** 11 minutes on 167 days in year 1; 0 days in years 2–3*

Inputs (for 1 ha with 70 sheep)	Costs (US$)
Labour: 1.7 person-days*	4
Equipment: 21 poles (replacement)	21
TOTAL	**25**

** 14 minutes on 178 days in year 1; 0 days in years 2–3*

Remarks: Labour costs incur in a 3-years cycle: putting and changing the poles on a specific field is done in year 1, while in years 2 and 3 the respective field is cultivated, and no corralling takes place. Actual labour input for corralling in year 1 is 4–5 days (= 10–15 minutes during approx. 170 days), equivalent to US$ 10–13; maintenance costs given in the tables above refer to the average expenses of the whole 3-years cycle.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	positive
Maintenance	highly positive	positive

Remarks: Labour input in year 1 (dry season) pays through high yields in harvest seasons of years 1–3.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 250-500 mm
- Soil parameters: well drained, sandy, shallow soils, low to very low soil fertility; low organic matter; low pH (< 4)
- Slope: mostly flat (0-2%), partly gentle (2-5%)
- Landform: mainly plains, partly pediments
- Altitude: 100-500 m a.s.l.

Socio-economic conditions

- Size of land per household: average land holding is 13 ha (near Niamey) and 10 ha (near Filingué)
- Type of land users: small-scale farmers
- Population density: no data
- Land ownership: mostly individual, titled
- Land use rights: individual for fields, communal for pastures
- Market orientation: mostly subsistence (self-supply), partly mixed (subsistence and commercial)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased crop yield (in year 1 - 3; corralling only done in year 1)
++ Increased farm income

Ecological benefits

+++ Improved soil organic matter (medium term)
+++ Increased soil fertility
++ Increased water holding capacity
++ Reduced risk of soil crusting

Socio-cultural benefits

++ Revaluation of traditional knowledge
++ Community institution strengthening through rotational corralling of multiple-owner herds on individuals' fields
++ Revitalisation of ties with transhumant groups

Weaknesses

- Implementation constraint: organisation of rotational corralling is necessary to effectively manure fields of a village community; this needs skilful organisation.
- Need to invest in poles.
- High labour investment in year 1.
- Difficulty to revitalise trustful partnership with transhumant pastoral groups, as more and more crop residues are harvested and stored at the homestead (no dry season feed for mobile herds).
- Extensive consultation and coordination is needed if rotational (community) corralling or involvement of transhumant herders is necessary due to low animal numbers (<12 cattle, <50 small ruminants) at the level of individual households.

Adoption

Relatively high, but incomplete in the sense that homogeneity of dung application is lacking.

Main contributors: Eva Schlecht, Animal Husbandry in the Tropics and Subtropics, University of Kassel and Georg-August Universität Göttingen, Witzenhausen, Germany.; schlecht@uni-kassel.de
Key references: Schlecht E., A. Buerkert. 2004. Organic inputs on millet fields in western Niger: the implications of farmers' practices for sustainable agricultural production. Geoderma 121, 271-289 ■ Schlecht E., P. Hiernaux, I. Kadaouré, C. Hülsebusch, F. Mahler. 2006. A spatio-temporal analysis of forage availability, grazing and excretion behaviour of cattle, sheep and goats in Western Niger. Agric, Ecosys Environ 113, 226-242. ■ Schlecht E., H. Richter, S. Fernández-Rivera, K. Becker. 2007. Gastrointestinal passage of Sahelian roughages in cattle, sheep and goats, and implications for livestock-mediated nutrient transfers. Anim Feed Sci Technol 137, 93–114.

ROTATIONAL FERTILIZATION - NIGER

Rotational fertilization is an integrated crop-livestock management measure practised by the agropastoralist *Peulh*. At intervals of 2-3 years they relocate with their livestock to a new area previously used for crop cultivation - where they install their temporary dwellings and improve soil fertility by applying farmyard manure and other organic materials.
The rotation of temporary habitation areas leads to successive fertilization of the land. Livestock (cattle or small ruminants) are corralled or tethered in the rehabilitation area over-night. They feed on crop residues and emerging grasses after harvesting of the crops. Dung dropped within the coral area is collected and then distributed on the fields. The main criterion for site selection is the level of land degradation. The size of the area occupied is maximum 500 m^2, and depends on family size, herd size and on the quantitative and qualitative objectives of soil fertilization of the land owner.
In the years after settlement (after families move to a new location) the treated area is used for crop cultivation, and crop rotation / intercropping are practiced (e.g. millet / legumes) for increased and diversified production, improved pest control and fertility management.
The effectiveness of this technology has led to field-fertilization contracts between agropastoralists and sedentary farmers. The farmers offer post-harvest grazing rights to the agropastoralists who in turn fertilize the land and benefit from the access to the important weekly markets in the area where they can sell milk. In this case the agropastoralist families and their livestock split up after the rainy season: a part assures fertilization of the own land, the other part is in charge of fertilizing foreign land (during 3-4 months) before returning home.

SLM measure	Management and agronomic
SLM group	Integrated Crop-Livestock Management
Land use type	Cropland: temporarily: settlement area
Degradation addressed	Soil fertility decline; Soil erosion by water; Soil erosion by wind
Stage of intervention	Rehabilitation
Tolerance to climate change	Tolerant to temperature increase and reduction of vegetation period; sensitive to droughts, floods, wind storms and rainfall variability

Establishment activities

1. Identification of site where level of land degradation is high.
2. Level and clean the land.
3. Layout / disposition of infrastructure (dwellings, barns, corral, poles, poultry habitat) according to type and degree of land degradation.
4. Establishment of infrastructure.

Maintenance / recurrent activities

➜ On land being treated
1. On-going fertilization by applying farmyard manure and any kind of organic material accruing from daily human activities to the soil during 2-3 years.
2. Maintenance / re-location of huts to improve fertilization of land (after rainy season).

➜ On previously treated land:
3. Land preparation (ploughing, e.g. cowpea).
4. Cultivation of millet and legumes (‘*niébé*’) as intercrop or in the form of crop rotation.

Labour requirements

For establishment: high
For maintenance: low

Knowledge requirements

For advisory service: na
For land users: low

Photo 1: Dung dropped by animals feeding on crop residues; sheltered corrals in the background. (Pierre Hiernaux)
Photo 2: Millet growing on fertilized fields. (Adamou Kalilou)
Photo 3: Increased yields are an important impact of the technology: millet sold on village market. (Adamou Kalilou)

Case study area: Damari, Kollo district, Tillabéry region, Niger

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 100 person-days	150
Construction material: lumber and straw for hut	200
TOTAL	**350**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 10 person-days	15
TOTAL	**15**
% of costs borne by land users	100%

Remarks: Establishment of housing infrastructure is done collectively, involving dozens of community members within less than a week. Construction material is taken from the woodlands; many parts are re-used after moving. While expenses are expressed in US$, in reality costs are in kind (mutual help) or not paid for (free lumber). Maintenance activities include: maintenance and re-building of dwellings. Costs for crop cultivation (US$ 335-535 annually) are not included.

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	positive	very positive

Remarks: The impact of the measure on soil productivity is increasing in the mid and long term.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 400-550 mm
- Soil parameters: very poor sandy soils with low soil organic matter content, usually well drained (low in case of soil crusting)
- Slope: mostly flat (0-2%)
- Landform: mainly plains / plateaus, valley floors
- Altitude: 0-100 m

Socio-economic conditions

- Size of land per household: 1-2 ha
- Type of land users: groups / community, family; small-scale, poor
- Population density: 10-50 persons/km^2
- Land ownership: mostly individual, untitled
- Land use rights: individual, communal (organised)
- Market orientation: mostly subsistence (self-supply), partly mixed (subsistence and commercial)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased crop yield
+++ Increased farm income
+++ Increased animal production
++ Increased fodder quality and fodder production

Ecological benefits

++ Increased soil cover
+++ Reduced wind velocity
+++ Increased soil fertility
++ Increased biomass / above ground carbon
+++ Reduced soil loss
+++ Increased animal diversity

Socio-cultural benefits

++ Conflict mitigation
+++ Community institution strengthening through mutual aid in technology implementation
+++ Improved cultural opportunities

Off-site benefits

+++ Reduced damage on public / private infrastructure
+++ Reduced damage on neighbours' fields
++ Reduced wind transported sediments

Weaknesses ➜ and how to overcome

- Growing costs and decreasing availability of timber and poles for establishment of infrastructure ➜ re-introduce traditional techniques of long term conservation of housing materials.
- High labour input for implementation ➜ reinforce community structures for mutual help.
- Area treated by the technology is too small regarding the area in need of treatment (degraded land) ➜ reinforce the solidarity between communities to increase the treated area.
- Negative effect on the woodland (*brousse tigrée*): cutting for building materials, clearing for cultivation ➜ identify new ecological materials for house construction; tree plantation.
- Marginalisation of families with low activity potential ➜ reinforce mutual help systems to support poor / small families.

Adoption

High spontaneous adoption of this indigenous technology. Its high effectiveness has helped spread the technology to adjacent areas on the other side of the river Niger, where farmers contract the agropastoralists for their 'fertilization service'. The area covered by the technology is approximately 1,500 km^2.

Main contributors: Abdoulaye Sambo Soumaila, Groupe de Recherche d'Etude et d'Action pour le Développement (GREAD), Niamey, Niger; leffnig@yahoo.fr

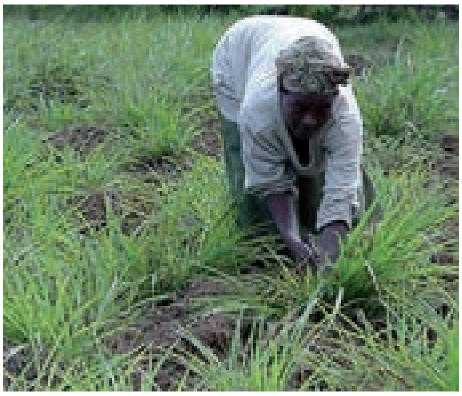
Key references: Caroline Dandois Dutordoir (2006): Impact de pratiques de gestion de la fertilité sur les rendements en mil dans le Fakara (Niger), Université catholique de Louvain, 2006 ■ Bationo, A., Ntare, B. R. 2000: Rotation and nitrogen fertilizer effects on pearl millet, cowpea and groundnut yield and soil chemical properties in a sandy soil in the semi-arid tropics, West Africa. Journal of Agricultural Science, 134, p. 277-284 ■ Ministère du développement agricole (2005): recueil des fiches techniques en gestion des ressources naturelles et de productions agro-sylvo-pastorales.

GRAZING LAND IMPROVEMENT - ETHIOPIA

Grazing land improvement is based on enclosures and planting of improved grass and fodder trees to enhance fodder and consequently livestock production and simultaneously control land degradation. This case study focuses on the highly populated, humid highlands of Ethiopia where the little remaining grazing land areas are overused and under enormous pressure.

The technology involves a combination of management, agronomic and vegetative measures: fencing to exclude open access, application of compost to improve soil fertility, planting of improved local and exotic fodder species, including multipurpose shrubs / trees (including nitrogen fixing species) legumes, and the local *desho* grass (*Pennisetum pedicellatum*). *Desho* has a high nutritive value and ensures regular cuts. It is planted by splits, which have high survival rates and establish better than grasses which are seeded. Other grass seeds and legumes are mixed with fodder tree seeds and then broadcast. Legumes include alfalfa (*Medicago sativa*) and clovers in some cases. The area is permanently closed for livestock. Fodder is cut and carried for stall-feeding and once a year, grass is cut for hay, which is stored to feed animals during the dry season.

In the study area, the fenced and protected communal grazing land has been divided into small plots (<0.5 ha) and distributed to individual users for cutting hay, as an incentive to stimulate proper management. The government provides training, technical assistance, close follow-up, and some inputs for initial establishment.



SLM measure	Management, agronomic and vegetative
SLM group	Integrated Crop-Livestock Management
Land use type	Extensive grazing (before), silvopastoral (after)
Degradation addressed	Soil erosion by water; Fertility decline
Stage of intervention	Rehabilitation
Tolerance to climate change	Tolerant to rains with high intensity, storms

Establishment activities

1. Delineate the area to be conserved and establish a fence (deadwood).
2. Subdivision of protected (communal) land into individual plots of 0.3 – 0.5 ha.
3. Prepare seedlings in nurseries (grass splits and tree seedlings).
4. Prepare seedbed (with a hand hoe, partly with oxen plough).
5. Prepare compost / manure (ash, animal manure, leaf litter, soil, water).
6. Plant grass splits and tree / shrub species in lines and on conservation bunds; sow grass seed by broadcasting (early rainy season).
7. Compost application (one month after planting).
8. Weeding.

Maintenance / recurrent activities

1. Cut and carry grass and leaves to feed stall-fed animals (after 2-3 months growth, during rainy season, end of August).
2. A final cut for hay making is taken early in the dry season (end of October) when the grass has matured well.
3. Weeding.
4. Enrichment planting and gap filling (once a year), combined with application of compost / manure (mixed with soil).

Labour requirements

For establishment: high
For maintenance: low

Knowledge requirements

For advisory service: high
For land users: moderate

Photo 1: *Desho* grass and multipurpose trees established to increase productivity of grazing lands.
Photo 2–3: Cut and carry of grass for stall-feeding from improved pasture. (All photos by Daniel Danano)

Case study area: Chencha, Ethiopia

Establishment inputs and costs per ha

Inputs (for 1 ha with 15 cattle)	Costs (US$)
Labour	320
Equipment	22
Agricultural inputs	710
TOTAL	**1,052**
% of costs borne by land users	56%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour	35
Equipment	4
Agricultural inputs	87
TOTAL	**126**
% of costs borne by land users	100%

Remarks: Seedlings are given by the government for initial establishment. For further extension of area and replanting, the land users set up their own nurseries. After 2–3 years maintenance costs decrease substantially as the grass cover closes up and maintenance activities such as replanting and compost application are reduced or cease. The local daily wage is about US$ 0.70 a day.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	very positive
Maintenance	positive	very positive

Remarks: Milk production compensates for some of the high investment costs (previously, production was low).

Ecological conditions

- Climate: humid (local term: *wett dega*)
- Average annual rainfall: 1,000-1,500 mm
- Soil parameters: good drainage; mostly medium soil organic matter, partly low
- Slope: moderate (5-8%) to rolling (8-16%), partly hilly (16-30%)
- Landform: ridges and hillslopes, partly footslopes
- Altitude: mostly 2,000-2,500 m

Socio-economic conditions

- Size of land per household: < 1 ha
- Type of land user: small-scale farmers (individually), mainly poor land users, partly average level of wealth
- Population density: 200-500 persons/km^2
- Land ownership: state
- Land use rights: individual for cropland, usually open access (communally used) for grazing land, except for the case study area where the rights to rehabilitated grazing land are given to individuals
- Market orientation: subsistence (self-supply)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased livestock production
+++ Increased fodder production and fodder quality
++ Increased income (selling animals and their products)
+ Increased wood production

Ecological benefits

++ Improved soil cover
+++ Increased soil fertility
+++ Reduced soil loss
+++ Increased soil moisture
+ Biodiversity enhancement

Socio-cultural benefits

+++ Improved household diets (milk), improved health
+++ Community institution strengthening
+++ Increased willingness of the national institution to assist and support organised farmer groups (i.e. community institutions)
+++ Improved conservation / erosion knowledge
++ Increased availability of livestock products on the market (lowers prices for the consumers)

Off-site benefits

+++ Reduced transported sediments
++ Reduced downstream flooding
++ Reduced downstream siltation
++ Increased stream flow in dry season

Weaknesses ➜ and how to overcome

- At the initial stage of establishment it is very labour intensive ➜ use of improved land preparation methods such as oxen ploughing.
- It is an expensive technology (availability of cash for inputs, particularly seedlings) ➜ produce seedlings of improved species and compost in backyards.
- Needs high fertiliser application ➜ focus mainly on organic fertilizers.
- High pressure on remaining grazing areas ➜ keep animals in stall (stable) or park, at least part of the day and during the night and introduce cut-and-carry more widely.

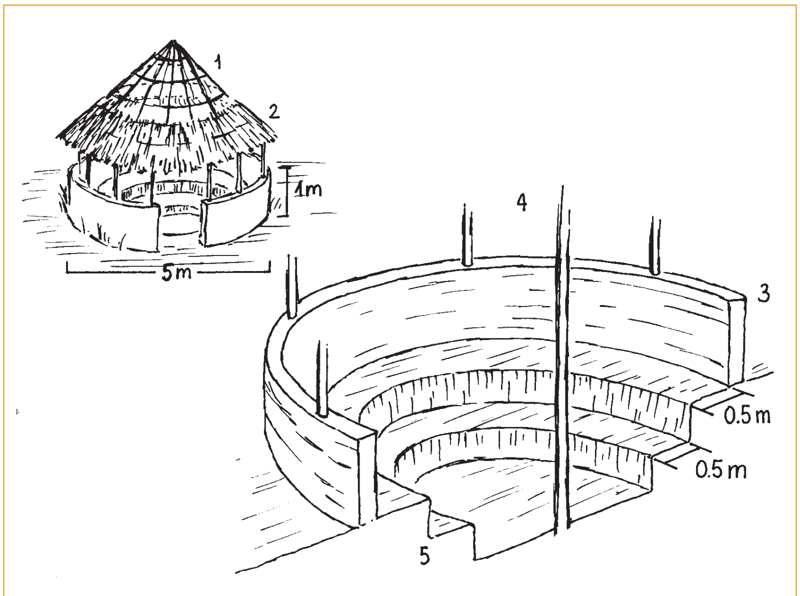
Adoption

The 50 households who accepted the technology in the initial phase, did so with incentives. They were provided with planting material and hand tools. The rate of spontaneous adoption is very high. At present over 500 households have taken up the technology and the total area covered is about 20 km^2.

Main contributors: Daniel Danano, Ministry of Agriculture and Rural Development, Addis Ababa, Ethiopia; ethiocat@ethionet.et
Key references: Adane Dinku, Chencha Wereda, Natural Resources Management Annual Report, 2001 and 2002 ■ Danano, D (2008, unpublished): Soil and Water Conservation Practices for Sustainable Land Management. WOCAT. 2007. ■ WOCAT database on SLM technologies. www.wocat.net

SMALLSTOCK MANURE PRODUCTION - TOGO

Smallstock manure production is an easy and efficient method to produce organic fertilizer for the conservation and improvement of soil fertility. The main item within this practice is the so-called *fosse fumière* - a 1-2 m deep and 3-4 m diameter circular pit, enclosed by a stone wall. The pit has a double function: it is the place where manure is produced and it serves as shed for small ruminants (goats, sheep), particularly to avoid uncontrolled grazing / browsing during the cropping season (from April until November). Animals are fed in the fosse, and they drop their faeces, which together with chopped organic material accruing from the kitchen and field activities, piles up in the pit for decomposition.
The fosse is partly roofed to provide optimal micro-climatic conditions: partial shading, partial exposure to sunlight and appropriate moistening through rainfall. Inside the pit, one or more circular terraces (0.5 m high, 0.5 m wide) serve as resting area for the animals. The terrace riser need to be plastered or reinforced with stones, particularly in case of loose soil, to avoid damage caused by animal trampling.
After decomposition the manure is removed from the pit and distributed on the fields beginning of each cropping season (March). Then straw bedding is renewed and the process starts from scratch. During the dry season from December to March smallstock is left to graze freely on the fields and pastures.



SLM measure	Management and agronomic
SLM group	Integrated Crop-Livestock Management
Land use type	Mixed: Agropastoralism
Degradation addressed	Fertility decline, reduced organic matter content
Stage of intervention	Mitigation and rehabilitation
Tolerance to climate change	Technology not much affected by climatic extremes or changes

Establishment activities

1. Delimitation of the perimeter of the pit and the position of the steps.
2. Excavation of the pit, shaping a terraced structure: 1-3 circular, 0.5 m high and 0.5m wide terraces.
3. Build up a stone wall around the pit, spaced at minimum 0.5 m from the pit, with an integrated gate.
4. Build a roof, which partly covers the pit.
5. Put straw on the ground and corral the animals.
6. After one year (April to March) the compost is ready for application on the field.

All activities carried out by manual labour.

Maintenance / recurrent activities

1. Continuous depositing and piling up of vegetative material (dung, kitchen waste, crop residues).
2. Let decompose the organic material inside the pit (during 1 year).
3. Twice a year (between April and November) the material is actively mixed for aeration.
4. Distribute the manure on the fields (during rainy season).

Labour requirements

For establishment: high
For maintenance: moderate

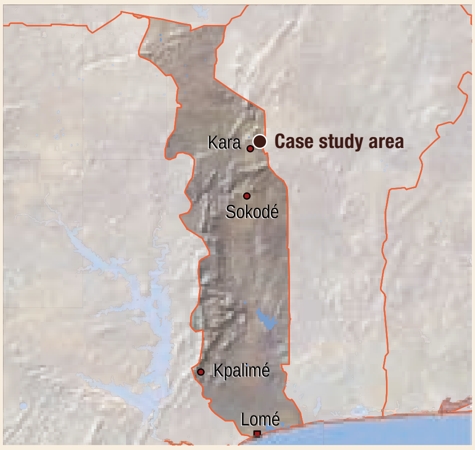
Knowledge requirements

For advisory service: moderate
For land users: moderate

The technology was early traditional and passed from father to son. It was improved in 1987.

Photo 1: Manure production with small ruminants. (Idrissou Bouraima)
Technical drawing: Dimensions and main components of a manure production pit: (1) open part of the roof; (2) covered part of the roof; (3) stone wall; (4) poles (holding the roof); (5) terraces (where animals can rest).(Mats Gurtner)

Case study area: Lassa, Kara, Togo



Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour (36 person-days)	200
Equipment*	182
Agricultural inputs	0
TOTAL	**382**
% of costs borne by land users	100%

**poles, crossbars, stones / bricks, rope, etc*

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour	150
Equipment	0
Agricultural inputs	0
TOTAL	**150**
% of costs borne by land users	100%

Remarks: Main cost-relevant factor is labour. Material such as stones and straw are available on the farm (no monetary costs).

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	positive
Maintenance	slightly positive	positive

Ecological conditions

- Climate: subhumid
- Average annual rainfall: 1,000-1,500 mm
- Soil parameters: good drainage; low soil organic matter
- Slope: mostly flat (0-2%), some gentle (2-5%)
- Landform: mostly plateaus / plains, some footslopes
- Altitude: < 100 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha
- Type of land users: small-scale farmers; average level of wealth, partly rich land users; technology implementation mostly done individually, sometimes in groups
- Population density: 300 persons/km^2 in the region
- Land ownership: individual, titled
- Land use rights: mostly leased, some individual
- Level of mechanisation: manual labour
- Market orientation: mainly mixed (subsistence and commercial), partly subsistence

Production / economic benefits

+ Increased crop yields
+ Increased farm income

Ecological benefits

++ Increased soil fertility / soil organic matter
+ Increased soil moisture

Socio-cultural benefits

++ Increased conservation / erosion knowledge
+ Improved food security

Weaknesses ➜ and how to overcome

- Manual construction is very labour-intensive ➜ mechanised excavation.
- Air pollution through smelly animal dung ➜ add products which attenuate the smell; establish the manure pit outside the residential area.
- Accident risk for children ➜ establish the manure pit outside the residential area.

Adoption

The technology covers an area of 0.15 km^2. All land users in the study area (totally 60) have adopted the technology voluntarily, without any external support other than technical assistance. There is a moderate trend towards further spontaneous adoption (about 60 %), depending mainly on the availability of livestock.

Main contributors: Mawussi Gbenonchi, Ecole Supérieure d'Agronomie, Université de Lomé (ESA UL), Lomé, Togo; gmawussi@gmail.com
Key references: WOCAT. 2007. WOCAT database on SLM technologies. www.wocat.net

PASTORALISM AND RANGELAND MANAGEMENT


Silvopastoral system, Senegal. (Christoph Studer)

In a nutshell

Definition: Pastoralism and rangeland management refer to extensive production of livestock using pastures and browse, and is mainly found in arid and semi-arid areas. In SSA the term 'pastoralism' is usually associated with the use of common property resources subject to some group agreements rather than 'open access'. 'Ranching' on the other hand implies individual, privatised land ownership. Pastoralism is based on open grazing lands, e.g. savannas, grasslands, prairies, steppes, and shrublands, managed through herding. Pastoralists adopt opportunistic land use strategies, that is they follow resources of grazing / browsing and water, destock in times of drought (often *de facto* through livestock mortality rather than stock sales) but have rapid response post-drought restocking strategies (commonly based first on the high reproduction rates amongst indigenous sheep and goats).
There are many types and degrees of pastoral mobility, which vary according to environmental conditions or the given household situation. Mobility can be seasonal, regular between two well-defined pasture areas, or following erratic rain. It is rarely the same from one year to another. Movement is not necessarily undertaken only for resource-based reasons; it can be for trade or because of conflict.
Pastoral activities have conventionally been considered uneconomic and ecologically destructive. Current thinking increasingly recognises these strategies as economically viable, environmentally sustainable, and compatible with development. The challenge is to adapt traditional pastoralism to today's changing environmental conditions. Establishment of feed banks, improvement of herd composition and health, a more dense distribution of wells, collection and storage of surface water by, for example, 'charco dams', adaptive grazing, land use plans, access to markets, and empowerment are such opportunities.
Applicability: A production system for marginal, dry lands: relatively low inherent productivity due to aridity, altitude, temperature and / or a combination of all factors. Pastoralism is becoming increasingly constrained because of weakening of traditional governance over communal natural resources, restricted mobility, sedentarisation, boundaries and advancing agriculture.
Resilience to climate variability: By definition pastoralism is based on continuous adaptation to highly uncertain environments, especially climate. Traditional pastoralism has / is losing flexibility and options for coping with drought (e.g. loss in mobility due to encroachment of cropping and growing human populations) leading to increased risk.
Main benefits: Mobile herding systems combine economic production in marginalised land and environmental protection (biodiversity) of vulnerable ecosystems, which have been modified over time by pastoralism itself; improved food security and livelihood of marginalised and disadvantaged people. The vast areas of degraded rangeland play a vital role in sequestering carbon. Dry soils are better longer term sinks for C than soils in more humid environments.
Adoption and upscaling: Effective pastoral management of the drylands depends on livestock mobility (access to dry season grazing sites and water points), effective communal tenure and governance systems, and herd adaptation.

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	++

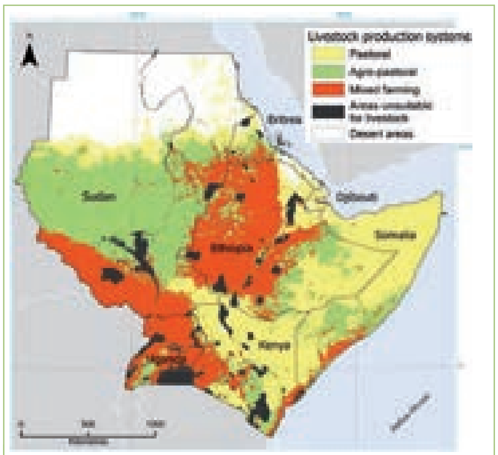
Climate change mitigation	
Potential for C Sequestration (tonnes/ha/year)	0.1 - 0.3*
C Sequestration: above ground	+
C Sequestration: below ground	++

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 proper rangeland management in US$ and for a duration of the first 10-20 years of changed land use management (Schumann et al., 2002 in FAO, 2004).*

Origin and spread

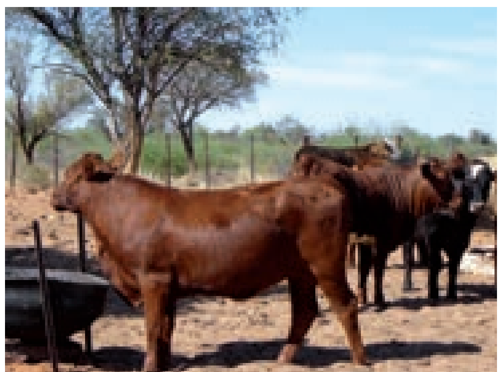
Origin: Pastoralism is one of the most ancient forms of agricultural activity and pastoralists maintain diverse cultures, ecological adaptations, and flexibility in management systems. It evolved in arid and semi-arid regions as a result of increasing population densities and domestication of livestock. Pastoralism made efficient use of the extensive rangelands, and could cope with climate variability - particularly uneven and erratic distribution of rainfall. Between 1960s and 1980s international donors invested heavily in rangeland and livestock projects by introducing 'ranching' models where boundaries were delineated and destocking programmes encouraged or enforced. These misguided efforts to develop livestock systems have contributed to the current vulnerability of many pastoralists.
Mainly applied in: the arid and semi-arid zones extending from Mauritania to the northern parts of Chad, Eritrea, Ethiopia, Kenya, Mali, Niger, Somalia, Sudan, Tanzania and Uganda. Pastoralists who are principally dependent on camels are confined to areas north of the equator. Communities practicing agropastoralism are found throughout: opportunistic cropping (sometimes based on RWH) is common in 'pastoral' areas.
Also applied in: arid zones of Namibia, parts of Botswana and southern Angola.



Modelled distribution of livestock production systems in Eastern Africa (Source: Cecchi et al, 2010).

Principles and types

Traditional pastoral systems utilise, modify and conserve ecosystems by extensive grazing / ranching with rotational grazing and by using a variety of livestock: sheep and cattle, principally as grazers; and goats, donkeys and camels as browsers.
The Fulbe / Fulani herders in Nigeria, for example, faced with rapidly vanishing grass, switched from the Bunaji cattle breed, which depends on grass, to the Sokoto Gudali, which readily browses (FAO, 2001).
Nomadism: Nomads are livestock producers who grow no crops and depend on the sale or exchange of animals and their products to obtain food (e.g. Tuareg and Fulbe). Their movements are opportunistic and follow pasture and water resources in a pattern that varies from year to year according to the availability of resources.
Transhumance is the regular movement of herds between fixed points in order to exploit the seasonal availability of pastures. A feature of transhumance is herd splitting; the herders take most of the animals to search for grazing, but leave the resident community with a core of lactating female cows and / or camels (e.g. Maasai and Fulbe). For the Fulbe it follows a century–old grazing route northward to the borders of the Sahara, and southward to the moist savanna during the wet and the dry seasons, respectively. Available grazing lands are diminishing and movement channels are blocked through land use change, urbanisation, and frontiers. In West Africa, governments have tried to demarcate transhumance corridors and to legislate for trans-boundary mobility.
Agropastoralism describes settled pastoralists, who live in villages and cultivate sufficient areas to feed their families and keep livestock as valued property (herds are usually smaller). Mixing of crops and livestock primarily serves to minimise risk: failed crops provide animal fodder for example.
Mixed systems: Traditionally some systems are mixed where crops and livestock are managed by different communities based on a long standing relationship. After harvest of the crop, pastoralists are allowed to feed their livestock on the residues. However, since keeping livestock has been promoted amongst crop farmers, this practice is diminishing in importance.
Enclosed systems and ranching: Land is individually owned and usually fenced. In the colonial era, livestock ranches were established in Botswana, Kenya, Namibia, Mozambique, South Africa and Zimbabwe and a substantial proportion of these remain today. Animal movement and pressure are adjusted to the available fodder within the ranch by controlled and rotational grazing and well distributed water points thus reducing degradation as much as possible.



Top: Cattle and camels in a pastoral system, Kenya. (Wiliam Critchley)
Middle: Livestock in a pastoral system, Mali. (William Critchley)
Bottom: Livestock ranching close to a water point on a private estate, South Africa. (William Critchley)

Applicability

Land degradation addressed

In the pre-colonial era, pastoralists were limited principally by disease and insecurity. In the twentieth century occupation of land by cultivators (competition for water and land) and the presence of boundaries impeded free movement of livestock which led to overgrazing of vegetation and soil resources. Overgrazing is a function of time (grazing and recovery) and not simply numbers of animals. Most of the environmentally harmful effects of livestock production in dry areas occur around local water points and settlements.

Biological deterioration: Grazing reduces soil cover and changes the composition of the vegetation. Both, heavy and light grazing can reduce the density of palatable perennial species, which are replaced by less palatable ones as their competitive ability declines.

Water degradation: Low and unreliable rainfall, pasture degradation leading to reduced water infiltration and limited permanent sources of surface water can exacerbate competition for water.

Land use

Mainly extensive grazing land: natural, semi-natural grasslands, savannas, shrubland (*brousse*).

Ecological conditions

Marginal lands and challenging climates with heterogeneity and high variability of resources in space and time. Low in *tsetse* infestation.

Climate: pastoralism: in semi-arid zones with <600mm annual rainfall and a growing season of less than 120 days; seasonal mobility: every wet and dry season; agro-(silvo-) pastoralist systems: semi-arid zones with rainfall ranging between 650 - 1,000 mm. Length of growing period: 130–170 days.

Terrain and landscape: no restrictions - whole range from flat to hilly.

Soils: no restrictions; camels, cattle, donkeys, sheep and goats can utilise a broad range of poor quality forage thriving on marginal soils.

Socio-economic conditions

Pastoralists are usually the most politically and economically marginalised, have the least access to resources (land, water, pasture) and basic services such as health and education and suffer from insecurity, conflicts, poverty, environmental degradation and exposure to climatic risks.

Market orientation: Pastoralists sell livestock products (meat and milk) and livestock to local and domestic markets through both formal and informal channels. Cross-border trade is common. In contrast to crops - where crop failure due to drought results in price increase - livestock destocking, in response to drought, results in price decrease due to a market flooded with poor quality animals. Caravan trade, for example using camels to carry salt, still exists in inaccessible regions of the pastoral zone, but its economic importance has been much reduced by modern transport.

Land ownership and land use / water rights: Pastoralists, due to their opportunistic grazing strategies, have fluid tenure systems that are traditionally based in customary arrangements. However, in some places these have broken down, and uncontrolled open-access regimes have emerged. Traditional wells are often collective property of a community who dug and / or maintained them, but access rights for other groups are usually negotiable. Surface water sources have less clear ownership. A combination of land 'privatisation', fragmentation of communally grazed land, loss of key resources (e.g. water points on transhumance routes), creation of barriers (fences, national parks, roads), imposition of state and district boundaries hamper these rights.

Skill / knowledge requirements: High but exist traditionally and are passed on through the generations.

Labour requirements: A weak relationship between herd size and labour up to the point at which herds beyond a certain size cannot be managed with household labour alone, and outside herders must be hired. In pastoral societies women are typically responsible for milking and dairy processing and for feeding the family. Men are responsible for herding and selling livestock products. In systems with split herds, women stay at the homesteads while men move with the animals.

Land degradation

Erosion by water	Low
Erosion by wind	Moderate
Chemical degradation	Low
Physical degradation	Low
Biological degradation	High
Water degradation	Moderate

Key: High / Moderate / Low / Insignificant

Land use

Cropland	Low
Grazing land	High
Forests / woodlands	Low
Mixed land use	Moderate
Other	Insignificant

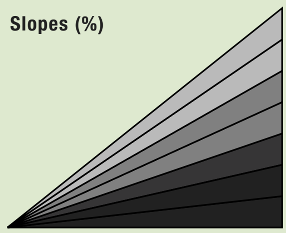
Climate

Humid	Insignificant
Subhumid	Low
Semi-arid	Moderate
Arid	High

Average rainfall (mm)

> 3000	Insignificant
2000-3000	Insignificant
1500-2000	Insignificant
1000-1500	Low
750-1000	Moderate
500-750	High
250-500	High
< 250	Insignificant

Slopes (%)



very steep (>60)
steep (30-60)
hilly (16-30)
rolling (8-16)
moderate (5-8)
gentle (2-5)
flat (0-2)

Farm size

Small scale	Low
Medium scale	Insignificant
Large scale	Insignificant

Land ownership

State	High
Company	Insignificant
Community	High
Individual, not titled	Moderate
Individual, titled	Low

Mechanisation

Manual labour	High
Animal traction	Low
Mechanised	Insignificant

Market orientation

Subsistence	High
Mixed	Moderate
Commercial	Insignificant

Required labour

High	Moderate
Medium	High
Low	Insignificant

Required know-how

High	High
Medium	Insignificant
Low	Insignificant

Economics

Establishment and maintenance costs

Pastoralism entails high marketing and transaction costs, especially because of the absence of formal markets and existing monopolies, high transport costs, poor infrastructure, long distances to processing plants, poor access to information, lack of financial services such as credit facilities, and excessive government bureaucracy and fees. Transaction costs reduce the returns to labour under pastoralism.

Production benefits

Pastoral production provides multiple products. It tends to focus on animal products (especially milk), rather than animals for slaughter.

Annual direct values accruing per TLU* of cattle in Afar (Ethiopia)

Direct value	US$
Estimated annual value of milk	54
Mean annual livestock sales	15
Annual herd growth rate	9
Total	78

** Tropical Livestock Unit, 4 hectares of rangeland per TLU (Source: Hatfield and Davies, 2006)*

This data does not capture the full direct value of pastoralism in Afar as it omits the value of leather, the value of processed butter and the transportation values of camels and donkeys. Nevertheless, the data provides an estimated mean pastoral livestock productivity of US$ 78 per 4 hectares. This range of products and species can make pastoral systems significantly more cost-effective and productive than the meat-focussed ranching models that have been promoted.
Transhumance in particular is an extremely productive system, yielding between 50 and 600% more protein per ha than ‘modern’ ranching in comparable ecological areas within the USA and Australia (Ogle, 1996). In Sub-Saharan Africa the economic importance of livestock rises as rainfall declines.

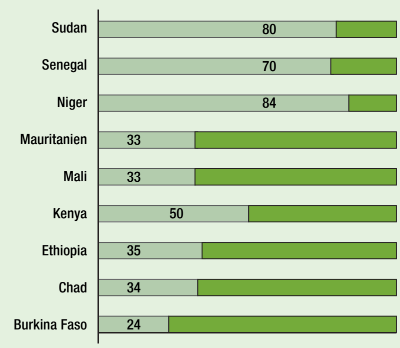
Benefit-Cost ratio

Pastoralism has considerable economic value and latent potential in the drylands but little is known or has been quantified. It encompasses less tangible benefits including financial services (investment, insurance, credit and risk management), ecosystem services (such as biodiversity, nutrient cycling and energy flow) and a range of social and cultural values.
The value of livestock production in the drylands is often grossly underestimated in official statistics, and thus does not attract the investment attention that it deserves.

Example: African pastoralism has been shown to out-produce ranching
In Botswana, communal area production (in cash, energy and protein terms) per hectare exceeds - by at least three times per hectare - returns from ranches in Australia and North America. The difference in soil erosion levels between the two production systems is negligible, despite much higher stocking rates under the communal areas (in Hatfield and Davies, 2006).

Example: Transhumant pastoral systems
In Mali, transhumant pastoral systems yield on average at least two times the amount of protein per hectare per year compared to both sedentary agropastoralists and ranchers in the US and Australia (in Hatfield and Davies, 2006). Pastoralism is economically viable to the extent that it contributes significantly to the economy of many developing countries despite continued underinvestment (Hatfield and Davies, 2006).

Pastoralism as a percentage of agricultural GDP[1]



1 Gross Domestic Product

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	+++ increased animal productivity ++ greater production and better survival of arid rangeland plants (fodder) ++ greater diversity of livestock and goods that are produced + improved crop yields	+++ maximising production in a highly variable environment ++ reduced risk of production	++ improved food security
Economic	+++ high overall returns due to multiple benefits ++ provides a stable livelihood (e.g. Maasai, Fulbe pastoralists)	++ can contribute 'significantly' to the national economy ++ diversification and rural employment creation ++ less damage to off-site infrastructure + enables drylands to be economically exploited	+ improved livelihood and well-being
Ecological	++ increasing live plant cover ++ reduced soil erosion (by water / wind) ++ efficient and flexible way of managing sparse vegetation and relatively low soil fertility ++ biodiversity enhancement ++ reducing old vegetation (threat of fires) + improved water availability + improved micro-climate	++ reduced degradation and sedimentation ++ efficiency of opportunism in environments that are characterised by uncertainty (intact ecosystem) + increased water availability + increased water quality	++ maintained ecosystem integrity and resilience to climate variability ++ reduced degradation and desertification incidence and intensity ++ enhanced biodiversity
Socio-cultural	++ pastoralists traditional knowledge of environment, livestock genetics, livestock breed selection, medicinal plants and weather forecasting	+ increased awareness for environmental health ++ attractive landscape ++ reduced conflicts	+++ protection of national heritage ++ knowledge leading to sustainability

	Constraints	How to overcome
Production	• Availability of feed / fodder in quantity and quality during the dry season • Increase productivity without adverse environmental consequences	➜ allow sufficient flexibility to move and destock; In SSA products such as cotton seed, groundnut cakes and molasses are now regularly sold to pastoralists, together with mineral licks
Economic	• Poor livestock prices due to lack of marketing infrastructure and knowledge of prices • Access to markets and financial services (credits and savings) • Milk (mainstay of most pastoral economies) not well marketed leading to a shift in production towards meat • Many young people now go to school, while others are moving to the cities to do unskilled jobs (availability of labour)	➜ processing facilities for dairy products and better marketing strategies ➜ Encourage banking facilities: spread of mobile phones and mobile phone-based banking; create alternative saving and investment opportunities ➜ improve image of pastoralism and show its potentials
Ecological	• Sufficient and efficient recovery of nutrients that were relocated from grazing land to cropland • Bush encroachment • Risk and vulnerability of the system	➜ reinforce customary ability to manage rangelands ➜ human capital development (education and health)
Socio-cultural	• Limited livestock mobility • Competition and conflicts over rangelands of pastoralists, farmers and foragers • Wealthier farmers and urban farmers invest their surplus capital in livestock (competition) • Sedentarisation • Traditional tenure systems (usually gained through cultivation), land access and fragmentation • Marginalisation of pastoralists (often seen as backward, archaic and a political threat) • Low education of pastoralists • Inappropriate training of extension agents and absence of useful extension packages • Inappropriate policies aiming at transforming rather than enhancing pastoralism	➜ e.g. demarcation of transhumance corridors and legalisation for trans-boundary mobility ➜ make use of group or collective rights (policies often exist) re-aggregation of fragmented grazing land to still use land communally and / or leasing arrangements ➜ qualify what pastoralists contribute to the economy ➜ political empowerment ➜ capacity building ➜ technical and institutional reforms ➜ put in place or emphasise land reforms and land use rights that support pastoralism

Adoption and upscaling

Adoption rate

Despite the high investments that were made in rangeland development projects during the last 30 years, they have generally been a failure because they based their assumptions on concepts of equilibrium systems developed for individually owned ranching systems. The projects, by changing traditional patterns of land use, weakened the indigenous pastoral production systems by misidentifying 'pastoral crisis'. Collective action arrangements are emerging:
– Awareness of pastoralists themselves
– Economic diversification
– Intensification and diversification of livestock production strategies
– Empowerment of communities through Community-Based Natural Resource Management (CBNRM)
– Reinforcement of favourable land and water use rights, access to resources and regional planning

Upscaling

Planning for / with pastoral societies must have a long term perspective, and needs to recognise that herds will recover eventually, as they always have in the past, and that the utilisation of 'inaccessible' zones will always be the preserve of pastoralists. New policy must address issues of diversity without undermining the common factors that unite pastoralists everywhere in Africa. A key is to enable pastoralists themselves to adapt and enhance their production system (e.g. through improved animal health). Adequate attention needs to be placed on learning from pastoralists' production methods and finding ways to fit new technologies into those systems.
One problem that is rarely addressed is the lack of security (e.g. theft) which acts as an inhibitor to outside investment and which leads people to invest a lot of their resources in providing their own security. Furthermore, in many places where smuggling and trade are key sources of income, pastoralists' economic dependence on livestock is low. Therefore herders may not make investments required in their livestock because their attention is directed elsewhere.

Incentives for adoption

Incentives for key elements of pastoralism such as communal tenure, seasonal movements, flexible stocking rates that can be adopted afresh are:
– legal support for communal arrangements
– legislation for transhumance
– relevant services that are tailored to the needs of communal and mobile management
– infrastructure / investments and technologies for access to water
– insurance and credit services
– animal health programmes
– market integration to survive on smaller herds than would be possible with exclusive subsistence
– promotion of mobile phones for information sharing (animal prices; climate prediction) and for banking
– contingency planning for disaster mitigation / emergency relief

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	+
Training and education	+
Land tenure, secure land use rights	+++
Improved marketing	++
Research	++
Enabling policies	+++
Maintain mobility (trans-boundary)	+++
Safety net (risk and emergencies)	++
Access to services	++

Example: Ethiopia
Communal grazing lands are important sources of livestock feed in developing countries. In the highlands of Tigray, northern Ethiopia rural communities have a long tradition of developing and enforcing use and regulations of grazing areas. Restricted use of grazing lands tends to be maintained once it is established. Village organisations are responsible for the management with technical assistance from the regional Bureau of Agriculture (Gebremedhina et al, 2004).

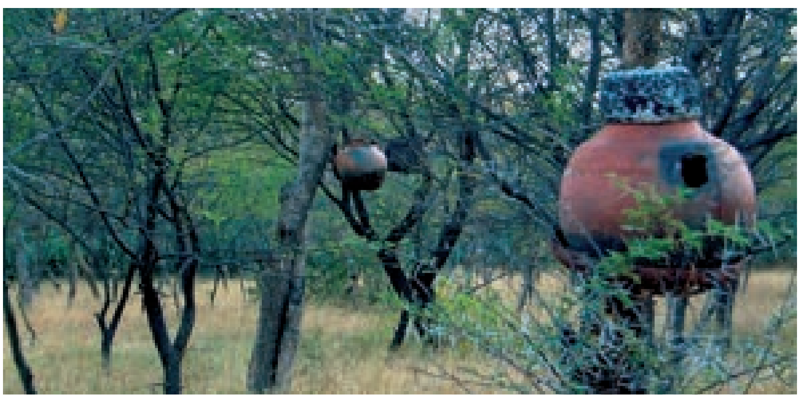
References and supporting information:
Briske D. D., J. D. Derner, J. R. Brown, S. D. Fuhlendorf, W. R. Teague, K. M. Havstad, R. L. Gillen, A. J. Ash, and W. D. Willm. 2008. Rotational Grazing on Rangelands: Reconciliation of Perception and Experimental Evidence. Rangeland Ecol Manage 61:3–17.
Cecchi, G., W. Wint, A. Shaw, A. Marletta, R. Mattioli and T. Robinson. 2010. Geographic distribution and environmental characterisation of livestock production systems in Eastern Africa. Agriculture, Ecosystems and Environment 135 (2010) 98–110.
Davies, J., M. Niamir-Fuller, K. Kerven and K. Bauer. 2010. Extensive livestock production in transition: the future of sustainable pastoralism. In Livestock in a Changing Landscape, Volume 1, Drivers, Consequences, and Responses. Steinfeld, H., H. A. Mooney, F. Schneider and L. E. Neville (eds). Washington, DC: Island Press.
Davies, J. 2008. Turning the tide: Enabling sustainable development for Africa's mobile pastoralists Natural Resources Forum 32 (2008) 175–184.
Derry, J.F. and R.B. Boone. 2010. Grazing systems are a result of equilibrium and non-equilibrium dynamics. Journal of Arid Environments 74(2): 307-309.
FAO, 2009. Grasslands: Enabling their potential to contribute to greenhouse gas mitigation. A submission by The Food and Agriculture Organisation of the United Nations1. workshop held at FAO Rome 15 -17 April 2009.
FAO. 2004. Carbon Sequestration in drylands soils. World Soil Resources Reports 102. FAO.
FAO. 2001. Pastoralism in the new millennium. Animal Production And Health Paper 150. FAO.
Gebremedhina, B., J. Pender and G. Tesfay. 2004. Collective action for grazing land management in crop–livestock mixed systems in the highlands of northern Ethiopia. Agricultural Systems Volume 82, Issue 3 pp 273-290.
Hatfield, R. and J. Davies. 2006. Global Review of the Economics of Pastoralism. The World Initiative for Sustainable Pastoralism, IUCN, Nairobi
Homann, S., B. Rischkowsky, J. Steinbach and M. Kirk. 2005. Towards endogenous development: Borana pastoralists' response to environmental and institutional changes. Deutscher Tropen tag. Stuttgart-Hohenheim, October 11-13, 2005.
Oba, G., N.C. Stenseth and W.J. Lusigi. 2000. New perspectives on sustainable grazing management in arid zones of SSA. BioScience, Volume 50: pp 35 - 51.
Ogle, B. 1996. Livestock Systems in Semi-Arid Sub-Saharan Africa, Integrated Farming in Human Development – Workshop Proceedings.
http://www.ardaf.org/NR/rdonlyres/E0E2790E-F1FF-4F65-818E-1716735E1070/0/199618BrianOgle.pdf

NGITILI DRY-SEASON FODDER RESERVES - TANZANIA

Ngitili are traditional enclosures for in-situ conservation and rehabilitation of vegetation, practiced by the Wasukuma agropastoralists in Shinyanga, Tanzania. Shinyanga is a semi-arid area characterised by shortage of fodder associated with problems of deforestation, fuelwood scarcity, food insecurity, declining soil fertility, severe soil erosion and unsecure land use rights. *Ngitili* is a dry-season fodder reserve, an indigenous practice which has been revived by a government programme from 1986-2001.

For initial regeneration of the vegetation and rehabilitation of denuded land absolute exclusion of up to 5 years is needed. Then, areas of standing vegetation are enclosed seasonally from the onset of the rainy season till the peak / end of dry season, before they are opened up for grazing. Two distinct vegetation strata are identifiable, an upper stratum dominated by trees and shrubs (*Acacia tortilis, A. nilotica, A. polyacantha* and *A. seyal)* and a lower stratum of grasses, herbs and forbs. Structure and composition of the *ngitili* areas are closely influenced by location, age, management practices and intensity of use. The reserves are established on degraded land and around homesteads. Individual plots usually reach 2-5 ha in size, while communal *ngitili* cover 10-200 ha. Mostly, the boundaries are not rigidly marked, and physical barriers are not established. Local guards and community by-laws are used to protect and enforce the system.

Ngitili alleviates dry season fodder shortages and prevents land degradation through reducing soil erosion and deforestation. The reserves provide a wide range of woodland goods - such as timber, fodder, fuelwood, medicinal herbs, wild fruits and honey. They help to enhance livelihoods, provide a vital safety net during dry seasons and droughts and generate additional income of up to US$ 500-1,000 per year and household. *Ngitili* greatly reduced women's labour, cutting the time spent on fuelwood collection by over 80%, and have a highly positive impact on biodiversity.



SLM measure	Management and vegetative
SLM group	Pastoralism and Rangeland Management
Land use type	Extensive grazing
Degradation addressed	Vegetation degradation; Decreased soil fertility; Loss of topsoil
Stage of intervention	Rehabilitation
Tolerance to climate change	Increased tolerance to climatic extremes (e.g. prolonged dry spells and droughts)

Establishment activities

1. Demarcation and closure of sites usually on degraded land around homesteads.
2. Total enclosure during up to 5 years for initial regeneration of vegetation (if land is degraded).
3. Establishment of tree nurseries to produce seedlings of native species.
4. Enrichment planting.
5. Removal of large trees (deterring grass growth), while protecting fodder trees.

Maintenance / recurrent activities

1. Closure of *ngitili* area at onset of rainy season. No management during rainy season.
2. Open area for grazing in July or August, after the crop residues and fallow vegetation have been depleted.
3. Temporary demarcation of paddocks for specific periods for rotational grazing within *ngitili* (controlled by experienced elders; based on utilisation level and fodder availability).
4. Controlled pruning and thinning (for firewood and poles).

Labour requirements

For maintenance: low
For establishment: low to medium (depending on the extent of enrichment planting)

Knowledge requirements

For land users: low
For advisors: low

Photo 1: Cattle grazing in a dry season fodder reserve. (Edmund Barrow)
Photo 2: Regeneration of trees has multiple benefits such a production of timber, fruit and honey. (Edmund Barrow)

Case study area: Shinyanga region, Tanzania

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	no data
Equipment	no data
Agricultural inputs	no data
TOTAL	**no data**

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour	no data
Equipment	no data
Agricultural inputs	no data
TOTAL	**no data**

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	very positive
Maintenance	slightly positive	very positive

Adoption

300,000-500,000 ha of woodland restored 1986-2001 (most of *Ngitilis* are individual, but area-wise half-half), over 800 villages; 60-70% of all households have *Ngitilis*.

Ecological conditions

- Climate: semiarid, unimodal rainfall
- Average annual rainfall: 600-900 mm; rainy season: October–May
- Soil parameters: medium to poor drainage; vertic soils are very extensive covering 47% of all soil types in the region
- Slopes: flat (0-2%) – gentle (2-5%)
- Landform: plains and hill slopes
- Altitude: 1,000-1,500 m a.s.l.

Socio-economic conditions

- Size of land per household: no data
- Type of land users: no data
- Population density: no data
- Land ownership: individual (cropland), individual / communal 50% / 50% (grazing land)
- Land use rights: individual / communal
- Market orientation: no data

Production / economic benefits

+++ Increased income (from selling timber / fuelwood; to purchase agricultural inputs, manpower)
+++ Increased wood production (timber, fuelwood)
+++ Increased fodder production (dry season!)
+++ Increased livestock production
+++ Reduced workload (collection of fuelwood / fodder by women)
+++ Increased production of non-timber forest products (fruit, honey, medicines, edible insects)

Ecological benefits

++ Biodiversity conservation / restoration (152 plant species; 145 bird species; also mammals returning)
+++ Vegetation regeneration / improved soil cover
+++ Reduced loss of top soil through erosion
++ Increased soil fertility
++ Increased water availability

Socio-cultural benefits

+++ Food security, diet diversification, improved health
++ Improved housing (thatched grass for roofs)
++ Improved education (school fees payment due to income from *ngitili*)
\+ Income from communal *ngitili* used for village development (schools, health centres)

Weaknesses ➜ and how to overcome

- Damage to livestock and crops caused by growing wildlife populations ➜ outweighed by the benefits gained from *ngitili* (in most areas).
- Increased local inequity: benefit gap between richer and poorer households (who have no *ngitilis*); growing sales of *ngitilis* ➜ local institutions have to enable people to hold on to land and maintain *ngitilis*; allow poorer households to benefit from communal *ngitilis*.
- Scarcity of land, growing pressure (rising human and livestock populations); conflicts over grazing rights ➜ encourage villages to establish by-laws for protecting *ngitilis*.
- Insecurity of tenure impedes establishment of *ngitilis* (individual and communal) ➜ increase local people's and groups ownership and control over their resources; clearly acknowledge in national law the secure tenure of both private and communal *ngitili*.
- Productivity could still be improved ➜ introduction of improved fodder grasses. Planting of fast growing fodder trees and / or shrubs.

Key references: Kamwenda G.J. 2002. Ngitili agrosilvipastoral systems in the United Republic of Tanzania. Unasylva 211, Vol. 53, 2002. ■ World Resource Institute. 2010. Regenerating Woodlands: Tanzania's HASHI Project. http://www.wri.org/publication/content/8108; ■ Equator initiative. 2010. Nomination Form Equator Initiative. http://www.equatorinitiative.org/knowledgebase/files/2002-0128_Nom_HASHI_Tanzania.pdf; ■ Blay D., E. Bonkoungou, S.A.O. Chamshama and B.Chikamai. 2004. Rehabilitation of Degraded Lands in Sub-Saharan Africa: Lessons Learned from Selected Case Studies. Forestry research network for Sub-Saharan Africa (fornessa) ■ WRI (2005): World Resources 2005: The Wealth of the Poor—Managing Ecosystems to Fight Poverty. World Resources Institute (WRI) in collaboration with United Nations Development Programme, United Nations Environment Programme, and World Bank.

COULOIRS DE PASSAGE - NIGER

The '*couloirs de passage*' are formally defined passageways which channel the movements of livestock herds in the agropastoral zones of Niger, by linking pastures, water points and coralling areas, be it within village areas (internal *couloirs*) or on open land (external *couloirs*). The main goal of the *couloirs* is the prevention of conflict between agriculturalists and pastoralists regarding the use of limited land and water resources. These conflicts are often provoked by cattle entering cropping areas.
The establishment of demarcated passageways allows the livestock to access water points and pastures without causing damage to cropland. The corridors are regulated through the '*code rural*' – a national law defining the land use rights of the pastoralists. Demarcation of *couloirs* is based on a consensual decision of all concerned interest groups. Internal *couloirs* are negotiated in a general on-site assembly involving all stakeholders (farmers, breeders, women's groups, local authorities). For the demarcation of external *couloirs* the involvement of transhumance herders and neighboring villages is indispensable.
Once an agreement on the course of the *couloir* is achieved, demarcation with stones and / or boundary planting with selected tree species is carried out by the local land users - with financial and technical assistance of the government or NGOs. Common species involve: *Euphorbia balsamifera, Acacia spp.* (*A. nilotica; A. senegal*); and *Faidherbia albida*. Management committees at the community level draw up regulations for the management of the *couloirs* (maintenance and protection of vegetation). Protection of plants is achieved through dead branches (at the initial stage), daily control by forest guards, and information campaigns. The technology is a sustainable solution to the described conflicts. As a valuable by-product the trees along the demarcation lines provide wood and non-woody by-products.

SLM measure	Management and vegetative
SLM group	Pastoralism and Rangeland Management
Land use type	Cropland or agropastoral (before), (silvo-)pastoral (after)
Degradation addressed	Soil erosion by water; Soil erosion by wind; Biological degradation; Primary problem addressed is conflicts between livestock and agriculture producers around natural resources
Stage of intervention	Prevention
Tolerance to climate change	Technology is sensitive to climatic extremes (such as droughts and floods)

Establishment activities

1. Identification of an existing *couloir* or definition of a new passageway by means of a general assembly (photo 1).
2. Alignment of corridor boundaries e.g. by establishing stone lines. Internal *couloirs* are 10 to 50 m wide, whereas external *couloirs* exceed a width of 50 m.
3. Digging 40 cm deep pits; tree planting along boundaries (with a spacing of 1-3 meters, depending on the species selected and the secondary objective) (photo 2).

Maintenance / recurrent activities

1. Protection of trees (through dead branches, guards, information campaigns).
2. Replanting tree seedlings to fill gaps (annually, beginning of rainy season).

Labour requirements

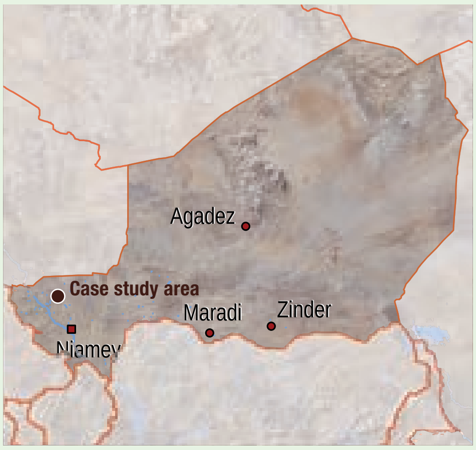
For establishment: low
For maintenance: low

Knowledge requirements

For advisors: high (facilitator of *code rural*)
For land users: low (pastors and workers)

Photo 1: Demarcation of a *couloir de passage* with two lines of Euphorbia seedlings. (LUCOP / Abdoulaye Soumaila)
Photo 2: A herd of small ruminants passing a well established *couloir*. (Fodé Boubacar Camara, PAFN)

Case study area: Tillabéri North, Niger



Establishment inputs and costs per km

Inputs	Costs (US$)
Labour: 25 person-days	38
Agricultural Inputs: 670 tree seedlings	1374
TOTAL	**1412**
% of costs borne by land users	5%

Maintenance inputs and costs per km per year

Inputs	Costs (US$)
Labour: 4 person-days	6
Agricultural inputs: 67 tree seedlings	137
TOTAL	**143**
% of costs borne by land users	100%

Remarks: The costs of the planning meeting (general assembly) and the stones for delimitation were not taken into account. Daily salary for field work is US$ 1.5. Costs for seedlings were calculated for a couloir length of 1 km and a spacing of 3 m between plants (one tree line on each side). Seedling production is financed by projects, only transport costs are met by land users.

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	positive	very positive

Remarks: Peace between communities is the key result in the short and long term. Ecological and economic benefits are linked to the plantation of trees and the improved management of natural resources.

Adoption

High growing spontaneous adoption (for prevention of conflicts and land degradation).

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 250-500 mm
- Soil parameters: sandy soils, with medium fertility, low soil organic matter and good drainage (low in case of soil crusting)
- Slope: mostly flat (0-2%)
- Landform: mainly plains / plateaus, valley floors
- Altitude: 0-100 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha
- Type of land user: mainly poor; land user groups / community
- Population density: 10-50 persons/km^2
- Land ownership: mostly individual, titled
- Land use rights: individual, communal (organised)
- Level of mechanisation: animal traction
- Market orientation: mostly subsistence (self-supply), partly mixed (subsistence and commercial)

Production / economic benefits

+++ Increased crop yield
+++ Increased farm income
+++ Increased animal production
+++ Increased fodder quality and fodder production

Ecological benefits

++ Increased soil cover
++ Reduced wind velocity
++ Increased soil fertility
++ Increased biomass / above ground carbon
++ Reduced soil loss
++ Reduced fire risk
++ Increased animal diversity

Socio-cultural benefits

+++ Cultural benefits
+++ Conflict mitigation
+++ Community institution strengthening through mutual aid in technology implementation
+++ National institution strengthening (*code rural* secretariat)
+++ Improved cultural opportunities

Off-site benefits

+++ Reduced damage on public / private infrastructure
+++ Reduced damage on neighbours' fields
+++ Reduced wind transported sediments

Weaknesses ➜ and how to overcome

- Implementation constraints: plant production is very expensive and reaching a consensus on the transformation of private cropland to communal passageways is very difficult ➜ definition of the *couloirs* as public infrastructure and enhancement of organisational capacities of the local population through training and information sessions.
- Maintenance constraints: maintenance can only be realised by adjacent land owners, as the community organisations are weak ➜ reinforce the institutional capacities of livestock owners and farmers to manage the *couloirs*.
- In the pastoral zone the *couloirs* lead to conflicts between pastoralists and private ranches ➜ establish community-based land tenure commissions and introduce new laws on land property in the pastoral zone.

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Key references: Projet LUCOP/Tillabéry. 2004. Referential des measures techniques de recuperation, de protection et d'exploitation durable des terres, 2nd edition, 2004, 51 pp ■ Soumaila A.S. 2003. Base de données du code rural (online): www.case.ibimet.cnr.it/den/Documents/code_rural/start.html ■ Hiernaux P., E. Tielkes, E. Schlecht. 2001.Elevage et gestion des parcours au Sahel, Workshop proceedings organised by Eric Tielkes et Abdoulaye Soumaila, Verlag Ulrich E. Grauer, Beuren, Stuttgart, Germany, 2001

IMPROVED WELL DISTRIBUTION FOR SUSTAINABLE PASTORALISM - NIGER

Pastoralism, as practised in the case study area, is the traditional mode of extensive livestock husbandry, based on the movement of herds between the rich pastures in the northern pastoral zones (rainy season) and the southern areas (dry season) according to seasonal availability of water and grazing land / fodder (including residual vegetation of cropland). Both forms of pastoralism – nomadism and transhumance – are facing increasing water and fodder availability problems, due to a variety of reasons: change of climatic conditions, expansion of cropland, overstocking and overgrazing, amongst others. In view of these problems, the government of Niger has defined by law a pastoral zone, where crop production is limited to subsistence.

Within this area 'Pastoral Modernisation Zones' have been implemented, based on a new concept of semi-pastoralism to assure the sustainability of the pastoral land use system. Several practices are promoted at field level: improved distribution of water points, establishment of water harvesting structures, improved passageways for herds, improved fodder production, etc.

An optimal and efficient network / distribution of water points is a key element of modern sustainable pastoralism: it assures a balanced distribution of herds, and thus avoids overuse of vegetation around a limited number of wells. Since 1998, the number of traditional wells within the 3,000 km^2 of Akoubounou pastoral area has increased from 7 to 58. Construction is done by the local community – through trained well diggers. Support is provided by different development actors (government and NGOs). Well committees on community level are responsible for proper management of the wells. A fund for maintenance is established and is topped up through contributions of well users.

As a result of the improved well distribution, pastoral areas have been utilised in a more balanced manner, and overgrazing problems have been reduced by 30-40% compared to the situation in 1990.

SLM measure	Management
SLM group	Pastoralism and Rangeland Management
Land use type	Extensive grazing; Mixed (agro-silvo-pastoral)
Degradation addressed	Soil erosion by water; Soil erosion by wind; Biological degradation (overgrazing)
Stage of intervention	Mitigation and rehabilitation
Tolerance to climate change	Technology is sensitive to droughts and rainfall decrease

Establishment activities

Preparation:

1. Information and awareness raising campaign in village. Participatory planning (1-2 days).
2. Identification of sites by population, accompanied by field technicians
3. Formation and training of members of well management committee: laws, responsibilities, steering, evaluation, organisation, etc. (3-4 days).
4. Training of traditional sinkers (by external experts 1998-2000, then farmer-to-farmer training).

Establishment of well:

5. Dig well shaft: 0.8-1.5 m in diameter and 20-60 m deep (using pickaxe, shovel, bucket).
6. Install a scoop device (with cow leather or tire-tube; wire and poles).
7. Optional: Lining of the well shaft with stones / cement (e.g. if soil is not compact enough).
8. Build a wall with stones and cement around the well for protection (0.2-0.3 m wide, 0.5-1 m high).

Maintenance / recurrent activities

1. De-silting of wells (beginning of rainy season; May-June).
2. Reinforce walls of wells with cement (end of rainy season, October-November).
3. Deepen the well in case of descending groundwater level (dry season).
4. Constant monitoring of the wells by the Management Committee.

Labour requirements

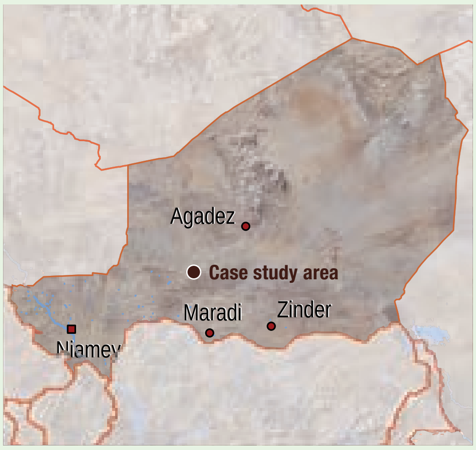
For establishment: medium
For maintenance: medium

Knowledge requirements

For advisors: medium
For land users: low

Photo 1: One of the traditional wells that have been built to achieve a more balanced grazing throughout the pastoral area of Akoubounou.
Photo 2: Touareg family with a cattle herd in the pastoral zone during the rainy season.
Photo 3: Small ruminants around a traditional well during dry season. (All photos by Abdoulmohamine Khamed Attayoub / ADN)

Case study area: Akouboubou, Abalak, Tahoua region, Niger



Establishment inputs and costs per well

Inputs	Costs (US$)
Preparation (information campaign, planning, establishment of committee, etc.)	800
Construction of well (labour, equipment and material)	1,200
TOTAL	**2,000**
% of costs borne by land users	9%

Maintenance inputs and costs per well per year

Inputs	Costs (US$)
Labour, equipment and material	280
TOTAL	**280**
% of costs borne by land users	100%

Remarks: A management fund is established and managed by each well committee. Well users contribute annually, or each time maintenance work is needed. Amounts of contribution are not fixed but up to the individual, and generally proportionate to herd size. Committee can fine land users who damage the wells.

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	positive	very positive

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 300 mm; rainy season May-October
- Soil parameters: good drainage, in case of soil crusting low drainage, mainly low soil organic matter but high in swampy area
- Slope: mostly flat (0-2%)
- Landform: mainly plains / plateaus, valley floors
- Altitude: 0-100 m a.s.l.

Socio-economic conditions

- Size of land per household: < 1 ha
- Type of land user: community, mainly average level of wealth
- Population density: 9 persons/km^2
- Land ownership: mostly individual, titled
- Land use rights: individual, communal (organised)
- Market orientation: mostly mixed (subsistence and commercial)

Production / economic benefits

+++ Increased animal production
+++ Increased fodder quality and fodder production

Ecological benefits

++ Increased soil cover
+++ Increased soil fertility
+++ Increased biomass / above ground carbon
+++ Reduced soil loss
+++ Increased animal diversity

Socio-cultural benefits

+++ Conflict mitigation
+++ Community institution strengthening through mutual aid in technology implementation
+++ National institution strengthening (*code rural* secretariat)
+++ Improved cultural opportunities

Off-site benefits

+++ Reduced damage on public / private infrastructure
+++ Reduced damage on neighbours' fields
+++ Reduced wind transported sediments

Weaknesses ➜ and how to overcome

- High cost of implementation and maintenance ➜ active participation of pastoralists in establishment and maintenance activities; public investments; national funding system.
- Extinction of pastoral culture and traditional practices ➜ integrate pastoralists into structural transformation process; promote capacity building of pastoralists.

Adoption

The technology is well adopted in the case study area. 50 wells have been built in 12 years within a pastoral area of 3000 km^2. Implementation is based on incentives (establishment costs mainly paid by projects). However, there is a medium trend towards spontaneous adoption (by new actors).

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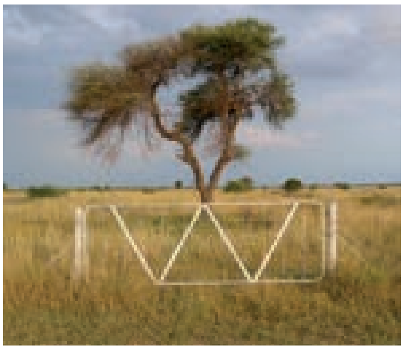
Key references: Soumaila A.S. 2003. Base de données du code rural (online): www.case.ibimet.cnr.it/den/Documents/code_rural/start.html ■ Hiernaux P., E. Tielkes, E. Schlecht. 2001. Elevage et gestion des parcours au Sahel, Proceedings de l'atelier organisé par Eric Tielkes et Abdoulaye Sambo Soumaila, Verlag Ulrich E. Grauer, Beuren, Stuttgart, Allemagne, 2001 ■ Project documents and annual monitoring reports of develpment projects by ADN Nourriterre and HEKS EPER Suisse (2003-2009) ■ Jochen Suchantke, Abdoulaye Sambo Soumaila (2001): Etude cadre pour le programme NIGETIP IV, KfW, Niamey, Niger, 2001

ROTATIONAL GRAZING - SOUTH AFRICA

Rotational grazing is a management system based on the subdivision of the grazing area into a number of enclosures and the successive grazing of these paddocks by animals in a rotation so that not all the *veld* (grazing area) is grazed simultaneously. Consequently, rotational grazing allows higher stocking rates than continuous grazing. The main principles of rotational grazing are: (1) Control the frequency at which pasture is grazed: adjustment of the rotation cycle ensures a good forage quality in each paddock. Pasture plants (including the most preferred and therefore overused species) are provided with a period of recovery or rest following grazing; (2) Control the intensity at which the pasture plants are grazed by controlling the number of animals which graze each paddock and their period of occupation; (3) Reduce the extent of selective grazing by confining a relatively large number of animals to a small portion of the *veld*: little opportunity for selection prevents domination of undesirable species.

Intensity of grazing should be adapted to the climatic conditions: in drier areas recovery periods should be longer due to limited plant recovery potential and high sensitivity to misuse and degradation. The ratio between periods of occupation and absence determines the plant yield and vigour: the shorter the period of occupation in a paddock the greater will be the yield of the *veld*: a second 'bite' is avoided and consequently the recovery period is at least equal to the period of absence. However, the shorter the period of occupation and the longer the period of absence, the greater is the number of paddocks required in a rotational grazing system.

Ideal resting periods vary with growth rate, and with the rate at which the *veld* loses its quality with maturity. Depending on the season, the climate and the use of irrigation, resting periods vary between 14 and 70 days, and even longer in the semi-arid grasslands (90–150 days). Appropriate stocking rates are assessed through 4 rating factors (defining the veld condition): species composition, basal cover, topography and soil erodibility.



SLM measure	Management
SLM group	Pastoralism and Rangeland Management
Land use type	Grazing land
Degradation addressed	Mainly biological degradation: reduction of vegetation cover, decreasing vegetation diversity
Stage of intervention	Prevention (partly mitigation and rehabilitation)
Tolerance to climate change	The technology is tolerant to climatic changes: land users can adjust grazing and resting periods according to changing conditions

Establishment activities

1. Farm planning: including technical design of farm plan with grazing paddocks, rotational system and livestock watering system conducted mostly by extension workers or specialists from Dept. of Agriculture.
2. Fencing.
3. Establishment of stock watering system including the construction of a dam, windmill, drinking trough, pipeline and borehole.

Maintenance / recurrent activities

1. Fencing.
2. Maintenance of windmill, pipeline, dam and drinking trough.
3. Implementing the system (moving livestock from one paddock to another, attend to livestock watering requirements (opening and closing of valves and attending to windmill brake on windy days).

Labour requirements

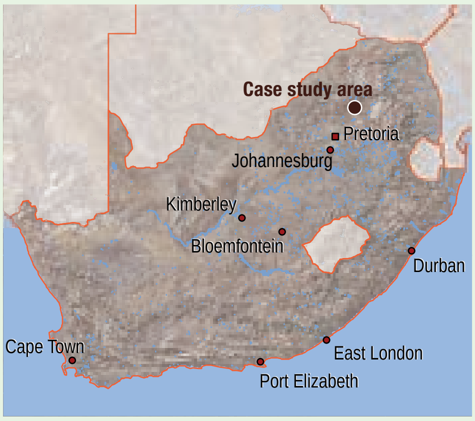
For establishment: medium
For maintenance: low

Knowledge requirements

For advisors: high (layout of the camps and design of stock watering and grazing system)
For land users: medium (implementation of the system, building of fences and stock watering system, maintenance)

Photo 1: Cattle drinking from a water trough near a windmill which pumps the water from a borehole into the dam or reservoir. From there drinking troughs are supplied. These have to be spread in a paddock to avoid local overgrazing.
Photo 2: Typical steel gate used in a rotational grazing system to allow access to and from grazing paddocks.
Photo 3: An example of a rested paddock (on the left) and a lightly grazed camp (on the right) with a barbed wire dividing the paddocks. (All photos by Lehman Lindeque)

Case study area: Crecy area, Springbokvlakte region, Limpopo Province, South Africa



Establishment inputs and costs per 500 ha

Inputs	Costs (US$)
Labour: 85 person-days	6,080
Equipment / tools: specify	1,160
Agricultural Inputs: specify	–
Construction material: specify	45,173
TOTAL	**52,413**
% of costs borne by land users	100%

Maintenance inputs and costs per 500 ha per year

Inputs	Costs (US$)
Labour: 32 person-days	3,173
Equipment / tools: specify	–
Agricultural inputs: specify	–
Construction material: specify	10,213
TOTAL	**13,386**
% of costs borne by land users	100%

Remarks: Estimated establishment time for a 500 ha farm with 8 paddocks more or less 6 months. The establishment and maintenance costs depend on farm size and the details of the farm plan / design of the paddock system including variables such as number of paddocks, number of stock watering points, number of boreholes, etc. Above mentioned costs are merely an indication for a typical livestock farm of 500 ha.

Benefit-cost ratio

Inputs	short term	long term
Establishment	very negative	positive
Maintenance	slightly negative	positive

Remarks: Establishment costs are very high and discourage many farmers from using a multi-paddock grazing system.

Ecological conditions

- Climate: mainly semi-arid, partly subhumid
- Average annual rainfall: 500 – 1,500 mm
- Soil parameters: shallow soils, medium soil organic matter, good to medium soil drainage / infiltration, soils with high fertility are used for cultivation
- Slope: 0-8 %
- Landform: plateau / plains and valley floors
- Altitude: 500 - 1000 m a.s.l.

Socio-economic conditions

- Size of land per household: 100-500 ha
- Type of land user: mainly large-scale commercial livestock farmers (large areas allow for many grazing paddocks)
- Population density: < 10 – 200 persons/km^2
- Land ownership: mainly individual not titled or partly communal village ownership
- Land use rights: mainly individual, partly communal organised
- Level of mechanisation: mechanised
- Market orientation: commercial

Production / economic benefits

+++ Increased fodder production (in available dry-material)
+++ Increased water availability / quality for livestock (through improved livestock watering systems)
++ Increased animal production (due to increased and better fodder)
++ Reduced risk of production failure
++ Increased farm income
++ Increased production area (due to better drinking water availability)

Ecological benefits

++ Increased soil moisture and reduced surface runoff
++ Reduced evaporation (through better plant cover)
++ Reduced hazards towards adverse events (floods, droughts, etc.)
++ Improved soil cover
++ Increased biomass / above ground carbon
++ Increased plant diversity and increased / maintained habitat diversity

Socio-cultural benefits

+++ Improved food security / self-sufficiency

Off-site benefits

+ Reduced groundwater and river pollution
+ Increased water availability (groundwater, spring)

Weaknesses ➜ and how to overcome

- Cost of construction or initial implementation ➜ convince farmers to see it as a long term investment to ensure sustainable production.
- *Veld* fires damage fences and drinking troughs ➜ prevent accidental *veld* fires by making fire bunds at the start of the dry season.

Adoption

Since 1994 rotational grazing is no longer subsidised by the government (subsidies restricted to small-scale communal and subsistence farmers). There is a moderate trend in adoption of the technology. Farmers realise the importance of vegetation management in sustainable livestock production, in view of the increasing pressure on grazing land and the risks of drought and climate change.

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Key references: Tainton N.M. 1988. Veld and Pasture Management in South Africa. Shuter & Shooter, Pietermaritzburg in association with University of Natal Press, Pietermaritzburg. ■ Department of Agriculture and Water Supply. 1989. Veld management in the Eastern Cape. Government Printer, Pretoria

SUSTAINABLE PLANTED FOREST MANAGEMENT

Protective pine plantations on degraded slopes and in gullies, Tanzania. (Hanspeter Liniger)

In a nutshell

Definition: Planted forests, or 'plantations', comprise trees established through planting seedlings and / or through direct seeding. Species may be native or introduced. Establishment may be on previously forested land or land that was not forest before. The purpose of planted forests can be either (1) commercial; or (2) for environmental / protective use; or (3) for rehabilitation of degraded areas. It may be a combination of more than one of these. The challenge is to develop planted forests that are financially viable as well as ecologically sustainable. The applicability and sustainability of planted forests depends on what they replace and how they are managed and harvested. Planted forests cannot act as a substitute for natural forests, they should rather complement and mutually reinforce the environmental and production services of the latter. In developing countries seventy percent of people depend on trees and forests as their major source of fuelwood. Due to declining supplies, planted forests are an increasingly important source of fuelwood and other forest products. Proper sustained management of planted forests is the only way to avoid shortages of wood and further deforestation of natural forests - planted forests lessen the need to log natural forests. However, there are very controversial opinions about the sustainability of planted forests, especially related to industrial large-scale monoculture plantations. On-going debate concerns whether planted forests constitute the best answer to the growing demand for wood, and whether they are an efficient way of 'carbon-offsetting'. In some situations planted forests can be excellent to rehabilitate degraded land, leading to improvements of the environment, whereas a similar plantation can have negative impacts elsewhere. A further key aspect is whether the mature trees are harvested, and if so, whether the stand is replanted (or left to coppice) or abandoned. It is at establishment and harvesting when most environmental damage can be done. Environmental guidelines need to be adhered to, or developed where inexistent.

Applicability: Planted forests with fast-growing species should only be established in areas with no water constraints.

Resilience to climate variability: Even small areas of planted forests (given the warning about water consumption above) can positively influence the microclimate, which can enhance the resilience to climate variability.

Main benefits: Rehabilitation of degraded areas (e.g. eroded or overgrazed areas), increased availability of wood products, fuelwood, and some non-wood forest products. They can lead to employment and income generation. There is reduced pressure on natural forests; planted forests are carbon sinks (unless they replace natural forests), especially on marginal agricultural land and degraded soils – and only if replanted / left to coppice after use.

Adoption and upscaling: Delineation of clear resource rights with respect to planted forests is essential. Research is important for scientifically based information about appropriate management, species compositions and the impact on the ecosystem. Capacity building and training should be provided to all stakeholders. Incentives may be needed for the establishment of planted forests, especially for the rehabilitation of degraded areas.

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	na
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	++

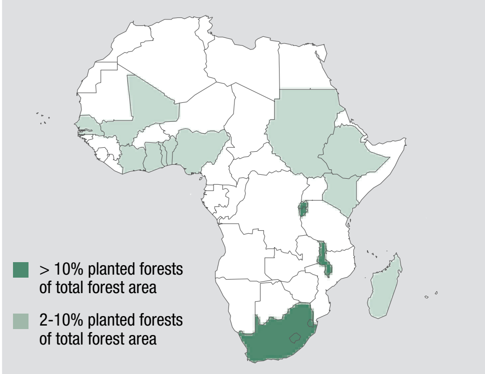
Climate change mitigation	
Potential for C sequestration (tonnes/ha/year)	1.2 – 2*
C Sequestration: above ground	+++
C Sequestration: below ground	++

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 first 20-30 years of afforestation in drylands, depending on the selected tree species (FAO, 2004 and GTZ, 2009)*

Origin and spread in Africa

Origin: Large-scale plantation of exotic tree species in Africa originated during the colonial period with foreign investments and regulated by governments. Nowadays, there is a shift from previously government controlled management towards increased involvement of the private sector and small-scale producers. Since the 1960s, the emphasis has been maintained on fast-growing species primarily grown for supplying industrial wood (pulp and paper industry, fuelwood). In 2000, the total plantation area in Africa was 8,036,000 ha of which 42% are commercial-industrial plantations. Planted forests represent, only a very small fraction of the total forest cover in SSA (between 0.3% - 2.3% of the total).
Mainly in (more than 10% planted forests of total forest area): Burundi, Cape Verde, Lesotho, Malawi, Rwanda, Swaziland, South Africa.
Partly in (between 2-10% planted forests of total forest area): Benin, Ivory Coast, Ethiopia, Ghana, Kenya, Mali, Madagascar, Nigeria, Sudan, Senegal, Togo.
Plantation forestry is negligible in countries with large tracts of natural forests.



Spread of planted forests in SSA.

Principles and types

Technical aspects of sustainable planted forest management:
- **Sustaining soil fertility:** confining harvesting of forest products to stem wood, use of soil conservation measures, and application of fertilizer, etc.
- **Proper harvesting planning**, e.g. careful re-use of extraction routes.
- **Selection of species:** diversity of trees enhances resilience to pests and diseases and to climate variability / change.
- **Natural corridors** to enhance biodiversity especially of industrial plantations.
- **Fire breaks** to limit the extent of fires, often combined with access roads.

Planted forests vary from strictly protected conservation forests to highly productive, short rotation plantations. In this continuum the boundary between different categories is often indistinct.
Plantations for industrial purposes are mainly 'fast-wood' plantations, and are intensively commercially managed. They are usually blocks of single species producing round wood at high growth rates - often initiated with government support or through corporate investment projects. They may also have an environmental protection rationale. To be sustainable, industrial plantations should provide fair job opportunities, consider the environmental aspects of monoculture plantations, not be established on productive agricultural land nor replace natural forests. Commercial industrial plantations may also focus on the production of non-wood forest products (NWFP) such as gum arabic. There is a recent trend towards plantations to lock up carbon in 'carbon-offsetting schemes'. One risk is of farm land being taken out of production for this.
Out-grower schemes bring in private landowners (individuals / communities) into wood production. Forest companies are guaranteed a steady supply without being involved in land acquisition, whereas out-growers profit from employment opportunities and income. Out-grower schemes have potential to contribute to rural wealth creation, resulting in smaller and diverse production units.
Plantations for energy production form a main source of fuelwood in SSA. Most of these fuelwood plantations are within the public sector and the maintenance is often relatively neglected. For sustainable management clear land resource use rights must be given to land users.
Environmental / protective plantations have the purpose of protection and provision of environmental stabilisation. They can decrease soil erosion, stabilise slopes, fix sand dunes, serve as windbreaks, etc. Usually they are initiated with government support or project funding. Environmental plantations are gaining more importance with the increasing awareness of desertification.
Farm / home plantations and woodlots can provide a substantial amount of fuelwood and timber. Trees may be within an agroforestry system, homestead gardens or woodlots. Woodlands around small-scale farms can protect against shortages of fuelwood and construction poles, can be used for fodder production or for NWFPs, and have the potential to produce industrial wood.
Wood is the most important energy source in SSA, and the pressure on wood resources rises. Therefore farm plantations should be encouraged and alternative renewable energy resources (wind, solar) and energy-saving stoves promoted.

Top: Watering nursery seedlings for desertification control, Senegal. (Lyes Ferouki)
Middle: Eucalyptus plantation for timber and fuelwood production, Ethiopia. (Hanspeter Liniger)
Bottom: Environmental protective plantations on steep slopes, Eritrea. (Mats Gurtner)

Applicability

Land degradation and causes addressed

Biological degradation: loss of biodiversity in monocultures
Physical soil deterioration: little soil cover and undergrowth can lead to sealing and crusting
Chemical soil deterioration: loss of soil nutrients due to short rotations of industrial plantations
Soil erosion: especially in fast growing and high rotation industrial plantations with insufficient soil cover, and during establishment and harvesting phases
Planted forests can rehabilitate badly degraded land, helping to restore protective and environmental functions.
Planted forests which are under government tenure are very often poorly managed and financially not viable, leading to illegal logging and fires.

Land use

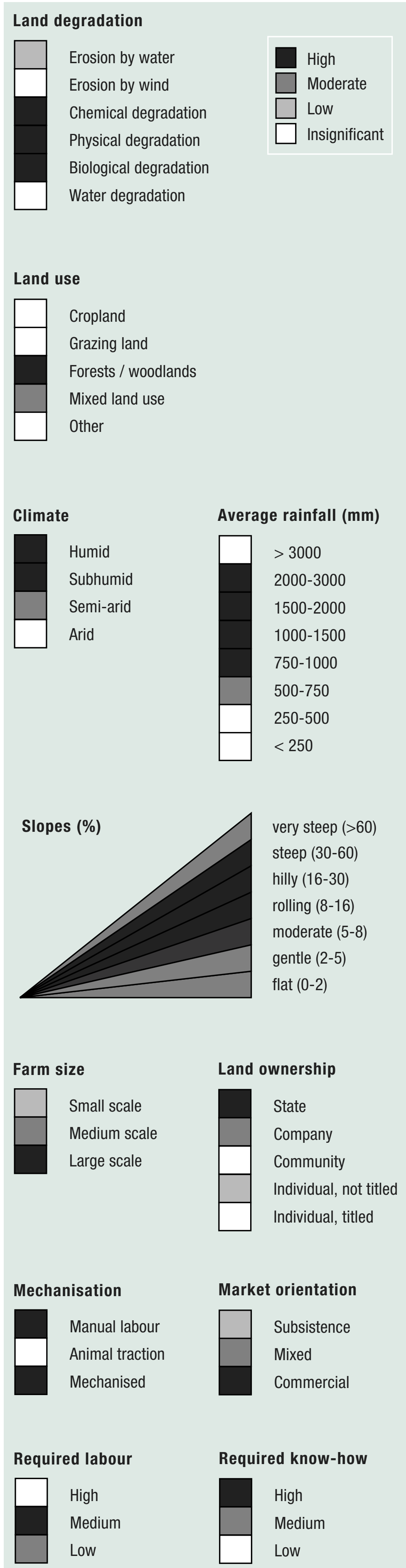
Mainly forest and mixed land.
The species planted vary in different regions; overall, conifers account for 52 percent, broadleaves for 37 percent, and unspecified for 11 percent. In order of importance the main coniferous genera by area are *Pinus, Cunninghamia, Picea, Larix* and *Cryptomeria* whilst the main broadleaf genera are Eucalyptus, Acacia, Tectona, and Populus species.
The majority of the trees are exotics with emphasis on short rotation plantations, only little emphasis on growing valuable indigenous trees due to slow growth rate and low economic return.

Ecological conditions

Climate: Humid zones emphasis on high value industrial plantations. Plantations used for commercial purposes are not suitable for water scarce areas due to restricted water availability for fast growing tree species and their ability to deplete already dry soils. In the dry zone (e.g. Sahelian region) planted forests are mainly for fuelwood production and for providing improved environmental conditions (e.g. sand dune stabilisation, windbreaks, etc.).
Terrain and landscape: There are terrain restrictions for planted forests related to very steep slopes and respecting riparian buffer zones.
Soils: No restrictions.

Socio-economic conditions

Farming system and level of mechanisation: Commercial fuelwood and environmental plantations are often owned and managed by the public sector: little mechanisation is involved. Large-scale industrial plantations are usually managed with a high degree of mechanisation – especially for harvesting. Farm plantations can be found in highly populated areas where not enough fuelwood from public forests is available.
Market orientation: Very large-scale commercial industrial plantations; plantations providing fuelwood and timber for subsistence and some commercial use; small-scale farm plantations for subsistence and some commercial use.
Land ownership and land use / water rights: Plantations are mainly owned by governments, partly by large industrial corporations and some by individual farmers. Industrial plantations in SSA are more than 50% publicly owned and about 34% privately owned. Non-industrial plantations are 62% publicly owned and 9% privately owned, and 29% are unspecified. In South Africa plantations are mainly owned by companies and small growers.
Skill / knowledge requirements: Theoretically a very high level of knowledge about the impacts of planted forests on the ecosystem is required.
Labour requirements: The establishment and the harvesting of large-scale plantations can be very labour demanding. Maintenance of farm plantations do not need much labour input.



Economics

Establishment and maintenance costs

Establishment costs: The establishment of a new forest usually implies very high initial investments, especially if established on a large-scale.
The extra investments for a management change from an 'old' planted forest system to 'sustainable management' does not involve very high 'establishment' costs. Those are mainly related to the development of a management plan, resource rights, regulations, etc.
Seedling production: 500 US$/ha
Land preparation, planting: ≈ 1,500 US$/ha
Maintenance costs: Tending, maintenance, pest and fire control: 600 US$/ha

Comment: It is very difficult to provide figures to the costs of planted forests. There are large differences by the type of planted forests, by initial conditions and by country.

Production benefits

Tree	Rotation length (year)	Productivity (m^3/ha/year)
Eucalyptus		
Congo	7	30
Rwanda	8	8.5
South Africa	8-10	18-20
Pines		
Malawi	20-25	17
Madagascar	15-18	6-10
Mozambique	18-28	11

(Source: FAO, 2001)

Comment: The figures above show the rotation length and the productivity of different commonly used tree species in planted forests.

Benefit-Cost ratio

Planted forests (by purpose)	short term	long term	quantitative
Industrial	–	++	Benefit-cost ratio at 10% discount ratio, Ghana: Teak: 4.9 (<10 ha) Cedrela: 3.5 (<10 ha) Pine: 1.8 (<10ha)
Energy production	– –	+	
Environmental	– –	– /+	
Farm plantations	–	++	

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive
(Source: FAO, 2002)

Comment: Generally there is very limited data available related to the benefit-cost ratio of planted forests. However, the internal rate of return achievable with well-managed planted forests ranges between 5 and 20% depending on soil fertility, topography, species choice, growth performance, incidence of pests and fire and market prices for timber.
Efficiency in plantation management and success in achieving sustainable wood supply depends mainly on whether a plantation is publically or privately owned, and how it is managed. It is important here to distinguish between *financially* well managed plantations and *sustainably* managed. Usually, privately owned, forest plantations are well managed in financial terms - being aimed at profit maximisation. In Southern Africa it has been demonstrated that privately owned plantations can be profitable due to the integration of the plantation with wood processing companies. Many public sector plantations are poorly managed in financial terms being not profit oriented; however, often they have environmental and social benefits as objectives, which are not quantifiable.

Example: Industrial wood production by small farmers in the central highlands of Kenya
Economic analyses of cropping and tree enterprises have been carried out in some locations in the central highlands of Kenya. The average gross margin from trees per farm per year was Kshs 57,808 (US$ 734). This figure includes the contribution of coffee and tea, which was 65% of the total. Fruits contribute 28%, while timber and firewood contribute 8%. For 70-80% of the households the trees grown on farms function also as major sources of fuelwood. The remainder obtain their supply of firewood from neighbours or nearby forests. Following a temporary ban in 1999 on the sale of timber from government-owned forest plantations and natural forests, there has been an increase in the sale of timber from farms, and some farmers have formed associations to facilitate the marketing of timber. Accurate information on the profitability of this new timber enterprise is not available. However, the farmers also face many problems like lack of knowledge about tree management and market, permits needed for the felling and transport, etc. (Chamshama and Nwonwu, 2004).

Example: South Africa
Small-scale out-grower schemes in South Africa represent an investment of more than R 50 million (US$ 7 million), which should generate revenues of about R 175 million (US$ 24 million) for growers when the plantations are harvested. The small timber growers supplement their livelihoods with growing of food crops on the periphery of their woodlots. They make good profits and many have extended their operations from a single woodlot to three or four. Furthermore, the local community benefits from increased participation in the monetary market and from job opportunities created by the contracting by the companies of support services for planting, maintenance, harvesting and transportation. Small growers and rural communities also benefit from training programmes offered by the forest companies (Chamshama and Nwonwu, 2004).

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	+++ increased availability of fuelwood + diversification of production + increased availability of NWFP	+++ reduced risk and loss of production +++ decreased pressure on natural forests + improved access to clean drinking water	+ improved food and water security
Economic	+ job creation (depending on the previous land use) + increased and diversified household income of small-scale land users (through farm plantations)	+++ less damage to off-site infrastructure ++ stimulation of economic growth ++ diversification and rural employment creation	+++ improve livelihood and human well-being
Ecological	++ improved soil cover ++ regulation of micro- and meso-climate ++ rehabilitation of degraded areas and restoring productive and environmental functions (e.g. due to overgrazing) ++ prevent soil erosion ++ used as windbreaks, shelterbelts, etc. ++ reduced pressure on farm manure ++ stabilisation of slopes, riverbanks, etc. ++ less nutrient mining than cropland + increased biodiversity + regulation of ground water (e.g. salinity) + increased soil organic matter and soil fertility	+++ reduced degradation and sedimentation + intact ecosystem	++ reduced land degradation and desertification incidence and intensity ++ increased resilience to climate change ++ carbon sequestration (when applied on degraded land / soil)
Socio-cultural	+/- can help to preserve the social and cultural values attached to forests + community institution strengthening	+ increased awareness for environmental 'health'	

	Constraints	How to overcome
Production	• Large-scale plantations are often monocultures	➜ mixed plantations, with intercropping, use of natural corridors to enhance biodiversity, etc.
Economic	• Lack of markets and access to markets • Establishment of plantations can be expensive and often rely on donor funding • Long time period between planting and harvesting of trees with no or only limited income (especially a problem in out-grower schemes) • Availability of fertilizers (e.g. phosphorous) • Availability of land and competition with other land use (e.g. demand for cropland and grazing land) and land grab for establishment of industrial plantations for wood or NWFP can lead to a loss of agricultural land affecting small-scale land users with no clear land tenure • Can increase pressure on natural forests by replacing tree diversity with monocultures that flood the market with cheap / fast growing wood.	➜ furthering the establishment of market and value chain ➜ credit schemes for small-scale land users to establish farm plantations ➜ providing of credits from timber companies ➜ support for small woodlots and farm plantations and regulations for new plantations, assessment of the economic, environmental and social sustainability of new forests, ensure land use rights for small-scale users and promotion of out-grower schemes
Ecological	• Exotic tree species can spread at the expense of native forests, affecting the entire ecosystem • Water need: fast growing species can have a very high demand of water and can have an irreversible negative impact especially in water scarce areas • Plantations can have high water use leading to lower streamflows, etc. and strongly influence the hydrological system of an area • Water competition with crops e.g. eucalyptus trees and limited availability of water in dry areas • Susceptibility of planted forests to pest and diseases especially in plantations • Monoculture plantations can damage the ecosystem	➜ appropriate selection of species ➜ considering the demand for water of the selected species, take into account sensitive and water scarce areas ➜ watershed management planning, considering off-site effects of plantations ➜ select less competitive tree species (e.g. *Grevilla robusta*) with a reduced water demand and high water use efficiency, manage trees by pruning ➜ diversification of species can remarkably reduce the risk to pest and diseases, maintaining optimum stocking levels
Socio-cultural	• Lack of know-how in management, species composition, improper establishment, etc.	➜ needs good training and education in the proper management of planted forests

Adoption and upscaling

Adoption rate

There is an increase in the area of planted forests in SSA, the annual rate of planting in Africa is estimated to be about 194,000 ha. However, the adoption rate for sustainable management of planted forests is not known and is rather difficult to assess, since a clear delineation of what is sustainable and what is not, is very difficult. The out-grower scheme has been adopted with great success in Southern Africa (especially South Africa, Swaziland and Zimbabwe).

Upscaling

Policy framework: Forest management must be integrated into a coordinated national framework with a clear forest policy. The forestry sector needs to be strengthened, and formulation and implementation of national and sub-national sustainable forest policies and programmes are necessary.
Land tenure: Publicly owned and managed plantations tend to display low productivity. Public bodies should seek the involvement of the private sector (smallholders, communities, companies, etc.) to support and encourage the efficient financial management of planted forests.
Capacity building: Capacity building and good training in sustainable management of planted forests is needed for all stakeholders involved (e.g. smallholders, communities and forests services, commercial users).
Research: More research is required about the impacts of planted forests on water resources (decreasing or increasing water availability) and on biodiversity, for a better understanding of the behaviour of different tree species, etc. Knowledge and expertise should be enhanced - related also to suitable indicators for monitoring planted forest resources.
Timber market: (1) Small-scale land users and communities need to be empowered by improving their access to markets and market information; (2) Certification of planted forests provides an opportunity but needs clear regulations and standards for declaration of the source of wood, and also considers social and ecological aspects. (3) Promotion of the out-grower scheme, as a successful way for private landowners to participate in wood production.
Farm plantations: The establishment of farm plantations should be further promoted and supported through an enabling policy framework and financial incentive packages for private investors. Farm plantations can strengthen the economic situation of land users as well as reduce the pressure on natural forests.

Incentives for adoption

Incentives for the establishment of new planted forests are very often needed due to the long period before economic benefit is gained. However, only those afforestation projects which are known to be ecologically and socially viable should be financially supported. Incentives for private tree planting and the establishment of farm plantations should be created, since they can provide fuelwood and other woody products and decrease the pressure on natural forests. For the creation of new large-scale planted forests, e.g. for rehabilitation of degraded areas, investments either from donors or from the government / public sector are needed, and the involvement of local communities should be guaranteed.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	+
Training and education	++
Land tenure, secure land use rights	+++
Access to markets	++
Research	+

Example: Ethiopia
The Government of Ethiopia has initiated collaborative plantation management programmes to address growing problems of illegal logging and forest encroachment by involving local communities. The government expects cooperation by allocating communities rights to establish and manage plantations for certain periods and by guaranteeing them a share in the profits from the timber. The guaranteed equal and fair profit-sharing agreements between state and community groups have attracted many smallholders to tree planting and can help strengthen the communities' commitment to sustainable forest management. Since the 1990s the government has increasingly granted community management rights favouring more community involvement in forest management, including planted forests, leading to some plantations allocated to communities. New regional land administration policies allow issue of landownership certificates to landholders, and owners have the right to lease their plots to others for up to 25 years; however, land still cannot be officially bought or sold (Nawir et al., 2007).

References and supporting information:
Arborvitae. 2006. Forest plantations: the good, the bad and the ugly. The IUCN/WWF Forest Conservation Newsletter. September 2006. Vol.31.
Chamshama, S.A.O. and F.O.C. Nwonwu. 2004. Forests Plantations in Sub-Saharan Africa – A short report prepared for the project 'Lessons Learnt on Sustainable Forest Management in Africa.
Chamshama S.A.O., F.O.C. Nwonwu, B. Lundgren and G.S. Kowero. 2009. Plantation Forestry in Sub Saharan Africa: Silvicultural, Ecological and Economic Aspects. Discov. Innov., 2009; 21 (SFM Special Edition No. 1)
CIFOR. 1998. Centre for International Forestry Research. CIFOR Annual Report 1998. http://www.cifor.cgiar.org/publications/Html/AR-98/Plantation.html, accessed on 17 November 2009.
Cossalter, C. and C. Pye-Smith. 2003. Fast-wood forestry: Myths and realities. CIFOR, Jarkata, Indonesia. 50 p.
Ekisa G.T. 2009. Community Participation in Afforestation and Agroforestry Programmes in Kenya: The influence of biophysical environmental in the case of Teso District.
FAO, 2001. Mean annual volume increment of selected industrial forest plantation species. Luis Ugalde and Osvaldo Pérez. Working Paper FP/1, FAO Rome (Italy)
FAO. 2002. Hardwood plantations in Ghana. F. Odoom. June 2002. Working Papert FP/24.
FAO. 2003. Forestry Outlook Study for Africa – Subregional Report West Africa. African Development Bank, European Commission.
FAO. 2003. Forestry Outlook Study for Africa. African Development Bank, European Commission.
FAO. 2004. Carbon sequestration in dryland soils. World Soil Resources Reports, No. 102, Rome, Italy.
FAO. 2006. Responsible management of planted forests: voluntary guidelines. Planted Forests and Trees Working Paper FP37E, Rome, Italy
FAO. 2006. Global planted forests thematic study: results and analysis, by A. Del Lungo, J. Ball and J. Carle. Planted Forests and Trees Working Paper 38. Rome.
FAO. 2009. Planted Forests. http://www.fao.org/forestry/plantedforests/en/ accessed on 22 September 2009.
FAO. 2010. Forestry Photos. http://www.fao.org/mediabase/forestry/, accessed on 6 June 2010.
GTZ. 2009. Running dry? Climate change in drylands and how to cope with it. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH. Oekom Verlag, München
Kanowsky P. and H. Murray, 2008. Intensively Managed Planted Forests – Toward best practice. Summary and Recommendations from TFD's IMPF Initiative June 2005 – June 2008. The Forests Dialogue. TFD Publication Number 1 2008.
Nawir, A.A., H. Kassa, M. Sandewall, D. Dore, B. Campbell, B. Ohlsson and M. Bekele. 2007. Stimulating smallholder tree planting – lessons from Africa and Asia, Unasylva 228, Vol. 58.

CASUARINA TREE BELT FOR SAND DUNE FIXATION - SENEGAL

The *bande de filao*, a 200 m wide belt of *Casuarina equisetifolia* trees, was established along the Senegalese coast from Dakar to St.Louis, to protect the adjacent Niayes region from wandering sand dunes. The Niayes, a territory of 5-30 km width covering a surface of 4,200 km², is known for its favourable conditions for vegetable production. However, droughts, deforestation and overgrazing have caused gradual desertification and loss of stabilising vegetation cover on sand dunes. The dunes began to advance at a rate of up to 10-12 m per year and threatened villages and production areas.

The establishment of the tree belt started in the 1970s and continued until the late 1990s. The exotic nitrogen-fixing *Casuarina equisetifolia* was found to perfectly fit into the harsh ecological environment with its poor sandy soils, strong winds, shifting sand and proximity to the sea. Seedlings were raised in nurseries, then planted on a 2.5 x 2.5 m grid – protected by palisades and irrigated at the initial stage. The *filao* belt covers an area of about 9,700 ha and effectively halts wind erosion and movement of sand dunes, resulting in multiple positive impacts on the environment and the 120,000 people living in the area: it provides protection of villages, allowing vegetable production in inter-dunal depressions, and last but not least - builds up resources of wood. Without the tree belt, life in the Niayes would not be possible. Furthermore, wind speed was reduced also on the sea side, making inshore fishery possible during the whole year (before it was limited to 3 months).

The big challenge is to gradually replace the stands of *Casuarina* trees that have reached senescence (after approx. 30 years). A management plan has been developed to assure the continuity of this important protective system.

SLM measure	Vegetative
SLM group	Sustainable Planted Forests Management
Land use type	Forest (afforestation); Off-site land use: annual crops (vegetables) and fishery
Degradation addressed	Biological degradation: reduction of vegetation cover; Erosion by wind: loss of topsoil: uniform displacement, off-site degradation
Stage of intervention	Prevention and rehabilitation
Tolerance to climate change	Increased tolerance towards drought, floods, storms

Establishment activities

1. Initial protection with palisades (1 m high; 70 m from the coast; 1 year before planting).
2. Establish 0.5 m high palisades at a spacing of 10 - 20 m (depending on dune slope) perpendicular to wind direction; made of *Guiera senegalensis* on poles of *Euphorbia balsamifera* (before planting, November-June).
3. Enclosure: wire fence protects young plants from roaming animals.
4. Excavation of wells for watering of seedlings in nurseries and initial irrigation of the planted seedlings.
5. Production of seedlings in tree nurseries (January-February).
6. Plantations of seedling on a 2.5 x 2.5 m grid (1,600 plants/ha).
7. Guarding the plantation site (for protection of seedlings).

Maintenance / recurrent activities

1. Watering *filaos* during first year.
2. Guarding the plantation.
3. After 25-30 years replace the whole stand with new seedlings.

Labour requirements

For establishment: high

For maintenance: low (maintenance is needed only in 1st year after establishment; if high inputs for replacing the whole stand after 25-30 years are taken into account, overall maintenance is medium)

Knowledge requirements

For advisors: medium

For land users: high

Photo 1–2: Tree plantation in Lompoul. (Julie Zähringer)
Photo 3: *Casusarina* seedlings ready for planting (front), establishment of palisades to protect planted seedlings (middle), and a *Casuarina* plantation aged seven years (in the background). (Mailly et al. 1994)
Photo 4: Areal view: the tree belt protects not only the settlements and vegetable production areas in the south-west, but also the inshore area of the Atlantic ocean, making fishery possible all year round. (Google)

Case study area: Lompoul, Niayes, Senegal

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour	no data
Equipment	no data
Agricultural inputs: 1600 seedlings	225
TOTAL	**no data**
% of costs borne by land users	0%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour; Equipment; Agricultural inputs;	no data
TOTAL	**no data**

Remarks: Costs for establishment are high. All inputs were fully subsidised. Implementing agency was governmental 'Service des Eaux et Forêts' with funding from ACDI and USAID. Reestablishment starts after 25-30 years when trees reach senescence.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	very positive
Maintenance	slightly positive	very positive

Remarks: Land users emphasise that without the technology they would not be able to live in this area.

Adoption

The *Casuarina* tree was established along the littoral between St. Louis and Dakar, covering an area of 97 km^2. Project support included provision of tree seedlings, technical assistance and rewarding labour. High establishment costs make a spontaneous spread of the technology difficult.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 250-300 mm
- Soil parameters: low soil fertility, low organic matter content (< 1%); sandy texture, good infiltration and drainage, low storage capacity
- Slope: no data
- Landform: sand dunes (slopes and interdunal depressions)
- Altitude: < 100 m a.s.l.

Socio-economic conditions

- Size of land per household: no data
- Type of land user: poor medium-scale land users; technology is implemented in groups / by community
- Population density: 65 persons/km^2
- Land ownership: state / individual (not titled)
- Land use rights: communal (organised)
- Level of mechanisation: manual labour / animal traction / mechanised
- Market orientation: mainly subsistence (forest land)

Production / economic benefits

+++ Increased wood production
+++ Increased production of litter used as mulch and for composting by vegetable farmers or by fishermen to smoke fish

Ecological benefits

+++ Reduced wind velocity
+++ Reduced soil loss
+++ Increased biomass
++ Increased soil organic matter / below ground carbon
++ Reduced hazard towards adverse events (drought, floods, storms)
++ Increased soil cover (with litter)
++ Improved carbon storage

Socio-cultural benefits

++ Increased recreational opportunities
++ Community institution strengthening

Off-site benefits

+++ Reduced wind transported sediments
+++ Sand dune stabilisation
+++ Improved vegetation cover
+++ Making establishment of settlement possible in the region
+++ Making horticulture possible in the region
+++ Making fishery possible all year round and therefore creating an additional income source
+++ Reduced damage on public / private infrastructure
+++ Reduced damage on neighbours fields

Remark: The technology focuses on off-site benefits!

Weaknesses ➜ and how to overcome

- High establishment costs for large scale plantations.
- *Casuarina equisetifolia* trees reach senescence after 30-50 years and do not regenerate naturally ➜ plantation activities need to be taken up again; In the hinterland reforestation with local *Cocos* should be tried.
- Increased demand for irrigation water.
- Making all year round fishery possible and therefore loosing labour force for vegetable cultivation.
- Increased amount of plastic waste (due to attraction of tourists).

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Key references: Mailly, D., Ndiaye, P., Margolis, H. A., & Pineau, M. (1994). Fixation des dunes et reboisement avec le filao (Casuarina equisetifolia) dans la zone du littoral nord du Sénégal. The Forestry Chronicle, 70(3); Julie Zähringer, juliez@ethz.ch / Déthié Soumare Ndiaye, dethie@cse.sn

AFFORESTATION AND HILLSIDE TERRACING - ERITREA

Tree plantations in combination with hillside terracing to protect upper catchment areas are a widespread technology in the Central and Northern Highland Zone of Eritrea. In the early 1990s a large area was treated in the Toker catchment, northwest of Asmara. The first step was to establish hillside terraces on the steeper slopes where it is essential to conserve soil and water for improved growth of trees and other vegetation. The terraces comprise earthen embankments laid out along the contour, reinforced with stone risers, combined with a trench on the upper side to harvest runoff water. The trenches are subdivided into basins (by ties) to avoid lateral flow of runoff water. In a second step, trees were planted at a spacing of 2 m (in the trenches).

Mostly fast growing eucalyptus was used, with a very small percentage of the indigenous African olive (*Olea africana*) - which has good survival rates but grows very slowly. Afforested areas are closed for any use until the trees reach maturity: they are protected by guards. In 1995, the Ministry of Agriculture handed over user rights to communities allowing cut-and-carry of grass and cutting of trees (with permission of the government).

The technology requires appreciable expense, labor and expertise, but if maintained well, it results in multiple ecological and economic benefits: Soil cover has improved, water is conserved, the severe problems of soil erosion have been reduced, and dams further downstream are protected from siltation. Trees have become an important source of income for the rural communities, wood is a valuable resource mainly needed for construction, and also as fuel.

Since the 1960s, several afforestation campaigns have been initiated by the government, mainly using food-for-work or cash-for-work approaches as incentives. Nowadays, local tree planting initiatives (on community or individual level) without external support are dominant.

SLM measure	Vegetative and structural
SLM group	Sustainable Planted Forest Management
Land use type	Plantations, afforestation
Degradation addressed	Surface and gully erosion; Decline of vegetation cover, diversity and biomass; Loss of surface water; Lowering of ground water level
Stage of intervention	Rehabilitation
Tolerance to climate change	Sensitive to climatic extremes (e.g. rainfall decrease, especially in case of monocultures)

Establishment activities

1. Mark contour lines using a line level. Spacing between terraces depends on slope, vegetation status, soil depth. In the case study area horizontal spacing between terraces is 2.5 m.
2. Terraces are built (inward-sloping) by digging out trenches (0.5 m deep) and piling up risers (minimum 0.75 m high). Risers should be reinforced with stones (where available).
3. The trenches are separated into basins by ties at an interval of 2-5 m to avoid eventual lateral movement of water.
4. Dig planting pits (0.5 x 0.5 x 0.5 m), at 2 m intervals, in the trenches.
5. Plant tree seedlings (mainly eucalypts, some African olives); fill pit with top soil (optional: mix with 1 spade of manure).
6. Spot weeding and softening soil around the pits to improve percolation of water and soil aeration (during rainy season).
7. Supplementary irrigation during dry spells (using jerry / watering cans).
8. Prohibit open grazing. Area closure is done collectively.

All activities are carried out manually.

Maintenance / recurrent activities

1. Maintenance of structures (before onset of rainy season).
2. Replacement of missing plants at onset of rains (10% replacement of seedlings is expected in the 1st year).
3. Spot weeding and softening soil.
4. Supplementary irrigation.

All activities are carried out manually.

Labour requirements

For establishment: high
For maintenance: low

Knowledge requirements

For advisors: medium
For land users: high

Photo 1: Construction of hillside terraces: trees will be planted in the ditches at a spacing of 2 meters between plants. (Fikreyesus Ghilay)
Photo 2: An upper catchment area protected by hillside terraces and tree planting in the Central Highlands of Eritrea. (Mats Gurtner)

Case study area: Serejeka, Central Highlands, Eritrea

Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 660 person-days	1,760
Equipment / tools: hand tools	50
Agricultural inputs: seedlings and transportation	600
Construction material: stones (locally available)	0
TOTAL	**2,410**
% of costs borne by land users	73%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 180 person-days	480
Equipment / tools: specify	0
Agricultural inputs: seedlings and transportation	100
TOTAL	**580**
% of costs borne by land users	83%

Remarks: Labour costs include construction of hillside terrace, pitting, planting and spot weeding and cultivation. According to the work and payment norms of the Ministry of Agriculture the cost of 1 person-day is US$ 2.66. Production cost of one seedling is US$ 0.2. Maintenance costs include terrace maintenance, re-pitting and replanting of seedlings. Costs are calculated for gentle slopes with terraces spaced at 2.5 m.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly negative	very positive
Maintenance	neutral	positive

Remarks: Initial labour inputs payout on the long term.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 400 -450 mm
- Soil parameters: low fertility; shallow depth; low organic matter content; sandy-loam texture
- Slope: more than 50%
- Landform: hill slope, mountain slopes, ridges
- Altitude: 2,300 - 2,400 m a.s.l.

Socio-economic conditions

- Socio-economic conditions
- Size of land per household: 0.5-1 ha cropland and 0.01-0.05 ha forest land
- Type of land user: small-scale, poor, land user groups
- Land ownership: state
- Land use rights: communal (organised)
- Level of mechanisation: manual labour and animal traction
- Market orientation: subsistence (self-supply), partly mixed (subsistence and commercial)

Production / economic benefits

+++ Increased wood production
+++ Increased fodder production (cut-and-carry of grass)
+++ Diversification of income sources (selling timber and grass)

Ecological benefits

+++ Improved soil cover; increased biomass / above ground carbon
+++ Reduced surface runoff
+++ Reduced soil loss
++ Increased soil moisture
++ Increased soil organic matter
++ Recharge of ground water

Socio-cultural benefits

+++ Community institutions strengthened
+++ Improved food security / self sufficiency
+++ Improved conservation / erosion knowledge
++ Conflict mitigation
+ Increased recreational opportunities

Off-site benefits

+++ Reduced downstream flooding and siltation
+ Increased stream flow in dry season

Weaknesses ➜ and how to overcome

- Establishment cost is high and labour-intensive ➜ provision of hand tools and demanded seedlings.
- Fast growing eucalyptus trees have a high rate of water consumption; Indigenous trees are not favoured ➜ encourage people to protect naturally regenerated indigenous trees, assist villagers to get market channels for products of indigenous trees.
- Community mobilisation and high knowledge of land users is required ➜ awareness raising campaigns, strengthen village institutional arrangements, assist villages by-laws.
- Land use rights: because the afforestation area is communal, nobody feels responsible for maintenance ➜ promote plantations by individual households.

Adoption

Acceptance of afforestation areas has increased, since user rights have been given to land users: Communities located in Toker upper catchment areas have taken the initiative to maintain and protect their woodlots. Moreover, there is a trend toward locally initiated hillside terracing and tree planting without external initiative / incentives, apart from the provision of seedlings (through Ministry of Agriculture). The afforestation area covers approx. 30 km^2 with high potential to enlarge.

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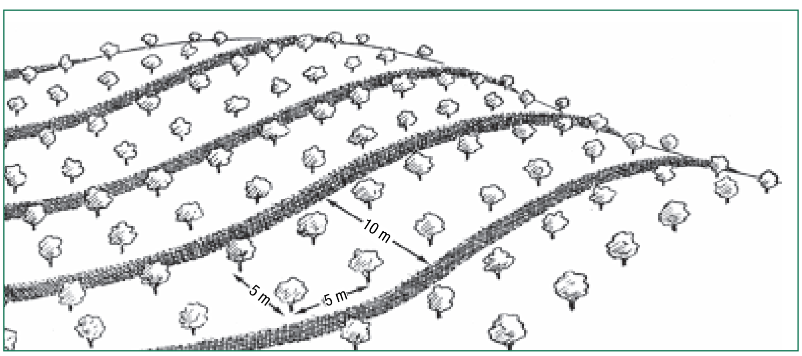
Key references: Zeremariam I. 2001. Assessment of upper catchment development technologies in the Central High Land zone of Eritrea. MSc Thesis; The Royal Veterinary and Agricultural University, Denmark. ■ Amanuel Negasi et al. 2002. Soil and water conservation Manual for Eritrea. RELMA. ■ Zeremariam I.2001. Assessment of upper catchment Development Technologies and Approaches in the Central High Land zone of Eritrea. MSc Thesis; The Royal Veterinary and Agricultural University, Denmark

SAND DUNE STABILISATION - NIGER

Stabilisation of mobile sand dunes is achieved through a combination of mechanical measures including palisades, and biological measures such as live fences and sowing of grass. These measures seek to stop sand encroachment and stabilise sand dunes on-site, in order to protect villages, cultivated land, roads, waterways and other infrastructure. The technology is currently applied on a very large-scale in the Niger river basin.

Palisades are made either of millet stalks, or doum or date palm fronds, according to availability in the region. They are established in a perpendicular direction to the wind, at a spacing of 10 – 20 meters depending on severity of sand encroachment and level of land degradation. The closer the spacing, the more effective is the protection. Tree seedlings or cuttings are planted on a 5 m x 5 m grid, with a density of 400 trees per hectare. Species include *Euphorbia balsamifera*, *Prosopis chilensis*, *Ziziphus mauritiana*, *Acacia senegal* and *Bauhina rufescens*. Grass seeds are broadcasted.

The increasing speed at which desertification is progressing in Sahelian countries makes this technology one of the main instruments for combating the impacts of climate change. Land that has been sown with grass needs to be enclosed in the early years to avoid interference by animals.



SLM measure	Structural and vegetative
SLM group	Sustainable Planted Forest Management
Land use type	Agro-silvopastoral
Degradation addressed	Desertification; Soil erosion by wind and water; Biological degradation
Stage of intervention	Prevention (partly mitigation)
Tolerance to climate change	Tolerant to temperature increase and rainfall decrease, but sensible to droughts and floods

Establishment activities

1. Preparation of tree cuttings or seedlings.
2. Preparation of palisades made either of millet stalks, *Leptadenia pyrotechnica*, or doum or date palm fronds, according to availability in the region.
3. Marking of planting lines perpendicular to wind direction.
4. Preparation of soil (April-May): dig holes for the cuttings or seedlings.
5. Dig trenches for the palisades.
6. Set up the palisades (spacing: 10 m).
7. Transport cuttings or seedlings to the sites.
8. Planting of cuttings or seedlings (spacing: 5 m).
9. Sowing of grass.
10. Spreading of manure (for grass and trees).

Maintenance / recurrent activities

1. In the first years: weeding and protection against animals, maybe using enclosure of land that has been sown with grass seeds.
2. Replacing of missing plants.
3. Strengthening of palisades and replacing those that have been destroyed.
4. Regular trimming of trees and shrubs to reduce competition with agricultural crops.

Labour requirements

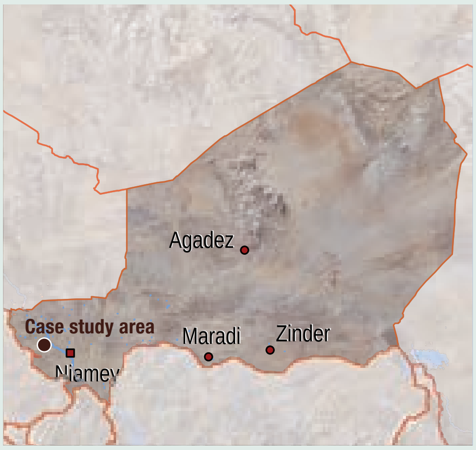
For establishment: high
For maintenance: high

Knowledge requirements

For advisors: low
For land users: moderate

Photo 1–2: Palisades with growing vegetation.
Photo 3: Two SLM experts examine a sand dune in the Niger river basin near Niamey. (All photos by Moussa Inja).
Drawing: Layout of palisades and tree planting for sand dune stabilisation. (Ministry for Agricultural Development, Niger)

Case study area: Kareygorou, Tillabéry, Niger



Establishment inputs and costs per ha

Inputs	Costs (US$)
Labour: 75 person-days	113
Palisades: 1,000 bundles	200
Agricultural inputs: - Seedlings / cuttings (400) - Organic manure (1.5 t)	 80 75
Transport: palisades, seedlings and organic manure	200
TOTAL	**668**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 10 person-days	15
Palisades: 15 bundles	3
Agricultural inputs: seedlings (20)	4
TOTAL	**22**
% of costs borne by land users	100%

Remarks: Figures are based on estimates. Costs for seedlings / cuttings are indicated for *Euphorbia balsamifera*. For other tree species costs need to be doubled or tripled (higher production costs at the nursery).

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	positive	very positive

Remarks: The technology is efficient in the mid to long term when it supports natural regeneration of ecosystems. In the Niger River basin, however, the benefits are lower.

Ecological conditions

- Climate: semi-arid
- Average annual rainfall: 250-500 mm
- Soil parameters: good drainage; low soil organic matter
- Slope: high dunes with steep slopes (> 20%)
- Landform: mainly dunes
- Altitude: 0-100 m a.s.l.

Socio-economic conditions

- Size of land per household: 1-2 ha
- Type of land user: mainly poor land user groups / community
- Population density: 10-50 persons/km^2
- Land ownership: mostly individual, untitled
- Land use rights: individual, communal (organised)
- Market orientation: mostly subsistence (self-supplying), partly mixed (subsistence and commercial)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Increased crop yield (indirectly; through protection from moving sand dunes)
+++ Increased farm income
+++ Increased animal production
+++ Increased fodder quality and fodder production

Ecological benefits

+++ Increased soil cover
+++ Increased biomass / above ground carbon
+++ Reduced wind velocity
+++ Reduced soil loss
+++ Increased animal diversity
++ Increased soil fertility

Socio-cultural benefits

+++ Conflict mitigation
+++ Strengthening of community institutions through mutual help with technology implementation
+++ Improved cultural opportunities

Off-site benefits

+++ Less damage on public / private infrastructure
+++ Less damage on neighbours' fields
+++ Less wind-transported sediments

Weaknesses ➜ and how to overcome

- Implementation constraint: high implementation costs ➜ improve access to technical and financial support.
- Maintenance constraint: the nature of the land discourages people from maintaining the established measures ➜ establish management committees for maintenance of the implemented measures.
- Labour constraint: the technology requires high input in terms of labour ➜ strengthen community work and solidarity between communities.
- Ecological constraint: negative impacts on existing *Leptadenia* plants due to excessive cutting for palisades ➜ find other species for making the palisades.
- Legal constraint: conflicts arise when land is claimed by people ➜ define tenure before land is claimed.

Adoption

Spontaneous adoption of the technology is growing because desertification is in progression and sand dunes endanger people's livelihoods.

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Key references: Ministère du développement agricole (2005) : recueil des fiches techniques en gestion des ressources naturelles et de productions agro-sylvo-pastorales ■ Abdoulaye Soumaila A.S., E. Tielkes, P. Sauter. 2004. Rapport final de l'atelier sur les techniques de conservation des eaux et des sols, et les données wocat Niger organisé à Niamey en novembre 2002 ■ ROSELT. 2009. Magazine d'information, N° 1, mars 2009, Niamey, Niger.

SUSTAINABLE FOREST MANAGEMENT IN DRYLANDS

Natural dryland forest with high biodiversity, Tanzania. (Hanspeter Liniger)

In a nutshell

Definition: Sustainable Forest Management (SFM) in drylands aims to ensure that the goods and services derived from the forests meet present-day needs, while at the same time securing their continued availability and contribution to long term development.

In Sub-Saharan Africa, forests and trees contribute significantly to rural livelihoods in the drylands accounting for more than 25% of rural household income. Forests have multiple functions and uses. They play a significant role in conservation of biodiversity adapted to the harsh ecological conditions. They provide ecosystem goods including fruits, gum arabic, shea nut (*karité*) butter, fodder for livestock, medicines and provide services such as desertification control, conservation and improvement of water quality. However they are relatively fragile and easily affected by drought, erosion, fires, browsing, and particularly, cutting for firewood. Forestry needs to be part of a comprehensive and sustainable land use planning and management strategy, and there is an urgent need for the forestry sector to show clear commitment and to work with other sectors in improving and designing appropriate policies and mechanisms. In addition SFM in drylands has to move towards participatory and community-based management with an integrated landscape planning approach.

SFM in drylands includes actions aimed at safeguarding and maintaining the forest ecosystem and its functions, reduced deforestation, fire management, restoration through natural regeneration or assisted natural regeneration, selective tree planting and felling. Main techniques used for sustainable management are: spatial zoning for various users, restricted interventions, protective measures, best practice in non-wood forest products harvesting, grazing management planning and improved governance.

Applicability: SFM is applicable to, and crucial for, any type of primary or secondary forests in the drylands.

Resilience to climate variability: SFM for forest diversity is a prerequisite to ensure a functioning ecosystem, and to maintain resilience to climate variability and change. A well-managed and diverse natural forest can adapt better to changes.

Main benefits: Protection of biodiversity, protection against water and wind erosion, improved water management and quality, improved livelihoods and human well-being through income diversification (e.g. beekeeping, ecotourism, etc.) and hence increased food security and poverty alleviation as well as improved governance. Hindering further deforestation and expanding the restoration of natural forests can provide an immense contribution to CC mitigation and adaptation.

Adoption and upscaling: A legal and institutional framework, including the integration of forests in overall sustainable landscape and rural development planning is needed in order to ensure a sustainable use of forest resources in drylands, and sustainable provision of the related social, economic and environmental goods and services.

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)	no data
C Sequestration: above ground	++
C Sequestration: below ground	++

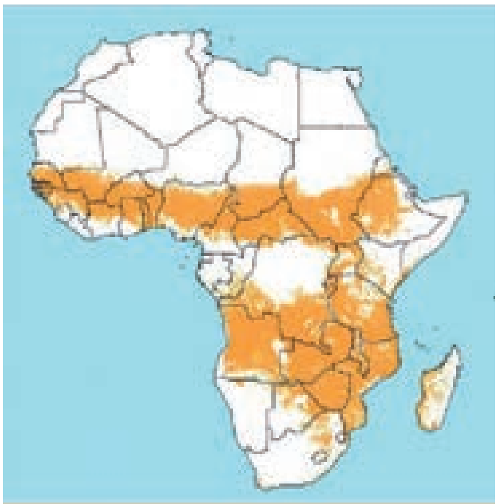
Climate change adaptation	
Resilience to extreme dry conditions	++
Resilience to variable rainfall	+++
Resilience to extreme rain and wind storms	+++
Resilience to rising temperatures and evaporation rates	++
Reducing risk of production failure	+++

Origin and spread

Origin: The sacred character of many forests helped to conserve them, as part of traditional community resource management systems. Forest degradation and deforestation began during the colonial era. Responses to degradation of forests also started during these times. As pressure on forests has increased, because of population growth, efforts were made to create protected forest areas. In the 1970s and 1980s many countries - with donor support - attempted to bring more forests under state tenure and protection. In recent times sustainable forest management based on community plans has been given increasing priority in the drylands of SSA. Successes are still only at the pilot stage.

Spread: 582 million ha are covered by forests in SSA of which 270 million ha (46%) are dry forests. Approximately 5% of Africa's forests are protected. However, protected areas are often still destroyed by illegal logging and overuse. No clear data is available about the spread of SFM in drylands, but it is only a very small area.

Dry forests are mainly situated in: Angola, Botswana, Burkina Faso, Cameroon, Central African Republic, Chad, Congo, DRC, Ethiopia, Gabon, Guinea, Kenya, Lesotho, Madagascar, Malawi, Mali, Mozambique, Namibia, Niger, Nigeria, Senegal, South Africa, Sudan, Swaziland, Tanzania, Uganda, Zambia, Zimbabwe.


Spread of dry forests in SSA. (Source: CIFOR, 2006)

Principles and types

Securing forest resources: National and local forest authorities need to be strengthened to assess, maintain and protect the remaining forest resources. Protected areas must be safeguarded through adhering to laws and regulations for effective management. The delimitation of forests should be made clear, and sufficient cropland made available to people neighbouring the forests. Simultaneously, productivity of cropland and grazing land need to be improved to reduce pressure on the natural forests. Plans must correspond to the ecological, economic and social concerns of the people living within and around the area: thus community-based approaches and management plans are the most promising way forward. Compensation to communities – ideally through judicious rights to forest products - can be considered as a means for ensuring sustainable use of the resources.

Maintaining or enhancing biodiversity: Building better knowledge of forest ecology can help to preserve their biodiversity. Capacity needs to be strengthened to conduct biological inventories and a monitoring system of forest condition. There is also a need to include fauna within the forest in management decisions.

Promoting healthy and vigorous forests and rehabilitating forests: The health of overused forests can be improved through the adoption of adaptive forest management, including aspects such as review of rotation length, enhancement of natural regeneration (e.g. social fencing), enrichment planting, selective felling and controlled logging. Upgrading species diversity and richness are also a means to improve 'forest productivity', and to ensure high value production in a well managed natural forest.

Fire management: Knowledge and awareness raising about fire (incidence and behaviour) and how to avoid uncontrolled fires is key in successful prevention. Lack of funding and of sustainable fire management strategies are prominent in SSA. Fire management is largely an agricultural issue, and therefore the key is to involve the agricultural sector in the controlled use of fire. Monitoring and reporting mechanisms should be established, and the regional collaboration that started through AfriFireNet should be built upon.

Alternative livelihoods options help reduce unsustainable felling and logging activities. Non-wood forest products (NWFP) provide a sustainable input to peoples' welfare. NWFP can be honey from beekeeping, mushrooms, medicinal plants, shea nut butter (from *Vitellaria paradoxa*) for the cosmetic industry, gum arabic (from *Acacia senegal*), baobab for ropes and baskets, etc. New niche markets for 'green' and 'fair trade' products and payments for ecosystem services provide new income opportunities for forest users (see group Trends & new Opportunities).

Top: Fencing of dryland forests for natural regeneration, Burkina Faso. (NewTree)
Middle: Women carrying gathered fuelwood, Senegal. (Roberto Faidutti)
Bottom: Close-up of shea nuts (karité) ready to be processed, Burkina Faso. (Roberto Faidutti)

Applicability

Land degradation and causes addressed

Dryland forests are fragile and are affected by drought, degradation / deforestation and desertification. The main direct and indirect drivers include: population increase, growing demand for resources (grazing, cultivation, urban development, logging, etc.), poverty, social conflict, lack of market opportunities, no recognition of the importance of dryland forests, lack of appropriate policies, governance and investment, lack of integration among different sectors, lack of technical capacity etc. All these drivers are potentially exacerbated by climate change.

Biological degradation: loss of forest ecosystem, loss of biodiversity, followed by physical and chemical soil deterioration and water degradation.

The loss of natural forests in the drylands is immense and the trend still continues. Annual loss of natural forests - between 1.2% and 1.7% - is highest in West and Southern Africa.

Land use

Primary and secondary forests can be defined as natural forests. Dry forests cover a spectrum of vegetation types from deciduous forests with a continuous tree canopy to moist savannas, dry deciduous woodlands, dry savannas and very dry scrub (bush, brousse). Dry forest landscapes are very variable, with crop lands, grazing lands and woodlands existing side-by-side.

Dry forests are used as mixed land for agricultural production and grazing. Beside wood products such as fuelwood and building material, non-wood forest products used are honey, mushrooms, fruits, medicinal plants, spices, shea nut butter, gums, fodder, tree bark, etc.

Ecological conditions

Climate: scarce and unreliable rainfall with long dry spells; dryland forests cover arid, semi-arid and subhumid areas.

Terrain and landscape: no restrictions, however in many countries (e.g. Ethiopia) forests have been reduced to marginal areas like steep hills, etc.

Soils: no restrictions

Socio-economic conditions

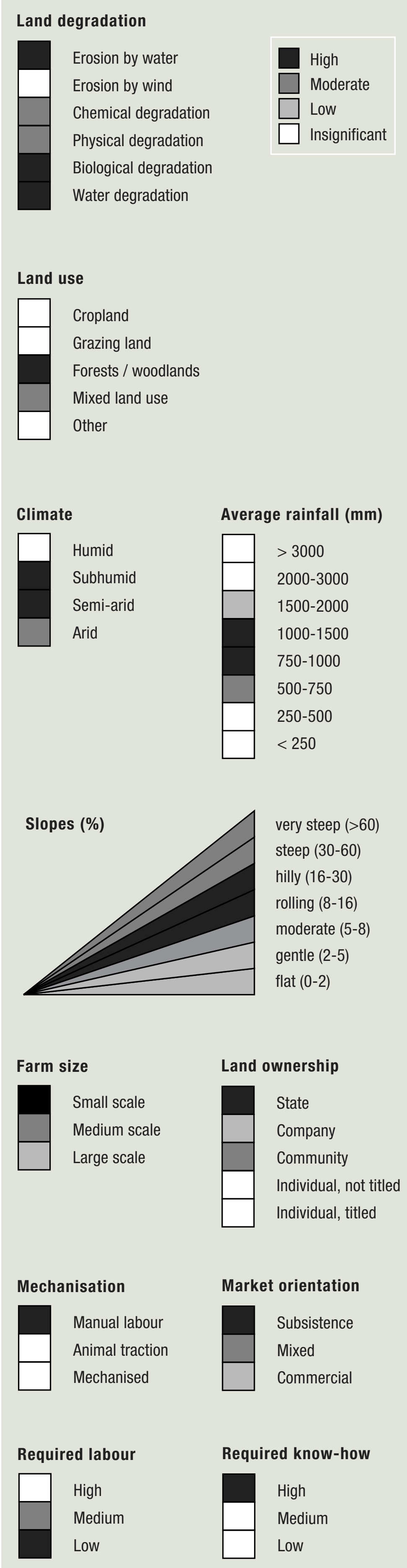
Farming system and level of mechanisation: Sustainable management mainly on small-scale basis, mainly manual labour (e.g. hand felling) and low level of mechanisation.

Market orientation: Subsistence to commercial system, by selling non-wood and or wood products on local market and also for increasing national / global market for special high value niche products.

Land ownership and land use / water rights: Land ownership is mainly state: some forests are on customary and trust lands, and may be managed through agreements with the chiefs or local councils on behalf of communities. Forests on private land are very limited with exceptions in South Africa and Zimbabwe. The areas of forests jointly managed with local communities or under the full responsibility of local communities are very limited. Open access forests and woodlands give rise to problems with destructive forest resource use.

Skill / knowledge requirements: Sustainable forest management requires a high level of technical knowledge. Sound education of forest management services for supporting the land users in the sustainable use of the forests resources is needed.

Labour requirements: Labour requirements vary depending on the interventions needed (see principles and activities).



Economics

Costs

Since Sustainable Forest Management (SFM) is mainly a management and organisational issue, the assessment of costs for establishment and maintenance is limited.

Production benefits

Apart from wood, natural forests provide a huge variety of products (non-wood forest products), which makes it difficult to quantify the production benefits of sustainable management in dryland forests. Recent studies are helping to put a price on the full range of forest goods and services. However research is needed on the value of environmental services such as water quality and supply, soil retention and fertility, carbon storage, and conservation of biodiversity, among other aspects. Furthermore, methodologies are required to calculate the direct or indirect cost of unsustainable forest management for comparison.

Benefit-Cost ratio

	short term	long term	quantitative
Community based forest management	–	++	No data available

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive;
(Source: FAO, 2002)

An estimated 65% of the population of Sub-Saharan Africa is rural and depends directly or indirectly on forests and woodlands for food, fuelwood, building materials, medicines, oils, gums, resins and fodder. The World Bank estimates that forests generate at least 20% of the disposable income of landless and poor families (WFSE, 2009).
Communities must be willing and economically able to involve themselves in sustainable forest management - they must receive greater economic benefits from conserving forests than from degrading them. Sustainable natural forest management should tangibly improve local economic welfare, and generate local economic benefits to sufficient levels, and in appropriate forms, to make SFM economically sound in the drylands also.
Since SFM is not yet widespread in SSA, it is difficult to make a realistic assessment of the economic aspects of natural forest management and the probability of change to sustainable management during the next two decades.
A mechanism for Reducing Emissions from Deforestation and Degradation (REDD), currently under negotiation, may provide incentives to reduce emissions from forests.

Example: Burkina Faso
The Kaboré Tambi National Park is situated approximately 100 km south of Ouagadougou in the south-central part of Burkina Faso, and covers 155,000 ha. Nine villages surrounding the park were surveyed, and 298 households completed a survey in 2008. Land cover in the park mainly consists of open forest with patches of savanna. The contribution of non-timber forest products to the rural household income was analysed. Fuelwood is the most important product collected from the forest: it accounts for 28% of household environmental and forest income on average. Fruits and shea nuts from Vitellaria paradoxa are the second most economically important wild forest product in the survey area (21%). Grass for roof thatching is another important non-timber forest product in the region, contributing 14% of household environmental and forest income. While fuelwood and thatching grass are mostly used for subsistence at the household level (86% and 84%), shea nuts and fruits are mainly source of cash income (66%) (CIFOR, 2008).

Example: Making Shea butter, Ghana
The production of shea butter is an important income earning activity for women in rural areas. Shea trees (Vitellaria paradoxa) grow wild in the semi-arid parts of the equatorial belt of central Africa. Shea butter is made out of the kernels and is used for cooking and for cosmetic purposes. The butter is increasingly valuable as an export commodity. However, lack of group business and management skills, competition from large-scale enterprises, inflation, and international commodity price fluctuations may hinder successful implementation of the technology. Bridge presses can now be used to mechanically extract shea butter and reduce the workload needed as they are easy to operate. The presses can be locally made and serviced. Although costs of processing by the improved and traditional methods are comparable, the benefits of the new technology are environmental (no need for fuel), time-saving (releasing time for other activities) and process simplification. However, the profitability of the shea butter production depends very much on high market prices (TECA-FAO, 2010).

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	++ diversification of production ++ enhanced long term forest productivity ++ increased production of NWFP + increased wood production	+++ reduced risk and loss of production + improved access to clean drinking water	+ improved food and water security
Economic	++ provides a wide range of wood and non-wood products ++ income diversification + increased farm income	+++ less damage to off-site infrastructure ++ diversification and rural employment creation (e.g. eco-tourism) + stimulation of economic growth	+ improved livelihood and well-being
Ecological	+++ improved protection of forest species and habitats +++ rehabilitation of natural forests +++ improved micro-climate +++ biodiversity enhancement ++ helps to maintain soil and hydrological systems (e.g. clean water) ++ reduced soil erosion (by wind / water) ++ reduced wind velocity and dust storms ++ less frequent uncontrolled forest fires ++ increased soil organic matter and soil fertility ++ improved forest cover + improved water availability	+++ reduced degradation and sedimentation ++ water availability ++ water quality ++ intact ecosystem	+++ reduced degradation and desertification incidence and intensity +++ increased resilience to climate change ++ reduced C emissions ++ increased C sequestration ++ enhanced biodiversity
Socio-cultural	+++ community institution strengthening ++ less conflicts among different users ++ improved SLM / conservation / erosion knowledge	+++ increased awareness for environmental 'health' +++ attractive landscape ++ reduced conflicts	+++ protecting national heritage

	Constraints	How to overcome
Production	• Restricted short-time use ('exploitation') of forests can have negative effect on income	➜ awareness of long term benefits and increase of other valuable ecosystem services provided through natural forests
Economic	• Inadequate budget for fire management • Availability of market for non-woody products and ecotourism	➜ integration of fire management into overall forest management plan ➜ support the diversified production and establishment of markets for NWFP and ecotourism
Ecological	• Impossibility of reconstituting forests exactly as they were	➜ promote the role of secondary forests and allow most suitable conditions for regeneration towards natural forests
Socio-cultural	• Increasing population leading to increased demand on fuelwood • Fire management: weak capacity and social and political environments that do not sufficiently enable or empower the affected population to deal with the fire problem • Political constraints: secure land tenure of communities is often not given and regulatory constraints, with modern and customary laws that are often in conflict • Poverty leading directly to indiscriminate extraction of forest resources • Knowledge is inadequate, scattered and poorly disseminated in many of the spheres involved in sustainable forest resource management • Lack of knowledge in terms of appropriate techniques to ensure sustainability and on the current state of forest resources	➜ promote alternative renewable energy resources (wind, solar) and energy saving stoves, establishment of home woodlots ➜ allocation of land use rights as well as training and education in fire prevention and management ➜ allocation of land use rights and consolidating / harmonisation of legal situation including customary laws ➜ supporting poor communities in and around forests to improve their livelihoods and make them independent from destructive forest use, introduce alternative income options through non-woody forests products (e.g. beekeeping) or ecotourism ➜ compilation and exchange of experiences made with SNFM, learning from others and capacity building of both government staff and community members ➜ better linkages to research and regular monitoring and reporting about state of natural forests

References and supporting information:

Blay, D., 2007. Multi-stakeholder forest management: A case from the humid zone in Ghana. Forest Management Working PaperWorking Paper FM/32. FAO, Rome (Italy).

CIFOR. 2006. African Dry Forest Website. http://www.cifor.cgiar.org/dryforest/_ref/home/index.htm, accessed on 15 February, 2010.

CIFOR. 2006. Map of Location. http://www.cifor.cgiar.org/dryforest/_ref/home/map.htm, accessed on 17 May 2010.

CIFOR. 2006. Miombo Woodland – Policies and Incentives. http://www.cifor.cgiar.org/miombo/project.htm, accessed on 23 September 2009

CIFOR. 2008. Poverty Environment Network – A comprehensive global analysis of tropical forests and poverty. http://www.cifor.cgiar.org/pen/_ref/news/penews/2010/penews-1-2010.htm#burkina, accessed on 17 Mai 2010.

CIFOR. 2009. CIFOR annual report 2008: Thinking beyond the canopy (2009).

FAO. 1997. R. Bellefontaine, A. Gaston and Y. Petrucci (online 2000), Management of natural forests in dry-tropical zones. Series title: FAO Conservation Guide - 32. http://www.fao.org/docrep/005/w4442e/w4442e00.htm#Contents

FAO. 2003. Forestry Outlook Study for Africa – Subregional Report West Africa. African Development Bank, European Commission.

FAO. 2003. Forestry Outlook Study for Africa. African Development Bank, European Commission.

FAO. 2006. Fire management – global assessment 2006 A thematic study prepared in the framework of the Global Forest Resources Assessment 2005, Series title: FAO Forestry Paper-151.

Adoption and upscaling

Adoption rate

The adoption rate of SFM in drylands tends to be very slow, and despite various efforts, sustainable management is not in place in most countries. However, in some areas of dry forests of savanna woodlands, progress has been made in this regard. Most of these areas are under community control.

Upscaling

The following aspects need to be considered for adoption and upscaling:

Legal and institutional framework: Integration of forest planning in an overall sustainable landscape planning approach, including all sectors from agricultural, pastoral, urban / rural and forest systems, is needed. Government and local administration must create enabling conditions for the establishment of proper SFM frameworks with clear regulations and control mechanism.

Legal titles, or at least confirmed land-use rights, are a prerequisite for villagers to define their forests boundaries and for community-based forest management.

Community-based approaches: Communities must be enabled to establish a clear management plan. Clear regulations and control mechanism need to be developed by forest services and local communities for the sustainable use of forests, and to avoid illegal use of the forests.

Awareness raising, education and capacity building: Local forestry services, land users and communities should be appropriately trained. Improved understanding of forestry issues through stakeholder meetings, user-friendly materials, documents in local language etc. is needed. It is necessary to become organised, coordinate efforts, share information and develop campaigns so that the governments adopt enabling policies, and to make sure people are informed about benefits of SFM.

Inventories and long term monitoring: Knowledge and expertise should be enhanced to assess and monitor forests and tree resources systematically.

Research related to SFM: This includes better knowledge of forest pests and diseases, and conditions related to adoption and upscaling, as well as better linkages to research institutions and networks for knowledge exchange.

Sustainable markets and networks for NWFP: So far there are many obstacles hindering the commercialisation - especially of NWFP of small-scale land users. The development of forest-based small enterprises and the establishment of local markets can enhance small-scale production of NWFP and hence reduce the pressure on timber harvesting. Priority should be given to strengthening the capacity of local producers of forest products, processors and traders, to ensure sustainable harvesting and management of forest resources while increasing the quality and added-value of the derived products.

Incentives for adoption

Micro-credit to establish small industries (e.g. for NWFP) can help build incentives towards better SFM. Furthermore, incentives are needed to bridge the time until trees become productive (e.g. for areas under natural regeneration). Recent discussions and development promote Payment for Ecosystem Services (PES) as an incentive for sustainable management. Clear commitment is needed to pay for the maintenance of the remaining forest resources.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	+
Training and education	++
Land tenure, secure land use rights	+++
Access to markets	++
Research	++
Infrastructure	+
Conflicts of interest	++

The Network for Natural Gums and Resins in Africa (NGARA) *was established in May 2000 to assist African producer countries and partners in formulating a coordinated strategy for the sustainable development of their natural gums and resin resources in order to improve rural livelihoods and environmental conservation. NGARA brings together members from varied fields, including farmers / collectors, traders, governments, non-governmental organisations, exporters and importers – all of whom have the common desire to improve the production and quality of locally produced gums and resins for domestic, regional and international markets. NGARA consists of 15 member countries. Since inception, NGARA has played an increasingly important role in the exchange of information on production and trade, training, technology transfer, assessment of resources and their sustainable use, enhancing capacities of stakeholders in beneficiary countries and harnessing efficient use of available resources by strengthening synergies. The establishment of NGARA was considered a significant step in the development of the gum arabic and resins sector in the dryland Sahel for ensuring food security, rural development and hence poverty alleviation (www.ngara.org).*

References and supporting information (continued):

FAO. 2008. Towards sustainable forest management. http://www.fao.org/forestry/sfm/en/ accessed on 23 September 2009.

FAO. 2008. Understanding forest tenure in Africa: opportunities and challenges for forest tenure diversification. Forestry Policy and Institutions Working Paper 19

FAO. 2010. Guidelines on sustainable forest management in drylands of Sub-Saharan Africa. 17th AFWC Session, revised draft version. (final document under publication in June 2010)

FAO. 2008. Links between National Forest Programmes and Poverty Reduction Strategies, by R.McConnell.

FAO. 2010. Forestry Photos. http://www.fao.org/mediabase/forestry/, accessed on 6 June 2010.

FARMAFRICA. 2009. Tanzania Participatory Forest Management Project. http://www.farmafrica.org.uk/smartweb/tanzania/tanzania-participatory-forest-management-project accessed on 23 September 2009 Forestry Policy and Institutions Working Paper No. 22. Rome.

German L.A. (ed.), Karsenty, A. (ed.), Tiani A.M., (ed.). 2009. Governing Africa's forests in a globalised world. Earthscan Publications. London.

Mogaka, H., Simons, G., Turpie, J., Emerton, L. and Karanja, F. 2001. Economic Aspects of Community Involvement in Sustainable Forest Management in Eastern and Southern Africa. IUCN - The World Conservation Union, Eastern Africa Regional Office, Nairobi.

NGARA. 2010. Network for Natural Gums and Resins in Africa (NGARA), http://www.ngara.org/index.htm, accessed on 18 March 2010.

Odera, J. 2004. Lessons Learnt on Community Forest Management in Africa. A report prepared for the project 'Lessons Learnt on Sustainble Forest Management in Africa.'

TECA-FAO. 2010. Technology for Agriculture – proven technologies for smallholders. http://www.fao.org/teca/content/replacing-need-labour-intensive-traditional-methods-mechanical-press-making-shea-butter-nort, accessed on 25 March 2010.

WFSE, 2009. Making Sub-Saharan African Forests work for People and Nature – Policy approaches in a changing global environment. Published by Special Project on World Forests, Society and Environment (WFSE) of the International Union of Forest Research Organisations (IUFRO), World Agroforestry Centre (ICRAF), the Center for International Forestry Research (CIFOR) and the Finish Forest Research Institute (METLA).

ASSISTED NATURAL REGENERATION OF DEGRADED LAND - BURKINA FASO

Assisted natural regeneration, as promoted by newTree in Burkina Faso, starts with enclosing 3 ha of degraded land with a solid fence. Fence materials (iron posts and galvanic wire) are externally sponsored and locally assembled and installed. Along the fence a dense living hedge of thorny trees (local tree species: e.g. *Acacia nilotica*, A. *senegal*, *Prosopis* sp, *Ziziphus mauritiana*) is planted. A strip of 10 m along the hedge is dedicated to agriculture. This area is equivalent to approximately 10% of the protected area. The rest is dedicated to natural regeneration of the local forest.

Once protected, natural vegetation rich in endogenous species can actively regenerate. Annual vegetation species inventories are made to monitor the biomass, biodiversity and the growth rate of the trees. The forest reaches a tree density of approximately 500 trees per hectare and consists of around 120 local species. Some enrichment planting of rare species enhances the allotments. The protected area is of paramount importance for biodiversity conservation.

Management activities in the protected area includes (1) seeding / planting of improved fodder species; and (2) establishing stone lines and half-moons (*demi-lunes*) for soil erosion control and water harvesting, (3) installing beehives for honey production; and (4) fodder production: the grass is cut, tied and carried to feed livestock outside the regeneration area.

Property rights for the protected area are clearly established through a contractual agreement that includes / respects traditional and government land rights. The local land users select the area, provide all labour inputs and ensure the long term management of the sites according to mutually agreed goals. Training is provided to enhance income generating activities – ranging from beekeeping and the production of high-value vegetable crops to the processing of non-timber forestry products – and to promote the use of fuel-efficient cooking stoves.

SLM measure	Management and vegetative
SLM group	Sustainable Forest Management in Drylands
Land use type	Before: Agro-silvopastoralism, wastelands; After: Agroforestry / Natural forest
Degradation addressed	Soil erosion by water and wind; Fertility decline; Sealing and crusting; Reduction of vegetation cover; Aridification
Stage of intervention	Rehabilitation
Tolerance to climate change	High tolerance

Establishment activities

1. Select an area of 3 ha of degraded land.
2. Establish a 1.5 m high fence around the selected area: install metal posts, manufacture / assemble chain-link fence materials (manually).
3. Plant a living hedge of spiny trees at a distance of 1 m to the fence, plants spaced at 0.4 m.
4. Reserve a 10 m strip along the fence / hedge for improved agriculture.
5. Plant a living hedge of *Jatropha curcas* to separate cropland from regeneration area.
6. Seed / plant improved fodder species within protected area.
7. Establish stone lines and half-moons for soil erosion control and water harvesting within protected area.
8. Install beehives (2-10 hives per protected area); purchase protection and harvesting equipment.
9. Construct fuel efficient cooking stoves.

Maintenance / recurrent activities

1. Supervise fence and protected area; repairing where necessary.
2. Replant / replace dead seedlings in living hedges.
3. Improved agriculture: agroforestry, water harvesting, compost application.
4. Beekeeping: monthly control of beehive; yield 2-3 times per year (manually with protection equipment).
5. Improved fodder production: cut grass and tie hay with simple tying machine (once a year after rainy season).

Labour requirements

For establishment: high
For maintenance: medium

Knowledge requirements

For advisors: medium
For land users: medium

Photo 1: The components of the system (from right to left): Metal fence, living hedge (recently planted seedlings), agricultural zone with SLM measures (e.g. agroforestry), forest regeneration area.
Photo 2: Fabrication of chain-link fence by land users.
Photo 3: Dense vegetation cover in the protected area behind the fence. (All photos by Franziska Kaguembèga-Müller)

Case study area: Soum Province; Burkina-Faso

Establishment inputs and costs for 3 ha

Inputs	Costs (US$)
Labour	1,300
Equipment / tools: pick, shovel, hammer, glove, tong, iron rod	100
Agricultural inputs: training, seeds, compost	260
Components for fence construction: sand, gravel, rock and water, poles, galvanised wire, cement, tree seedlings	2,900
TOTAL	**4,560**
% of costs borne by land users	33%

Maintenance inputs and costs for 3 ha per year

Inputs	Costs (US$)
Labour	730
Training	40
Agricultural inputs: seeds	40
TOTAL	**810**
% of costs borne by land users	95%

Remarks: A unit relates to a protected area of 3 hectares (average size; feasible and beneficial for participating land users, namely farm families / womens' groups). Labour for establishment includes: digging of planting pits / ditches, post installation, fabrication of chain-link fence materials, all plantations, stone lines, half-moons, etc. Components for fence construction are locally available.

Benefit-cost ratio

Inputs	short term	long term
Establishment	neutral	very positive
Maintenance	positive	very positive

Ecological conditions

- Climate: arid, semi-arid
- Average annual rainfall: 300 - 600 mm per year
- Soil parameters: soils are often very poor and overexploited; laterite
- Slope: mostly flat 0-2%
- Landform: mainly plains / plateau
- Altitude: 0-100 m a.s.l.
- Altitude: 2,300 - 2,400 m a.s.l.
- NewTree works in 2 different climatic zones with different ecological conditions

Socio-economic conditions

- Size of land per household: 3 ha
- Type of land user: small-scale, very poor or poor, implementation by families (up to 60 members) or groups (e.g. women's groups)
- Population density: 30 persons/km^2 in the Nord, 70 persons/km^2 in the centre
- Land ownership: state (officially); traditional family property rights (factually)
- Land use rights: families

Production / economic benefits

+++ Increased wood production
+++ Increased farm income and diversification of income sources
++ Increased fodder quality and quantity
++ Increased crop yield

Ecological benefits

+++ Increased biomass / above ground carbon
+++ Increased soil organic matter / below ground carbon
+++ Improved soil cover
+++ Increased nutrient cycling / recharge
+++ Increased plant diversity / habitat diversity
+++ Improved harvesting / collection of water
+++ Reduced soil compaction and crusting
++ Reduced surface runoff / soil loss
++ Increased beneficial species (predators, earthworms, pollinators)
++ Reduced evaporation
++ Reduced wind velocity
++ Increased soil moisture

Socio-cultural benefits

+++ Improved food security / self-sufficiency
+++ Improved health
++ Improved conservation / erosion knowledge
+ Improved situation of socially and economically disadvantaged groups

Weaknesses ➜ and how to overcome

- High investment costs ➜ introduce income generating activities which amortise (help pay off) the initial investments and the waiting time until land users can harvest non-woody products from the forest; relocate the fence to enclose other degraded land when the living hedge is dense enough and takes over the function of protection.
- Insecurity of land rights is a constraint for implementation (government is official land owner) ➜ conclude contractual agreements which include / respect traditional and government land rights.

Adoption

All land users have implemented the technology through receiving incentives (payment for labour and other inputs). Regeneration sites have been established in 5 different provinces (Soum in the North, Kadiogo, Kourweogo, Boulkiemde and Oubritenga in the centre of Burkina Faso). There is high demand for establishment of further sites. The demonstration effect of improved agriculture within the fence (agroforestry, etc. resulting in higher yields) encourages farmers to adopt these measures in their fields outside the protected area also.

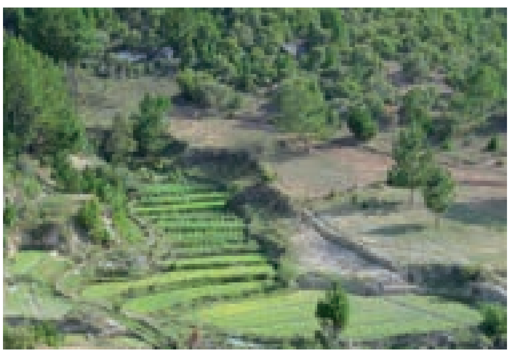
Main contributors: Franziska Kaguembèga-Müller, Coordinatrice ONG newTree, Ouagadougou, Burkina Faso; kaguembega@newtree.org; www.newtree.org
Key references: Diatta, M; Albergel, J.; Perez, P.; Faye, E.; Séne, M. et Grouzis, M. 2000. Efficacité de la mise en défens testée dans l'aménagement d'un petit bassin versant de Thysse Kaymor (Sénégal). 15 p. ■ Guinko S., 1984. Végétation de Haute Volta, Volume I. Thèse de Doctorat : Université de Bordeaux III (France). Tome, 394p.

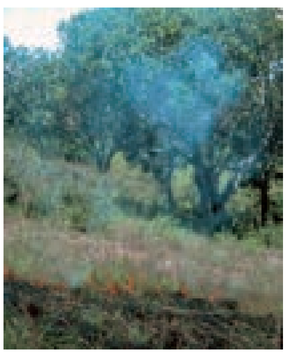
INDIGENOUS MANAGEMENT OF TAPIA WOODLANDS - MADAGASCAR

For centuries, the population of the highlands of central and south-western Madagascar has sustainably managed and conserved the local tapia woodlands. These woodlands play an important economic role as a source of non-timber forest products (NTFP) such as wild silk, fruit, mushrooms, edible insects, and herbal medicines. Tapia trees (*Uapaca bojeri*) comprise up to 90% of all trees in these woodlands, bear an edible fruit, and their leaves nourish an endemic silkworm (*landibe*). *Landibe* silk is used to produce ritual burial shrouds throughout the highlands. Trading silk products and tapia fruits is a crucial source of cash income for the local communities.

The tapia woodlands are maintained by the local villagers through burning and selective cutting. Burning favours the dominance of pyrophytic (fire-tolerant) tapia trees and protects silkworms from parasites. Selective cutting of non-tapia species and pruning of dead branches also favours tapia dominance and perhaps growth. Other common species include the endemic *Sarcolaena eriophora* and the invasive *Pinus patula / khasya*. The tapia woodland is clearly an anthropogenically shaped forest. However, the creation and maintenance of the woodlands should be seen as positive transformation rather than a form of degradation.

Local and state-imposed regulations protect the woodlands from overexploitation. The Forest Service has placed restrictions on forest cutting and burning while allowing for traditional use rights. The collection of forest products is regulated through a type of common-property regime. For example, fuelwood collection is limited to dead trees or fallen branches. It is forbidden to break off large branches to access cocoons. Thanks to these protective regulations, forest boundaries are mostly stable, and woodland density has increased in several cases.





SLM measure	Management
SLM group	Sustainable Forest Management in Drylands
Land use type	Natural forest; silvopastoralism
Degradation addressed	Reduction of vegetation cover; Quantity biomass decline
Stage of intervention	Prevention and mitigation
Tolerance to climate change	Silk and fruit harvests vary from season to season but drivers are poorly understood (could include precipitation and temperature)

Establishment activities

The management of the tapia woodlands has evolved over centuries and in recent times has been supported by state imposed regulations. Thus no establishment activities can be listed here.

Maintenance / recurrent activities

1. Selective cutting of non-tapia species, especially invasive pines.
2. Pruning of dead branches.
3. Controlled burning mainly through understory fires after the rainy season (January-May).
4. Collection of non-wood forest products such as fruits (September-December), medicinal plants, mushrooms, berries, insects, and hunting of mammals etc.
5. Collection of *landibe* silkworm twice a year (November-December and May-June). The cocoons are cooked, spun and woven into silk fabric.
6. Collection of fuelwood, limited to dead or downed wood.

Labour requirements

For establishment: na
For maintenance: low

Knowledge requirements

For advisors: na (traditional practice)
For land users: low (children often harvest fruit; silk cocoon harvest is easy)

Photo 1: Typical tapia woodland south of Antsirana.
Photo 2: Tapia woodland with some invasive pine trees bordering highland rice fields.
Photo 3: Small late wet season fire in a tapia woodland.
Photo 4: *Landibe* wild silk cocoon.
Photo 5: Bags of tapia fruit for sale on the side of the road.
(All photos by Christian Kull)

Case study area: Antsirabe and Ambositra, Col des Tapia, Madagascar

Establishments inputs and costs per ha

Traditional method; no establishment phase and costs.

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 10 person-days for harvest of NTFP	20
Equipment / tools: specify	0
Agricultural inputs: specify	0
Construction material: specify	0
TOTAL	**20**
% of costs borne by land users	100%

Remarks: The estimation of costs is difficult - fruit are gathered over a two month period by school children going out for an hour in the early morning each day; the silkworms are collected by individuals (usually experienced collectors) on free days. In some areas, projects exist that run silkworm nurseries, establish firebreaks in the woodlands, grow and plant tapia seedlings, and finance the purchase of silk looms. These projects obviously require much larger budgets.

Benefit-cost ratio

Inputs	short term	long term
Establishment	na	na
Maintenance	positive	positive

Remarks: The larger rainy season silk harvest provides crucial cash income during the meagre months before the rice harvest. In 1998, the price of 200 cocoons was between US$ 0.10-0.15. For a basket of tapia fruits villagers earned between 0.02-0.06 US$/kg. During the harvest the tapia woodlands produce about 4 kg of fruits per ha (= US$ 0.1-0.25/ha). Dependence upon woodlands for cash income varies from 0-40%.

Ecological conditions

- Climate: subhumid; 7 months of dry season
- Average annual rainfall: 1,000 – 1,500 mm
- Soil parameters: mostly nutrient-poor or rocky soils; low organic matter; high drainage; rockier, silica-rich soils compared to the main lateritic soils of highland Madagascar
- Slope: hilly to steep (20-80%)
- Landform: hill slopes
- Altitude: 800 - 1,800 m a.s.l.
- Tapia woodlands are short, endemic, sclerophyllous formations, resembling-Mediterranean oak forests or southern Africa's Miombo woodlands.

Socio-economic conditions

- Size of land per household: na (woodlands are communal)
- Population density: 20-40 persons/km^2 in the central highlands and 10-20 in the western highlands
- Type of land user: mainly small-scale, poor households
- Land ownership: state
- Land use rights: communal (organised)
- Level of mechanisation: manual labour
- Market orientation: subsistence (self-supply) and mixed (subsistence-commercial)

Woodlands are officially state-owned, but in practice managed by neighbouring communities (either unofficially, or increasingly through community-based management contracts).

Production / economic benefits

++ Increased cash income (through selling silk-fabrics and other NTFP)
+++ Production of NTFP as important dietary supplements (berry, mushrooms, protein (insect), etc.)
++ Stable supply of fuelwood
++ Provisioning of medicinal plants

Ecological benefits

+++ Maintenance of biomass,
++ Maintenance of soil cover and regulation of soil loss
++ Maintenance of endemic biodiversity

Socio-cultural benefit

+++ Improved food security / self-sufficiency (different forest products)
+++ Maintained cultural value (sacred forest)

Weaknesses ➜ and how to overcome

- Partly individual indiscriminate cutting and / or strong use of fires leads to overuse of the forest resources ➜ needs clear regulations, guidelines and observation of the rules by the local authorities as well as awareness raising about the multiple benefits of the forests.
- Invasion of exotic tree species such as pine and eucalyptus from private and village woodlots ➜ the forest service has rightly been encouraging communities to cut these trees from the tapia forests without the need for complicated permits.
- Insecure land use rights ➜ in 1996 a new legislation opened the way to officially decentralise management of state-owned renewable natural resources to adjacent communities, which would aid woodland protection by increasing stakeholder involvement.
- In some areas, silkworm populations have been very low for decades ➜ recent projects seek to establish silk nurseries and reintroduce the worm.

Adoption

This system of woodland management is applied in almost all endemic tapia woodland areas. The area of these woodlands is 2,600 km^2 (study area: approx. 50 km^2), affecting perhaps 100,000 people. It is a traditional practice – no incentives necessary.

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Key references: Kull CA (2002): The 'Degraded' Tapia Woodlands of Highland Madagascar: Rural Economy, Fire Ecology, and Forest Conservation. Journal of Cultural Geography Spring/ Summer 2002.

SUSTAINABLE RAINFOREST MANAGEMENT

Rainforest as natural habitat for mountain gorillas, Rwanda. (Hanspeter Liniger)

In a nutshell

Definition: Sustainable Rainforest Management (SRFM) in tropical and mountain areas aims to ensure that the goods and services derived from natural forests meet present-day needs while at the same time securing their continued availability and contribution to long term development. Central Africa contains the world's second largest area of rainforests and shelters some of the greatest biological diversity within the continent, and thus plays a vital role in global ecological services. Yet, illegal logging, agriculture and hunting seriously threaten the diversity and values of these forests. In many countries rainforests are now restricted to mountain areas, and to coastal and river areas. Mountain forests in particular play a crucial role in providing freshwater resources, and feeding rivers and groundwater tables which provide life to dry lowlands.

SRFM combines political and technical issues. On the political side, despite clear commitments of governments and local administrations (ratification of conventions, laws / regulations, etc.), effective measures for protection and sustainable management of the remaining natural forests must be better implemented at ground level. One major issue is improving country level integrated and participatory land use planning with a better recognition of the need for land tenure and customary rights to be afforded to the local populations. On the technical side, there are two main aspects: the protection and maintenance of undisturbed forest areas for conserving its rich biodiversity, and the sustainable management of forests for productive purposes either commercially or under a subsistence system, in other words how to balance profitability while still maintaining ecological and social integrity. Some critics say that conservation of biodiversity is not compatible with any use of the forests. However, for most of the population living in, or around, rainforest areas the use of forest products represents a vital means for food security. New trends and opportunities such as paying for ecosystem services should be further assessed and supported. This provides a promising solution to better integrate conservation and economic aspects.

Applicability: Applicable and crucial for any type of natural primary or secondary rainforests in tropical and mountain areas.

Resilience to climate variability: Rainforests are a common resource pool and how well the forest is maintained will determine how vulnerable community livelihoods and national development will be to climate change impacts.

Main benefits: Improved livelihoods and human well-being through income diversification and salaries from industrial forest sector, improved water availability since mountain rainforests are water towers for dryland areas, maintaining an ecosystem with rich biodiversity; hindering further deforestation can contribute immensely to the global carbon balance, providing a critical buffer against global climate change.

Adoption and upscaling: Success of SRFM depends on the establishment of policies based on poverty reduction and the active involvement of various stakeholders at the local, national, regional and international levels. Furthermore it requires financial resources, a political will, and social investment.

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	na
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)	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	+++

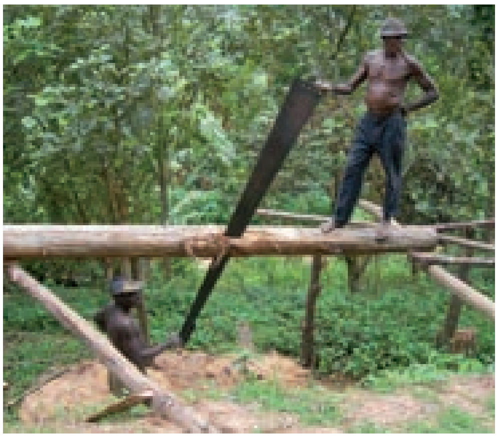
Origin and spread

Origin: Prior to the colonial era, the sacred character of forests helped to conserve them as part of traditional community resource management systems. After the 1992 Earth Summit, Central African countries adopted laws and regulations including sustainable management plans, community involvement and conservation objectives. However, the execution of these regulations is not sufficiently successful.
Spread of rainforests: 180 million ha are covered by rainforests (out of 582 million ha of forests). They are mainly found within the Central African Republic (CAR), the Democratic Republic of Congo (DRC), Equatorial Guinea (EG), Gabon and the Republic of Congo. Rainforests are also found in Cameroon, the high mountain areas of Ethiopia, Kenya, West Africa (e.g. Benin, Ghana, Guinea Bissau, Guinea, Ivory Coast, Liberia, Nigeria, Sierra Leone and Togo) and in costal zones in South Africa, Madagascar, etc.
Sustainable rainforest management mainly in: Forest management plans are in effect in Cameroon, Congo, Gabon and CAR. Cameroon and CAR have more than 75% of the concession with agreed management plans, whereas the larger DRC has none. In Central Africa, the forest area certified by the Forest Stewardship Council (FSC) was about 4.7 million ha in 2009: Cameroon (0.9 million ha), Congo (1.9 million ha) and Gabon (1.9 million ha). Cameroon, CAR and EG have more than 20% of their land under protection, whereas in Congo, DRC and Gabon the protected area ranges between 9-11% of the total land area.

Area of rainforests in Sub-Saharan Africa.

Principles and types

Good Forest Governance is a prerequisite for sustainable rainforest management (SRFM). It is presently pursued through three approaches: (1) the Forest Law Enforcement and Trade (FLEGT) process; (2) independent third party observers; and (3) forest certification and / or legal systems operating in the Congo Basin.
Land use planning: SRFM needs to be part of a broader national land use planning process. All stakeholders from small farmers, communities, NGOs, the private sector and government technical services should be involved and collaborate very closely - giving special emphasis to social and ecological aspects. A collective assumption of responsibilities is needed, to bring a transformation of responsibilities from state to private structures such as communities, NGOs, and concession-holders. SRFM for carbon, biodiversity and water resources needs global planning and compensation mechanisms.
Community forestry: The management of forests with or by local communities is an important mechanism for addressing social equity while pursuing the sustainability of the forest resources. Maintenance and protection of forest resources can only be achieved through awareness raising and active involvement of communities. For maintaining valuable natural forest resources, clear land tenure and user rights must be given to communities.
Management plan procedures: Inventories on resources potentially available for annual allowable cut / harvest and logging maps are, today, standardised features of any management plan. Through these documents, sustainable logging practices are encouraged and promoted within a forest concession. This includes the demarcation of annual felling coupes (quotas), adherence to minimum harvest diameters, respect for seed-trees to conserve the biodiversity and economic value of the forest – and so forth. The construction of access roads must be carefully planned, as well as timber extraction procedures.
Diversification of production: New niche markets for non-woody forest products, 'green' and 'fair trade' products can increase the competitiveness and income of small-scale producers. Ecotourism involving local communities and Payments for Ecosystem Services (PES) can be promising new income and market opportunities for forest users.
Biodiversity conservation: Beside national and international protected areas, small-scale protected areas may be established at the local level which can preserve habitats and serve as refuges for animals. Protected area management needs to be integrated within the framework of land use planning. These areas, including their buffer zones, must contribute to local economic development through the promotion of NWFP, ecotourism and community forestry. Hunting, where legally permitted, should be controlled and reduced to a sustainable level. Mechanisms to pay for biodiversity conservation need to be established.



Top: Teaching the sustainable use of rattans, Democratic Republic of Congo. (Robert Nasi)
Middle: Pit sawing eucalypt log, Uganda. (Jim Ball)
Bottom: View of natural rainforests in Guinea. (Jim Carle)

Applicability

Land degradation and causes addressed

Small-scale agriculture represents the main threat to the forest since expanding cropland and grazing land at the expense of forest land continues in many areas: it is effectively an intensification of the traditional system of slash and burn. In Central Africa, 32% of the rainforest is allocated to commercial logging concessions granted by governments to companies and individuals. Extensive forest logging does not generally lead to a significant loss of forest cover, and does not compromise forest sustainability directly. Yet forest roads penetrate and open up previously untouched forests, making them accessible, especially for hunting and illegal logging. Logging activities and the selective felling of certain tree species lead to a change in the biodiversity of the forests. Lack of buffer zones lead to polluted water courses. Increasing population pressure and the increasing demand for biofuels, or other NWFPs, may further heighten the threat to the remaining rainforest areas.
Biological degradation: loss of forest ecosystem, biodiversity, and wildlife
Water degradation: decline of water quality and regularity of flow
Physical and chemical soil deterioration: soil compaction, loss of nutrients

Land / forest use

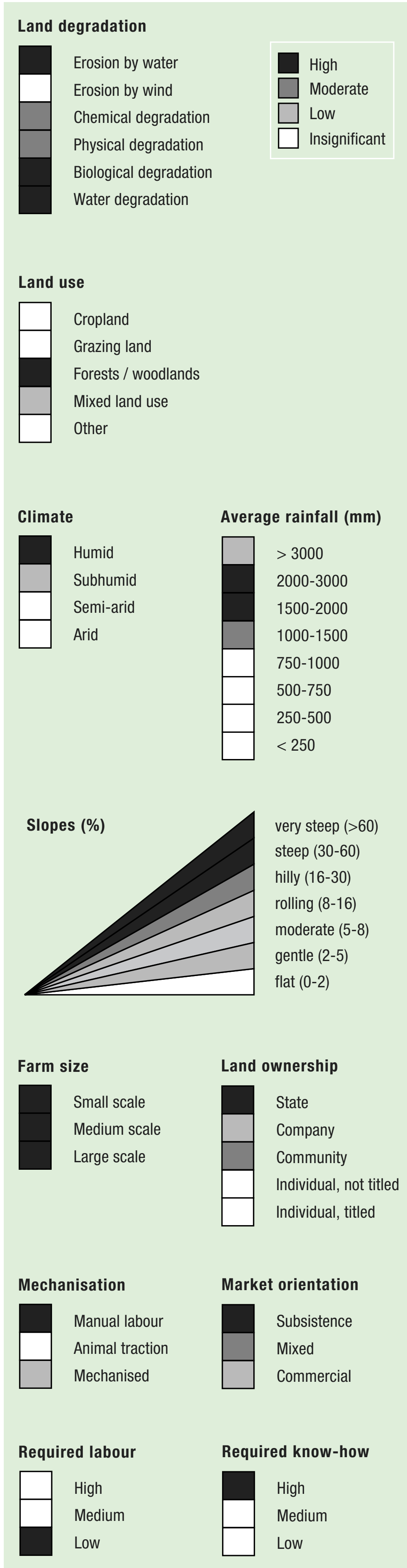
Primary and secondary forests can be defined as natural forests. Within a tropical rainforest, different layers can be distinguished: the ground layer (the forest floor), the shrub layer, the understory, the canopy and the emergent layer.
Naturally, there is only limited use of dense tropical forest, mainly by hunter-gatherers. However, conversion to agricultural land and the application of shifting cultivation have made it possible to use the land for agricultural production. In tropical rainforests the timber market and logging activities play an important role in the use and abuse of the forests.

Ecological conditions

Climate: Tropical rainforests thrive under an annual rainfall of 1,750 - 3,000 mm, and mountain forests between 1,400-2,500 mm. In tropical rainforests, mean monthly temperatures exceed 18°C.
Terrain and landscape: No restrictions; however, in many countries forests have been reduced to inaccessible areas – especially steep hills.
Soils: Soils of rainforests are very susceptible to soil degradation after removal or change of vegetation cover (e.g. after clear cutting).

Socio-economic conditions

Farming system and level of mechanisation: From small-scale land use to mechanised commercial logging activities.
Market orientation: Rainforests are used by subsistence small-scale land users using wood and NWFP as well as for commercial timber or NWFP extraction. The forestry sector is a main job provider for rural population in many Central African countries.
Land ownership and land use / water rights: In most tropical African countries, the state has claimed legal ownership of forest land since the colonial period, even though the customary ownership of the same areas dates back centuries, perhaps millennia. Africa lags behind other tropical forest regions in forest tenure reform with less than 2% of the continent's tropical forests legally owned by, or designated to, forest communities or indigenous groups. To ensure sustainable management of forests, land tenure rights must be ensured for local communities.
Skill / knowledge requirements: SRFM requires a very high level of know-how and technical knowledge regarding appropriate techniques. Good education of forest management services and local communities is a prerequisite.
Labour requirements: Labour requirements vary depending on interventions needed (see principles and types).



Economics

Establishment and maintenance costs

Since Sustainable Rainforest Management (SRFM) is mainly a political and management issue, the assessment of costs is limited and depends closely on the specific technical and political aspects implemented.

	Cost (US$/ha)	
	Establishment (2-4 year set up phase)	Maintenance (25 years operation)
Community forestry, Cameroon	2,600 – 32,000 (can be up to 59,000)	2,000

(Source: Ingram Verina, see case study on Community Forestry)

Community forestry in Cameroon includes very high establishment costs including marking the boundaries and agreeing on forest use zones, inventory of forest resources, management plans, etc. However, once established the operation of the system is at a low price.

Production benefits

It is difficult to give estimation about the production benefits of SRFM, since the benefits are related to management changes. However, recent studies are helping to put a price on the range of forest goods and services. Yet more research is needed on the value of environmental services such as water quality and supply, soil retention and fertility, carbon storage, and conservation of biodiversity, etc. Furthermore, methodologies are needed to calculate the cost of unsustainable forest management for comparison (FAO, 2008). People living in, and around, rainforests need to be rewarded as stewards / custodians of natural forests. Payments for Ecosystem Services (PES) comprise voluntary transactions for well-defined environmental services. New PES related markets for greenhouse gases, carbon, water and biodiversity are emerging around the world. The PES approach is still recent in Central Africa, and not widely implemented. Yet many sub-regional actors are beginning to pay close attention to this type of mechanism. As for donors, the African Development Bank launched a 'Congo Basin Forest Fund' in 2008 with more than US$ 110 million, which will be partly devoted to setting up PES, including the fight against climate change. Similarly, the World Bank, with its Forest Carbon Partnership Facility, and the United Nations - UNDP, UNEP, FAO - have significant funding for implementing sub-regional programs for reforestation or avoided deforestation. Finally, the Global Environment Facility has started a 'Strategic Program to Support Sustainable Forest Management in the Congo Basin', which is also targeted towards PES. All this funding is for three main environmental services – carbon sequestration, biodiversity conservation, and watershed maintenance – which are just starting to be implemented in Central Africa.

Benefit-cost ratio

	short term	long term	quantitative
Community based forest management	– –	++	No data available

– – negative; – slightly negative; –/+ neutral; + slightly positive; ++ positive; +++ very positive;

Since sustainable forest management is not yet widespread in SSA, it is difficult to make a realistic assessment of the economics, either current or potential, and the likely change to sustainable management during the next two decades.
If communities are willing and economically able to involve themselves, they must receive greater economic benefits from conserving forests than from degrading them. Sustainable natural forest management must tangibly improve local economic welfare, and generate local economic benefits to sufficient levels and in appropriate forms to make SRFM economically sound.

Example: Forest certification
There has been some international recognition of progress made towards sustainable forest management in Central Africa through forest certification. Among several competing processes, the Forest Stewardship Council's (FSC) certification system is considered the most demanding at the international level - focusing not only on technical, but also social and environmental aspects of forest management. From zero hectares at the end of 2005, FSC-certified forest area ballooned to a total of about 4.7 million hectares in July 2009, spread over three countries: Cameroon (0.9 million ha), Congo (1.9 million ha) and Gabon (1.9 million ha) (FSC, 2010 and based on expert knowledge).

Example: Ecotourism Cameroon
In Cameroon the ecological and cultural diversity of the country is an asset for tourism. This could be a means to develop the forest sector outside of timber, woodcrafts and NWFP. Even though Cameroon is trying to make money from biodiversity, through ecotourism, this sector is still underdeveloped. In 2007, tourism revenues, namely ecotourism in protected and hunting areas, amounted to € 297,260 (appr. US$ 365,000). Although some protected areas are visited by tourists there is a lack of adequate structures to valorise their resources. In 2008, 20 protected areas had information centres (Eba'a Atyi R. et al., 2009).

Example: Compensation payments
There are several initiatives in Central Africa to compensate protectors of biodiversity. There are three types: (1) 'freezing' potentially exploitable areas to promote conservation; (2) the labeling of goods produced in compliance with specific environmental standards; and (3) restrictions on practices impacting biodiversity in and around protected areas. Conservation concessions represent the most recent approach in the Congo Basin. The objective is to convert areas earmarked for logging into protected areas. No projects have started yet, but WWF and Conservation International (CI) have made proposals with the goal to conserve the habitat of several major species of large mammals. These conservation concession proposals have yet to convince the national governments to whom the land belongs. The reluctance of public authorities can almost certainly be attributed to the opportunity cost of these conservation concessions - estimated at 10-13 million Euros (US$ 12-16 million) per year - as well as the complexity of national and local institutional arrangements to put in place. (Based on expert knowledge)

Impacts

Benefits	Land users / community level	Watershed / landscape level	National / global level
Production	++ diversification of production ++ increased production of NWFP ++ enhanced long term forest productivity + increased wood production	+++ reduced risk and loss of production +++ improved access to clean drinking water	+ improved food and water security
Economic	++ provides a wide range of wood and non-wood products ++ income diversification (e.g. beekeeping, ecotourism) + increased income	+++ less damage to off-site infrastructure ++ markets for non-woody forest products (diversification) ++ new employment (e.g. ecotourism) and stewardship + stimulation of economic growth	+ improved livelihood and well-being
Ecological	+++ improved protection of biodiversity, endangered forest species and habitats +++ improved forest cover and stocking +++ reduced soil erosion (by water / wind) +++ improved water availability +++ increased soil fertility +++ improved micro-climate ++ restoration and protection of remaining natural forests	+++ water availability +++ water quality +++ reduced degradation and sedimentation +++ intact ecosystem	+++ decreased degradation and desertification incidence and intensity +++ increased resilience to climate change ++ reduced C emissions ++ increased C sequestration ++ enhanced biodiversity
Socio-cultural	+++ recognise value of stewards of natural forests +++ community involvement and strengthening ++ less conflicts among different users ++ improved knowledge and awareness raising on SRFM	+++ increased awareness for environmental 'health' +++ attractive landscape ++ reduced conflicts	+++ protecting national heritage

	Constraints	How to overcome
Production	• Restricted short time use ('exploitation') of forests	➜ awareness of long term benefits and increase of other valuable ecosystem services provided through natural forests
Economic	• Commercial constraints due to uncontrollable international wood markets • Availability of market for non-woody products and ecotourism • Insufficient payments for ecosystem services (PES)	➜ support the establishment of markets for NWFP and ecotourism ➜ improved national and international support and more efforts needed in establishing fair PES mechanisms
Ecological	• Impossibility of reconstituting forests exactly as they were • Difficult to assess the long term impact of a management practice due to the slow-growing of trees • Forest resources are still not sufficiently understood – lack of knowledge and monitoring	➜ promote the role of secondary forests and allow most suitable conditions for regeneration towards natural forests ➜ more investment in research is needed esp. on the contribution of biodiversity, provisioning of water, etc.
Socio-cultural	• Political constraints: secure land tenure of communities often not given, modern and customary laws are often in conflict • Poverty leading directly to indiscriminate extraction of forest resources and dependency on timber market • Knowledge is inadequate, scattered and poorly disseminated • Lack of knowledge on the current state of forest resources • Laws and regulations exist but are not adequately supported, community forest plan may exist, but communities have not enough possibilities to stop illegal logging	➜ allocation of land use rights and consolidating / harmonisation of legal situation including customary laws ➜ improving the livelihoods of poor communities in and around forests and make them independent from destructive forests use, introduce alternative income options through NWFP or ecotourism ➜ compilation and exchange of experiences made with SRFM, learning from others ➜ capacity building of both government staff and community members and regular monitoring and reporting about state of natural forests ➜ needs a clear political commitment and supervision of activities going on

References and supporting information:

Blay, D. 2007. Multi-stakeholder forest management: A case from the humid zone in Ghana. Forest Management Working PaperWorking Paper FM/32. FAO, Rome (Italy).
Central African Regional Program for the Environment (CARPE), 2010. http://carpe.umd.edu/, accessed on 15 February 2010.
Eba'a Atyi R., Devers D., de Wasseige, C and Maisels F. 2009. State of the forests of Central Africa: Sub-regional synthesis. In Dewasseige, C., Devers D., de Marcken P., Eba'a Atyi R., Nasi R. et Mayaux Ph., (eds) The forest of the Congo Basin: State of the forest 2008. P:127-140. Publications Office of the European Union, Luxembourg.
FAO. 1997. R. Bellefontaine, A. Gaston and Y. Petrucci (online 2000), Management of natural forests in dry-tropical zones. Series title: FAO Conservation Guide - 32.
FAO. 2003. Forestry Outlook Study for Africa – Subregional Report West Africa. African Development Bank, European Commission.
FAO. 2003. Forestry Outlook Study for Africa. African Development Bank, European Commission.
FAO. 2003. Sustainable management of tropical forests in central Africa. Forestry Paper -143 http://www.fao.org/docrep/006/y4853e/y4853e03.htm#P169_7514
FAO. 2008. Towards sustainable forest management. http://www.fao.org/forestry/sfm/en/ accessed on 23 September 2009.
FAO. 2008. Understanding forest tenure in Africa: opportunities and challenges for forest tenure diversification. Forestry Policy and Institutions Working Paper 19
FAO. 2009. State of the Worlds Forests 2009.
FAO. 2008. Links between National Forest Programmes and Poverty Reduction Strategies, by R.McConnell.
FARMAFRICA. 2009. Tanzania Participatory Forest Management Project. http://www.farmafrica.org.uk/smartweb/tanzania/tanzania-participatory-forest-management-project.
FSC. 2010. Forest Stewardship Council. http://www.fsc.org, accessed on 15 February 2010
German L.A. (ed.), Karsenty A. (ed.), Tiani A.M. (ed.). 2009. Governing Africa's forests in a globalised world. Earthscan Publications. London.
ITTO, 2010. International Tropical Timber Organisation. http://www.itto.int/en/feature09/, accessed on 15 February 2010.

Adoption and upscaling

Adoption rate

Considerable efforts have been made to implement sustainable forest management approaches to forest concessions in Central Africa (from 125,000 ha in 2000, to over 11.3 million ha in 2008). These figures are likely to increase. However, the rate of SRFM adoption differs greatly between countries. Global concern about sourcing wood from sustainably managed areas is encouraging thanks to the launching of the Forest Law Enforcement, Governance and Trade (FLEGT) process and to the progressive adoption of certification. FSC-certified forest area increased from zero in 2005 to a total of about 4.7 million ha in 2009. However, the overall extent of certification still remains low. Currently, Cameroon is the only country where community and communal forestry concepts are translated into concrete actions.

Upscaling

Political and institutional commitment: Governments must have the political will to shift from industrial logging to community forestry and take actions to do so. SRFM should be integrated into a coordinated national framework with a clear forest policy.
Land tenure rights: Without clear land tenure rights and ownership for communities there is little scope for improving forest management.
Decentralisation and new forest management plans: All stakeholders from small farmers, local communities, NGOs, the private sector, and government technical services must be involved in the development of a management plan. A collective assumption of responsibilities is needed, bringing a transformation of responsibilities from state structures to private structures (NGOs, concession-holders, etc.).
Environmental sustainable logging concession: Logging cannot be banned totally in rainforests, therefore environmentally and socially sound solutions must be considered under new concessions. Forest concession should not threaten the livelihoods of local communities and lead to their marginalisation, therefore local management and enterprises should be supported. Clear rules and guidelines must be available and enforced.
Research and improving knowledge of the forest resources: Multidisciplinary approaches are needed to take into account the various aspects of sustainability. Inventories of biodiversity / wildlife habitat are required as well as information and knowledge related to appropriate / reduced impact logging techniques. Further collaboration with research for an all-encompassing view of natural resources and ecosystems is needed.
Awareness raising and capacity building: Local forestry services should be well educated and trained to coordinate and maintain SRFM. Local communities / land users need to have a good understanding of all aspects of SRFM - traditional knowledge supported by more scientific concepts.
Protected forests need better involvement of local communities in order to reduce damaging and illegal use of the forests. A prerequisite is establishment of clear regulations and control mechanisms by forest services and local communities to ensure commitment to safeguarding protected forests and benefit sharing (e.g. through ecotourism) among all stakeholders.

Incentives for adoption

Payment for Ecosystem Services (PES) can, and must, increasingly be an incentive for sustainable management. Clear commitments are needed to pay for the maintenance of the remaining forest resources. Certification is another tool to enhance the adoption of sustainable rainforest management.

Enabling environment: key factors for adoption	
Inputs, material incentives, credits	+
Training and education	++
Land tenure, secure land use rights	+++
Access to markets	++
Research	++
Infrastructure	++
Conflicts of interest	++

Forest Governance
Improving forest governance in Central Africa is pursued through three approaches:
(1) The FLEGT (Forest Law Enforcement and Trade) process initiated by the European Union (EU), aims to culminate in the signing of a bilateral Voluntary Partnership Agreement (VPA) between each timber exporting country of the sub-region and the EU. Once signed, the VPAs will restrict timber exports to the EU to wood that meets the legal conditions agreed.
(2) In most countries of the sub-region, the process of linking Independent Observers (IO) with the monitoring of forest operations for greater transparency has been adopted. The IOs are generally recruited among international NGOs working to promote transparency. Cameroon, Congo and Gabon have also worked with the World Resource Institute (WRI) to develop interactive forestry atlases, making it available to users interested in basic information on forest concession management. In development by the Commission for the Forests of Central Africa (COMIFAC), the OFAC (Observatory for the Forest of Central Africa) will help all Central African countries to make a wide variety of forest sector data available in a transparent fashion, including: Forest cover, logging, biodiversity conservation and biodiversity development statistics. The private sector is also involved in initiatives to improve the law on forestry operations and enhance transparency. By the end of 2009, 25 certificates of legality (total area 2.6 million ha) have been granted to logging companies following audits by private auditors. Many companies are also involved in the Forest Transparency Initiative.
(3) Forest certification and / or legality systems operating the Congo Basin.
(Based on expert knowledgement)

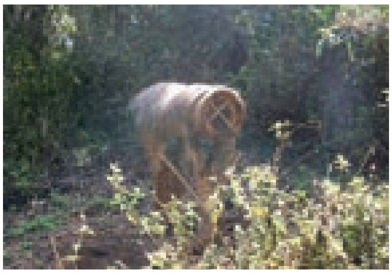
References and supporting information (continued):
Karsenty, A., and Gourlet-Fleury, S. 2006. Assessing Sustainability of Logging Practices in the Congo Basin's Managed Forests: the Issue of Commercial Species Recovery. Ecology and Society 11(1): 26. [online] URL: http://www.ecologyandsociety.org/vol11/iss1/art26/
Lescuyer, G., Eba'a Atyi, R. and Cerutti, P. 2009a. Consommations nationales de bois d'œuvre en Afrique Centrale: un enjeu majeur pour la gestion forestière durable. Paper presented at the world forestry congress. Buenos Aires, Argentina. 18-23 Octobre 2009.
Lescuyer, G., Karsenty, A., and Eba'a Atyi R. 2009b. A new tool for sustainable forest management in Central Africa: Payments for Environmental Services. In Dewasseige, C., Devers D., de Marcken P., Eba'a Atyi R., Nasi R. et Mayaux Ph., (eds) The forest of the Congo Basin : State of the forest 2008. P:15-41. Publications Office of the European Union, Luxembourg.
Mogaka, H., Simons, G., Turpie, J., Emerton, L. and Karanja, F. 2001. Economic Aspects of Community Involvement in Sustainable Forest Management in Eastern and Southern Africa. IUCN - The World Conservation Union, Eastern Africa Regional Office, Nairobi.
Nasi, R., B. Cassagne, A. Billand. 2006. Forest management in Central Africa: where are we? International Forestry Review 8(1):14-20.
Nasi, R., J.-C. Nguinguiri, D. Ezzine de Blas (Eds.). 2006. Exploitation et gestion durable des forêts d'Afrique Centrale : la quête de la durabilité. ITTO, CIFOR, CIRAD, L'Harmattan, Paris, 429p.
Odera, J., 2004. Lessons Learnt on Community Forest Management in Africa. A report prepared for the project 'Lessons Learnt on Sustainble Forest Management in Africa.'
Owen, J., 2004. Can Central Africa's Rain Forests Live With Logging? National Geographic. Novemter 2004.
Tropical Forest Update. 2009. Owning Africa's forests. A newsletter from the International Tropical Timber Organistion to promote the conservation and sustainable development of tropical forests. Vol.19-2
Tropical Forests and Climate Change Adaptation (TroFCCA). 2010. http://www.cifor.cgiar.org/trofcca/_ref/home/index.htm, accessed on 15 February 2010.

FOREST BEEKEEPING - CAMEROON

Apiculture (beekeeping) has been traditionally practiced for at least a century in Cameroon, with forest-based apiculture increasing in the last two decades. The ancient art of honey hunting, and the more recent apiculture and its products like honey, wax, propolis, bee venom and royal jelly, are examples of non-timber forest products (NTFP). A number of projects were supporting production and marketing, due to the conservation and development benefits of beekeeping. Beekeeping has low establishment costs and requires little land or labour, and by providing a suitable environment for the hives in a favourable location (i.e. forest with a range of melliferous trees and plants and sufficient water available year round) it is possible to sustainably harvest a range of bee products on an annual basis.

For processing of the honey, the honeycomb is filtered and honey can be bottled and sold. Higher value is obtained by packaging and labelling. In Cameroon up to 4 US$/kg can be achieved for good quality honey. It can also be sold for industrial use – for example bakeries, sweets. If combs are washed, the resulting honey-water can be made into wine. Wax needs to be melted and cleaned, and can then be sold 'raw' for a price of about 2-6 US$/kg, or further processed into candles, soaps and creams.

In Cameroon, the consumer market is expanding and a small, niche export market for high quality, certified organic and fair trade wax, honey and propolis, is emerging. The exports to Europe and the US require quality assurance schemes that entail costs, expertise and collaboration between government and beekeepers. The number of hives per bee-farmer can vary considerably from a few up to 150 hives. Approximately 15 hives can be installed per hectare. Beekeepers can be good 'guardians of the forests', because they know that the forest provides both forage and water for the bees, and the water and materials needed to make hives and process apiculture products.



SLM measure	Management
SLM group	Sustainable Rainforest Management
Land use type	Natural forest
Degradation addressed	Indirectly deforestation / overuse of natural forests
Stage of intervention	Prevention
Tolerance to climate change	Unknown sensitivity of bees to climatic extremes; resilience of bees is assumed, but changes in honey quality and quantity depending on forage available with changes in forest cover / structure

Establishment activities

1. Construction of hives (traditional or modern, depending on skills and availability / cost of materials).
2. Place hives on forest trees or on stands, above the level of fires, as well as away from ant and termite colonies.

Maintenance / recurrent activities

1. Wait for natural colonisation or capture a swarm and transfer to hive.
2. Regular (weekly or monthly) checking of hive conditions to ensure that the colony is not disturbed by pests or damaged through wind / rain. In drought periods a shallow bucket of water is provided to the bees. Reparation activities if needed.
3. Harvest honey (as soon as sufficient is available), wax and propolis, using a 'smoker' and clean bucket, leaving brood combs to maintain the colony (usually annually at end of rainy and / or flowering season; depends on location). Harvesting of honey combs often done at night to minimise disturbance of the bees.
4. Filter honey from combs to separate honey and wax; then bottle and pack.
5. Process wax (e.g. washing comb and boiling in water or solar melting box) and melt into moulds, using a press or centrifuge. Comb washing water can be used in honey beer or wine in lidded buckets / basins or bottles or using as fermentation airlock.

Labour requirements

For establishment: low
For maintenance: low

Knowledge requirements

For advisors: medium to high
For land users: low

Photo 1: View of the case study area: mountainous forests in Mount Oku region, Northwest Cameroon.
Photo 2: Women carrying harvested wax.
Photo 3: Modern bee hive.
Photo 4: Traditional bee hive. (All photos by Ingram Verina)

Case study area: Mount Oku region, Northwest Cameroon

Establishment inputs and costs per beehive

Inputs	Costs (US$)
Labour: 10 person-days	40
Equipment / tools: bee suit smoker 4 buckets filtering materials bottles for honey	 10 15 12 10 5
Construction material	2-15
TOTAL	**94-107**
% of costs borne by land users	100%

Remarks: For a start up, 5 beehives are needed. Labour includes collection / purchase of materials. Hives can be made from local materials (e.g. raffia palm, mud, rattan, lianas, grasses, wood, or sawn planks for top bar hives) and by using available tools (machete, axe, knife; lifespan 2-5 years).

Maintenance inputs and costs per beehive per year

Inputs	Costs (US$)
Labour: 15 person-days (US$ 4/day)	60
Construction materials for: replacement / repair hive materials, filtering / harvesting	5
TOTAL	**65**
% of costs borne by land users	100%

Remarks: Labour costs depend on number of hives and distance from household. Costs vary with production level and availability of equipment (knife, mesh filter, buckets). Harvest equipment can be basic and includes smokers (bunch of grass / metal smoker) and bee suits (also made locally).

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly negative	positive
Maintenance	neutral	positive

Remarks: Initial investment in hives often recouped in 2-5 years, depending on level of production.

Ecological conditions

- Climate: subhumid
- Average annual rainfall: 2,000-2,400 mm
- Soil parameters: lateritic clay
- Landform: plateau, valleys, mountain slopes
- Altitude: mountain forests
- Each forest type produces its own honey, with a specific taste, colour, consistency and moisture content determined by the pollen and nectar from the forest plants.

Socio-economic conditions

- Type of land user: small to medium scale, very poor to average level of wealth; individuals or groups; cooperatives are mainly used for marketing products and / or buying material
- Population density: 70-100 persons/km^2
- Land ownership: community forest or individual (titled and not titled)
- Land use rights: legal form of community management; many people keep bees by the forest edge on their farms, usually on privately owned land
- Market orientation: mixed (subsistence and commercial)
- Level of mechanisation: manual labour

Production / economic benefits

+++ Subsistence use and sales of apiculture products e.g. wax / honey / propolis soaps, cosmetic, creams, wine, candles etc.
+++ Increased income
++ Own consumption of honey for food and medicinal use

Ecological benefits

+++ Conservation of forests and particularly melliferous trees
+++ Pollination of forests and crops

Off-site benefits

+++ Pollination in area approx 4-6 km from hive

Weaknesses ➜ and how to overcome

- Pests destroy hives / eat honey (e.g. honey badgers, ants, termites, civets) ➜ relocate hives, stronger / different hive construction, regular checks.
- Theft of hives ➜ patrol forest, make agreements in community, locate hives near farms / houses, chain or lock hive.
- Low production ➜ relocate hives to more forested areas, ensure hive located with < 2 km from water source in dry season.
- Bush fires can destroy hive ➜ agreements with farmers / pastoralists about bush fire patrols in dry season, create fire breaks around hive and support trees.
- Rain can destroy hive ➜ use of metal, sheet, grass, raffia or wood as protective 'roof', place in a 'bee house' of locally constructed materials, or under a simple shelter, and experiment with different designs.

Adoption

Established and knowledgeable beekeepers in a community aid dissemination of technology and spontaneous adoption. The technology of hive building needs to be learned but there are many low-tech, local material designs known, as well as simple designs for 'modern' hives. In the mountainous forests of Northwest Cameroon, both traditional practices are passed on around Mt. Oku as well as being stimulated through cooperatives, associations and business groups, covering some 4,500 beekeepers mainly in Bui, Boyo, Mezam and Donga Mantung divisions.

Main contributors: Ingram Verina, CIFOR-Cameroon; Yaounde, Cameroon; v.ingram@cgiar.org

Key references: Bradbear N. 2004. Beekeeping and Sustainable Livelihoods. Diversification booklet 1. F. A. S. S. Division. Rome, FAO Food and Agriculture Organisation of the United Nations. ■ Bradbear N. 2009. Bees and their role in forest livelihoods. A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products. NON-WOOD FOREST PRODUCTS 19. FAO. Rome: 204. ■ Ingram V. 2009. Bees, trade and success. LEISA Magazine 25: 22-24. ■ Paterson P. 2000. The basis for success in beekeeping projects.Bees for Development Journal 57.

COMMUNITY FORESTS - CAMEROON

The 1994, Cameroon forestry law introduced the concept of community forests (CF), which gives communities the right to access forest resources in or around their villages, for an area up to 5,000 ha, over a period of up to 25 years. Villagers are allowed to manage, conserve and exploit the products of their CFs in a participatory manner. A manual of procedures guides the process of creating and managing a CF. Basic stages include:
(1) Inform the community of their rights, obligations and procedures;
(2) Select / create a suitable, legal community entity to manage the forest;
(3) Mark the boundaries and agree forest use zones;
(4) Inventorise the forest resources, such as timber species and NTFP;
(5) Hold consultation meetings to agree on forest use, zones and plans;
(6) Complete application file by the community and send to government;
(7) Draw up a management plan for a 5-year period, including the distribution of revenues in the community;
(8) Obtain the necessary felling permit for timber;
(9) Exploit forest and implement activities according to the management plan;
(10) Carry out annual review of logging exploits by ministry;
(11) Monitor revision of, and approve, the management plan (5-yearly).

Once the exploitation permit based on the management plan has been obtained, communities can start to exploit on an annual basis. Often small logging enterprises are contracted for timber extraction. Where the focus is on non-timber resources - e.g. *Prunus africana* in the Northwest and Southwest – these may be exploited collectively or individually. Activities also include hunting, farming, and management of the forest to secure environmental services. Revenues from forest resources should be distributed according to the management plan, involving payments for extraction and control services (patrolling for checking on fires, etc.), as well as contributions to the forest management institution and to community development projects (e.g. schools).

Results in Cameroon are mixed: Over 400 CFs have been requested since 1996, of which 174 are operating while the rest are still waiting to be approved. In 40% of the operating CFs timber is exploited. Issues of concern however include: (1) inequitable distribution of benefits and 'capture' by elites, contractors and NGOs; (2) low profits resulting from artisanal extraction methods and scale, and (3) the long and difficult process to obtain the permission. Determinants of CFs' success include: (1) communities' technical and managerial capacities; (2) access to market information about timber and non-timber prices and buyers; (3) access to finance and equipment.

Type of approach
Project / programme based innovation, incorporated into legal framework

Problems / constraints addressed
– Often low level of management and administration skills to obtain and then manage a CF
– Overcoming competing interests in forest use by communities
– Ensuring that all forest users benefit equitably from their community forest

Aims and objectives
– Devolve forest management and exploitation rights to local communities adjacent to forests
– Communities benefit from exploitation of forest resources
– Forest conservation

Target groups
Local communities

Participation and decision-making
All stakeholders / users in a community should be represented in the local institution set up to demarcate, apply for, managing and exploit a community forest, implemented through a management committee, often incorporates traditional authorities in a community, and in collaboration with local Ministry of Forests and Wildlife.

Implemented SLM / other activities
– SLM measures: participatory demarcation and landuse and forest use planning
– Other activities: sometimes community group work e.g. negotiation and conflict resolution, management and book-keeping skills

Implementing bodies
International institutions and NGOs with national government and national NGOs and local communities

Land users' motivation for implementing SLM
Profitability: harvest of timber
Prestige: social pressure to manage their own forest
Improved livelihood: by conserving forest values e.g. water source protection, sacred areas
Rules / regulations: agree on farm and forest land, hunting zones

Photo 1: Communities placing a boundary market at the edge of a forest. (Verina Ingram)
Photo 2: People with their beehives, in a community forest. (Verina Ingram)

Case study area: mainly southern part of Cameroon in the humid and mountain forest areas; 100,000 ha for 404 community forests

Costs and subsidies

Budget: Large set-up costs: average 2,600-32,000 US$/ha (max. 59'000 US$) over 2-4 years; operating costs: average 2,000 US$/ha/year over the 25 year period of a CF.

Approach costs were met by the following contributors / donors:

National government	5%
International NGO	20%
National NGO	20%
Local government	5%
Local community, land users	50%
Total	**100%**

Subsidies financed under the approach:

Externally financed inputs	
Labour	not financed (in kind)
Equipment / tools	Differs by CF: financed by project, leased, owned by a timber contractor
Agricultural inputs	not financed
Construction material	not financed
Infrastructure	not financed

Access to credits

In most cases no credit was provided. If a CF was supported by a programme / project, some receive financial credit to commence logging operations.

Training and awareness rising

- Form of training: on-the-job; forest visits, public meetings, training courses, exchange visits
- Topics: community group management, participative planning, financial management, timber exploitation, forest inventory. Training was provided to villagers and selected community representatives.

Advisory service

The communities have been made aware of the possibility to manage their forests and exploit timber. They were assisted to set up CF's, by projects / programmes, and sometimes also in the operation of the forests.
Method and key elements: advice (by NGOs, government, village elites) on group management, participative planning, financial management, contract negotiation, timber and non timber exploitation, inventories.

Research

Research has been conducted on successes, failures and contentious issues of CF in Cameroon; does it work? Is it really participative? Who benefits and how much? How can governance arrangements be reformed to create impacts intended in the forestry law?

Organisation / capacity development

Most CF's start with a capacity building and awareness raising phase by informing the communities of the CF concept, followed by on-the-job capacity building to set up a suitable functioning community organisation, inventorying forest resources, holding consultation meetings, and how to draw up and implement a management plan.

Benefits of SLM Approach

++ Improved sustainable land management: cost-benefit analysis indicate there are slightly more environmental and economic benefits than costs from CF than not having a CF
++ Adoption of Approach by other land users / projects: multiplier effect to other communities in Cameroon - also across Central African region
++ Improved livelihoods and human well-being: revenues for community from legal timber exploitation, conservation of forest environmental services

Strengths

- Offers legal, long term route for communities to zone and exploit forests, particularly for timber but also non timber products and environmental services.
- Devolves responsibility for forest management and conservation from national government to community level.
- Gives priority to communities to extract timber, rather than to logging companies.

Weaknesses ➜ and how to overcome

- Implementation costs and time can be higher and take longer than revenues ➜ good initial inventory needed to asses revenues.
- Usually external assistance or informed local community members needed for implementation, is a long and complicated process.
- Requirement only to use artisanal logging methods mean profits can be low and losses of timber high, due to wasteful artisanal methods ➜ proposals to modify legislative framework are emerging that make it possible to use more mechanisation and export to more profitable overseas markets.
- Danger of capturing revenues by elites and / or inequitable distribution ➜ support / needed to ensure equitable distribution of benefits.

Sustainability of activities

Once community forestry is up a running and exploitation activities show profitably, communities do continue the approach, but few CFs in Cameroon have more than 3 to 4 years of experience.

Main contributors: Ingram Verina, CIFOR-Cameroon; Yaounde, Cameroon; v.ingram@cgiar.org
Key references: Adeleke, W. 2006. Analysis of community forest processes and implementation in Cameroon. WWF-CARPO. Yaounde, Cameroon, WWF-CARPO: 32. ■ De Blas E., D., M. R. Perez, J. A. Sayer, G. Lescuyer, R. Nasi and A. Karsenty. 2008. External Influences on and Conditions for Community Logging Management in Cameroon. World Development 37(2): 445-456. ■ Oyono, P. R., M. B. Biyong and S. Kombo. 2009. Les Nouvelles Niches de Droits Forestiers Communautaires au Cameroun: Effets Cumulatifs sur les Moyens de Subsistance et Les Formes Locales de Vulnérabilité. RRI Project. CIFOR. Yaoundé, CIFOR: 101. ■ Poissonnet, M. and G. Lescuyer. 2005. Amenagement forestier et participation: quelles leçons tirer des forêts communales du Cameroun? VertigO – La revue en sciences de l'environnement 6(2). ■ SNV. 2005. Guide d'accompagnement à la mise en oeuvre de la Foresterie communautaire au Cameroun: Se renforcer par les expériences vécues en forêt humide S. Cameroun. Yaounde, SNV: 20. ■ Topa, G., A. Karsenty, C. Megavand and L. Debroux. 2009. The Rainforests of Cameroon: Experience and Evidence from a Decade of Reform. Washington, World Bank,.

Weaving baskets from sisal: women at work in Eastern Kenya. (William Critchley)

In a nutshell

To make Sustainable Land Management (SLM) and its products, impacts and services more valuable, and / or to connect SLM with emerging g l environmental issues, promising new technologies and opportunities need to be continually explored. Trends and opportunities encompass both technologies and approaches, and are based on new markets and market demands. They often involve new financial mechanisms.

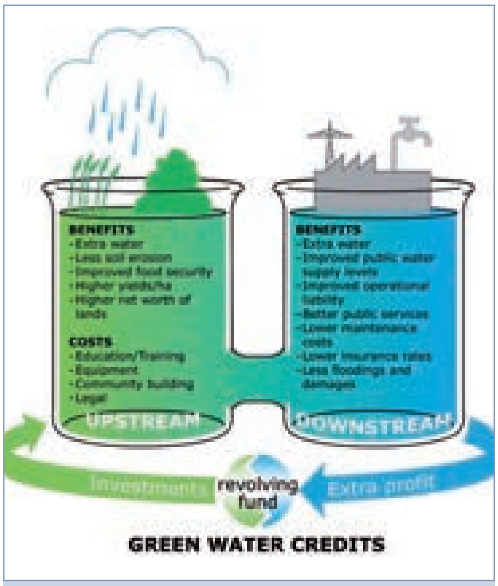
In various areas of agricultural production and agribusiness there is investment potential for small-scale land users, ranging from primary production and food processing to providing services. Some promising trends and opportunities in SSA include:

- Processing agricultural products or 'value chain' development
- New markets for certified agricultural products e.g. Fair Trade, Organic Farming, Forest Certification, etc.
- Markets for endemic plants grown under organic / fair trade conditions (e.g. rooibos tea in South Africa)
- Markets for medicinal plants (many indigenous to Africa, including 'devil's claw'; *Harpagophitis procumbens*)
- Origin labeling (e.g. traditional coffee varieties in Ethiopia, grown under shade)
- Biotechnology for higher yield, improved fruits, new varieties
- Genetically modified crops (BT Maize in South Africa) in combination with conservation agriculture
- Markets for ecotourism and agro-ecotourism
- Markets for bio-energy / fuel
- Markets related to compensation payments e.g. payment for ecosystem services (PES)
- Establishing training, research and agricultural information centers
- Productive gullies for producing cash crops

Furthermore, investment opportunities are related to support services such as establishing farm machinery and equipment plants; tractor hire centers; operating agriculture mechanisation centers; developing human and animal power technologies; seed multiplication farms; training of extension specialists and agricultural researchers. It is likely that increasing attention will be paid to addressing SLM concerns through new marketing opportunities, including wide ranging possibilities for accreditation and labeling schemes to command market premiums. Payment schemes based on PES are almost certainly forerunners for a new breed of programmes and projects. Currently the most promising and important trends and opportunities for SSA are organic farming, ecotourism and PES.

Payments for Ecosystem Services

Payments for ecosystem services (PES) are economic instruments designed to provide incentives to land users to continue supplying an environmental service that benefits society. The payments cover positive externalities, i.e. measures taken in one place that have positive impacts on another location, where currently people benefit from it without paying - which can be viewed as a 'market failure'. Therefore the costs can be internalised; those who benefit from the services pay and those who provide the services receive payment. PES includes voluntary transactions for well defined environmental or ecosystem services (ES) between an ES buyer and an ES provider. The transaction may vary from direct payments to upstream providers from downstream beneficiaries, or between companies paying to compensate for their emissions made in another country. What is being bought must be well defined and can be either a measurable service (e.g. tons of carbon stored) or a change of land use. The payment will naturally only be made if the provider of the services implements the agreed changes. The voluntary nature of the 'transaction' differentiates PES from the conventional command-and-control approach of many governments. Many PES-projects have been started in SSA, paying for carbon storage in forests, watershed services, Green Water Credits, etc. However, there are still many constraints to implementing PES. These include the lack of clearly defined property rights; the measurable and quantifiable input and service that improved land management achieves; assessing and setting the price for ES; limited institutional capacity to set up payment systems, etc.



Example: Green Water Credits
Green Water Credits (GWC) attempts to bridge the incentive gap between upstream and downstream water users. The project implements a regular compensation system by water users to water providers for specified water management services (e.g. for hydropower and irrigation) (Source: ISRIC, 2010).

Ecotourism

Ecotourism can be defined as the purposeful travel to natural areas to understand the culture and natural history of the environment, taking care not to alter the integrity of the ecosystem, while producing economic opportunities that make the conservation of natural resources beneficial to local people. Ecotourism seeks to minimise impacts on the areas visited and contributes to the conservation of these locations and the sustainable development of adjacent areas and communities. Community involvement in ecotourism is important, providing income opportunities and compensating for protecting and limiting use of the ecosystem by the community. Africa is an important ecotourism destination, e.g. the Kenyan Wildlife Service recorded a revenue of US$ 54 million from wildlife tourism in 1995. The protection of forests and other natural habitats are an important aspect of ecotourism. However, the 'ecotourism carrying capacity' is usually not precisely known and facilities are often established without prior assessment of the likely ecological impacts. There is future potential for agro-ecotourism, where the focus of attention is on – for example – ancient terraces combined with traditional farming methods.

Elephants crossing the Samburu river in Kenya. (Hanspeter Liniger)

Biogas Production

Biogas is gas that is naturally produced during the decomposition of organic waste. The gas is captured in a storage tank (on site) to be used for household energy needs such as cooking, heating and lighting. The most common form of input material is cow dung making it very appropriate for rural settings in SSA. The technology offers two major advantages: (1) On-site and low-cost energy production based on internal inputs; (2) Reduced usage of fuelwood which translates into less cutting down of trees leading to reduced deforestation and land degradation. The biogas plant generally consists of three main chambers: (1) The digester pit where all the microbiological reactions / decomposition of the material takes place; the digester has to be air-tight with the released gas only escaping into the gas holder; (2) The gas holder is connected to the digester through a pipe and collects all the gas that has been fermented; (3) The mixing pit is the input chamber where the dung is mixed with water and fed into the digester. Biogas is suitable either for a farm, cattle post or rural setting where the inputs (cow dung) are easily available. Energy can be saved at every level of use, i.e. individual or institutional. In Botswana for example this technology was introduced by the Rural Industries Innovation Center which is a government funded research institution.

Gas collection tank resting on the concrete-built digester. Pipes / tubes at the top of the gas tank supply the house with methane gas, Botswana. (Reuben Sebego)

Organic Agriculture

Organic agriculture is a holistic production management system that avoids the use of synthetic fertilizer, pesticides and genetically modified organisms. It minimizes nitrogen pollution, conserves soil and water, and optimizes the health and productivity of interdependent communities of plants, animals and people. Organic agriculture farmers need to implement a series of practices that optimize nutrient and energy flows and minimize risk. These include: crop rotations and enhanced crop diversity; different combinations of livestock and plants; symbiotic nitrogen fixation with legumes; application of organic manure; and biological pest control, such as 'push-pull'. All these strategies seek to make the best use of local resources. Findings in a 2008 report issued by UNEP that assessed 114 projects in 24 African countries stated that 'yields had more than doubled where organic, or near-organic practices had been used' and that soil fertility and drought resistance improved. Organic agriculture — with its emphasis on closed nutrient cycles, biodiversity, and effective soil management — has the potential to be more conducive to food security as well as sustainable in Africa than most conventional production systems and has the capacity to mitigate and even reverse the effects of climate change.
Demand for organic and fair trade products is increasing on the international market. These niche markets offer opportunities for small farmers in SSA. However, they demand high quality products and farmers need to meet certification requirements, which can be costly to establish. Furthermore, farmers depend closely on efficient marketing, and need support to access niche markets and fulfil the demand (for example) for specific organic products – including fibres as well as food. Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM), an international umbrella organisation established in 1972.

Top: Rooibos tea bushes in Western Cape, South Africa – and the product marketed in Europe. (William Critchley)
Bottom: Development agencies are promoting export of organic products from Africa. By now more than 50,000 certified organic growers in Uganda. (William Critchley)

Fair Trade

Fair trade is 'aimed at equitable social relations'. It aims to enhance trading conditions for small-scale businesses, improve labour conditions for employees and empower communities through ethical and sustainable trade. It includes producers, traders, retail, support organisations and, of course, consumers of fair trade products. Furthermore, it provides market access to otherwise marginalised producers, connecting them to customers and allowing access with fewer middlemen. Fair trade aims to provide higher wages than those typically paid to producers, as well as helping producers develop knowledge, skills and resources to improve their lives. Fair trade products are traded and marketed either by a 'MEDC* supply chain' whereby products are imported and / or distributed by fair trade organisations (alternative trading organisations, e.g. Max Havelaar) or by 'product certification' whereby products complying with fair trade specifications are certified by them, indicating that they have been produced, traded, processed and packaged in accordance with the standards. Use of labels or certifications for fair trade is mainly a market-driven approach. Fair trade governs land management through consumers' preferences and production demand. A label for organic production or for ecological wood production (FSC) serves as an incentive to implement SLM and allows the land user to gain a higher price for certain products. There are wide-ranging possibilities of labelling schemes. This may even go beyond fair trade and eco-labels and eventually into the realms of 'SLM-friendly' certified products.
The 'Fairtrade certification system' covers a growing range of products in SSA, including, coffee, cocoa, tea, cotton, fresh fruits, honey, spices, shea nut butter (*beurre du karité*), wine, flowers and handicrafts.

** 'Management and Executive Development Centre'*

FAIRTRADE

FLOWER LABEL PROGRAM

'Fairtrade' logos for fair trade products.

Example: Cooperation for Fair Trade in Africa – COFTA.
COFTA is a network of Fair Trade producer organisations in Africa involved and working with disadvantaged grass root producers to eliminate poverty through Fair Trade. COFTA was established by African producers in 2004 and aims to be the African voice in lobbying for greater market access and Fair Trade advocacy for African Producers, thus striving to empower the marginalised and disadvantaged to become organised, active and self-reliant African entrepreneurs. The cooperation is currently composed of over 70 member organisations from 20 African countries. COFTA members are predominantly handicraft producers, but are also involved in tea, coffee, vanilla, honey, dried fruit and juices, textiles among other income generating activities (COFTA, 2010).

Biotechnology and genetically modified crops

Non-GM (Genetic modification) biotechnological practices, such as traditional breeding, grafting / budding, cloning, radiation for mutations, where the organism's genes are manipulated indirectly, are more readily accepted and still have more potential in SSA. Practices that can improve the yield and quality of fruits e.g. grafted mangoes, grafted ziziphus, and budded citrus increase their value on local markets, and hence provide a good source of improved income.

Genetic modification (GM) is a specialised form of biotechnology and involves the manipulation of an organism's genetic make-up by introducing genes with desired traits from other species. GM is considered by some to be an opportunity because of its potential for 'pro-poor' production benefits. However, the whole debate about GM is still very controversial and any prospects for small-scale African land users are estimated to be 20 years away.

Ziziphus fruit in Africa wild (top) grafted (bottom); the grafted 'Pomme du Sahel' (*Ziziphus* sp.) is proving very popular and commands a good market both for fruit and graftlings. (William Critchley)

Productive gullies

Gullies can be rehabilitated for productive use: thus from an erosion problem they can be converted into a source of extra income. Untreated gullies can constitute a significant loss of productive agricultural land. Tree planting, natural grass regeneration and structural measures such as check dams of soil, stones, branches, and micro-basins are common practices that are used to avoid further soil erosion and for rehabilitation. In all cases the gullies then need to be protected from livestock. Such 'treated' gullies can furthermore offer an opportunity to produce more resource-demanding, higher yielding and better revenue crops e.g. fruit trees, banana and sugar cane (e.g. as in Tigray, Ethiopia), nut trees (e.g. cashew), vegetables, rubber, etc. Gully-gardens constitute rich 'micro-environments' being well supplied with water and sediment from above. For this practice to become upscaled, research is required to investigate resource ownership issues related to the gullies and runoff. There may potentially be upstream: downstream conflicts.

Diverse herbaceonsplants, bushes and trees turing the gullies into productive land. (Hanspeter Liniger)

References and supporting information:

CIFOR. 2006. Payments for Environmental Services. http://www.cifor.cgiar.org/pes/_ref/about/index.htm, accessed on 15 January, 2010.

COFTA. 2010. Cooperation for Fair Trade in Africa. http://www.cofta.org/en/en/index.asp, accessed on 21 June 2010.

Critchley W., 2010. Sustainable Land Management course presentation: "Biodiversity, GM and Organic Production". VU-University Amsterdam.

DESIRE. 2010. DESIRE-Project. http://www.desire-project.eu/

Ethiocat. 2007. Soil and Water Conservation Practices for Sustainable Land Management in Ethiopia.

Fairtrade Labelling Organizations International & International Fair Trade Association. 2008. A Charter of Fair Trade Principles. http://activistnotes.wordpress.com/2008/06/06/a-draft-charter-of-fair-trade-principles-flo-and-ifat/, accessed on 1 June 2010.

Falkenmark,M., P. Fox, G. Persson and J. Rockström. 2001. Water Harvesting for Upgrading of Rainfed Agriculture - Problem Analysis and Research Needs. SIWI Report 11. Stockholm International Water Institute.

FAO. 2003. Workshop on Tropical Secondary Forest Management in Africa: Reality and Perspectives. Proceedings. http://www.fao.org/Docrep/006/J0628e/J0628E30.htm, accessed on 15 January 2010.

FAO. 2004. The state of food and agriculture 2003-2004: agricultural biotechnology - meeting the needs of the poor? Food and agriculture organization of the United Nations, Rome, Italy.

FAO. 2007. The State of Food and Agriculture – Paying Farmers for Environmental Services. FAO Agriculture Series No. 38.

FAO. 2010. Organic Agriculture. http://www.fao.org/organicag/oa-home/en/, accessed on 29 March 2010.

FAO. 2010. Payments for Environmental Services from Agricultural Landscapes http://www.fao.org/ES/esa/pesal/index.html, accessed on 15 January 2010.

ISRIC - World Soil Information. 2010. Green Water Credits. http://www.isric.org/UK/About+ISRIC/Projects/Current+Projects/Green+Water+Credits.htm, accessed on 14 June 2010.

Meleca, A., 2008. The Organic Answer to Climate Change. http://www.organicguide.com/community/education/the-organic-answer-to-climate-change/

Moges A. and N. M. Holden. 2008. Estimating the rate and Consequences of Gully Development, a Case Study of Umbulo Catchment in Southern Ethiopia. Land Degrad. Develop. 19: 574–586 (2008).

Müller-Lindenlauf M. 2009. Organic Agriculture and Carbon Sequestration. Possibilities and constrains for the consideration of organic agriculture within carbon accounting systems. FAO. ftp://ftp.fao.org/docrep/fao/012/ak998e/ak998e00.pdf, accessed on 29 March 2010.

Salami A., B. Abdul Kamara and Z. Brixiova. 2010. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities, Working Papers Series N° 105 African Development Bank, Tunis, Tunisia.

The Katoomba group. 2008. http://www.katoombagroup.org/regions/africa/documents/2009_scoping_report.pdf, accessed on 15 January 2010.

UNEP-UNCTAD. 2008. Organic Agriculture and Food Security in Africa. United Nations, New York and Geneva.

UNESCO. 2005. Teaching and learning for a sustainable future. http://www.unesco.org/education/tlsf/TLSF/theme_c/mod16/uncom16t03.htm, accessed on 15 January.

Wikipedia. 2010. Fair trade. http://en.wikipedia.org/wiki/Fair_trade, accessed on 1.June 2010.

WOCAT. 2007. Where the land is greener – case studies and analysis of soil and water conservation initiatives worldwide. Editors: Hanspeter Liniger and William Critchley.

WOCAT. 2009. WOCAT Database on SLM Technologies. www.wocat.net

ORGANIC COTTON - BURKINA FASO

In the Ioba province of Burkina Faso, the production, storage, processing and marketing of organic cotton has been promoted since 2004 by Helvetas.
Organic cotton production adheres to the principles and standards of organic farming. Any application of synthetic fertilizers and pesticides and the use of genetically modified varieties are forbidden. Organic cotton relies on a combination of different measures: (1) the use of organic fertilizers (manure or compost) and recycling of organic matter; (2) crop rotation and / or intercropping; (3) careful selection of varieties adapted to local conditions (climate, soil, pests and diseases); (4) biological pest management (in combination with careful monitoring of crops); (5) clear separation of organic and conventional cropland, e.g. by growing border crops (to avoid contact with chemical substances through spray drift or surface runoff); and (6) soil and water conservation measures. Timely crop management (e.g. weeding) is very important.
In Ioba rotations crops include sesame (a cash crop), cereals and legumes (food crops), while intercrops include leguminous green manure and trap plants. The best adapted cotton variety is FK-37. Bio-pesticides are produced based on neem seeds (*Azadirachta indica*). The measures listed above help to improve soil fertility, reduce production costs (and thus financial risk) and avoid the negative effects of conventional farming: declining yields, resistance to pests and diseases, health hazards and environmental problems caused through the use of chemicals.
By relying on inputs available / produced on the farm and by getting a better price for certified organic products, profitability of the farm is improved in the long run despite of lower productivity compared to conventional or genetically modified (GM) cotton. Farms need to complete a 3-year conversion period to change their production system from conventional to organic. Farmers have to maintain records and documents for periodic inspection and certification (Internal control system).

SLM measure	Agronomic
SLM group	Trends and New Opportunities
Land use type	Annual crops / perennial crops
Degradation addressed	Fertility decline and reduced OM content; Biodiversity decline
Stage of intervention	Prevention and mitigation
Tolerance to climate change	Tolerant to climatic extremes due to higher water retention capacity of soils, reduced erosion and crop diversification (reduced risk of total crop failure)

Establishment activities

1. Purchase equipment (knapsack, etc).
2. Establish compost pits.

Remark: Certification requires a converting period of 3 years.

Maintenance / recurrent activities

1. Compost production.
2. Clear crop residues on fields where cotton will be planted, use for mulch or compost production (no burning).
3. Apply organic manure: 7.5 t/ha.
4. Ploughing (for incorporation of manure, pest and weed control).
5. Sow cotton and intercrops (such as *Hibiscus esculentus* – a trap plant for pests; or *Mucuna* – a green manure plant); Thin out cotton after 10-20 days (1-2 plants per pocket).
6. Weeding (3 to 4 times: 20/40/70/100 days after sowing).
7. Pest control (manual collection); Spraying of bio-pesticide (64 liters/ha, based on neem seeds): according to infestation: up to 3 times.
8. Ridging (form furrows and ridges using plough or manually).
9. Pre-harvest weeding.
10. Harvesting.
11. Cut cotton stems / residues and incorporate into the soil.

Labour requirements

For establishment: high
For maintenance: medium

Knowledge requirements

For advisors: high
For land users: medium

Photo 1: Land preparation using an oxen-drawn plough. (Helvetas)
Photo 2: Spraying bio-pesticides – one element of organic pest management. (Helvetas)
Photo 3: Harvesting cotton. (Jörg Böthling)

Case study area: Dano, Ioba province, Burkina Faso

Establishment inputs and costs per farm

Inputs	Costs (US$)
Labour: 2 person-days	2
Equipment / tools: 15-liter-knapsack	50
Agricultural inputs	na
TOTAL	**52**
% of costs borne by land users	100%

Maintenance inputs and costs per ha per year

Inputs	Costs (US$)
Labour: 145 person-days (at 1.1 US$)	160
Equipment / tools (see establishment)	0
Agricultural inputs: cotton & intercrop seeds, manure, neem seeds	28
TOTAL	**188**
% of costs borne by land users	100%

Remarks: Standard equipment (hoe, plough, wheel-barrow) is not included in costs, knapsack is provided by producer's association (UNPCB) on credit; transport bags are donated. Labour and other inputs for erosion control measures (e.g. stone bunds) are not included in costs. Neem biocide costs US$ 0.7 per liter; organic cotton seeds cost US$ 1.7 per 50 kg.

Benefit-cost ratio

Inputs	short term	long term
Establishment	slightly positive	very positive
Maintenance	very positive	very positive

Remarks: Establishment costs are higher than revenues due to investments & initial decrease in yield (conversion period). On the long term, advanced farmers can achieve same or even higher yields than conventional cotton systems.

Ecological conditions

- Climate: subhumid (tropical, with high rainfall variability)
- Average annual rainfall: 750-1,000 mm per year
- Soil parameters: medium soil fertility, medium organic matter content; sandy or sandy-clayey texture; medium drainage
- Slope: mainly flat (0-2%), partly gentle (2-5%)
- Landform: mainly plateaus / plains, valleys
- Altitude: 300-500 m a.s.l.
- Cotton prefers dry, hot and sunny climate, a minimum of 500 mm of rain distributed over the vegetation period (5 months), deep clay soils (vertisols)

Socio-economic conditions

- Size of land per household: average cotton production area ca. 1 ha
- Type of land user: individual small-scale farmers; men and women; certain activities carried out in mutual help groups
- Population density: 60 persons/km^2
- Land ownership: group (family clans) / state
- Land use rights: individual
- Level of mechanisation: mainly manual labour, partly animal traction
- Market orientation: mixed (organic products for market; other crops such as cereals, legumes and root crops for subsistence)

Production / economic benefits

+++ Improved income: better price due to organic premium (50% more than for conventional cotton) compensates initial decrease of yields
+++ Reduced production costs: less expenses for inputs (- 90% compared to conventional cotton), gross margin is 30% higher
++ Reduced financial risk, less indebtedness for input provision

Ecological benefits

+ Increased soil fertility and increased soil organic matter
+ Increased water holding capacity of soils
+ Increased biodiversity; Eco-balance between pests and beneficial insects
+ No pollution of the environment through toxic chemicals

Socio-cultural benefits

+ Income opportunity for women
+ Enhanced health of humans and livestock (no health risks due to pesticides, diversified and organic food crops)
+ Enhanced organisation (farmers groups)

Off-site benefits

+ Reduced water pollution

Weaknesses ➜ and how to overcome

- Coexistence of organic and GM cotton resulting in high risk of contamination ➜ intensify training of farmers; set up a coordination platform between organic and GM farms; establish a sampling and testing system.
- Insufficient application of manure / compost ➜ training on compost production; Promote supply / production of organic manure (e.g. through small enterprises).
- Large distance to cotton fields (resulting in high transportation costs) due to interfering of browsing livestock close to village ➜ hay-making and corralling of livestock.
- Lack of land, land ownership and land security ➜ promote land leasing; resolve tenure problem on political level.
- Lack of equipment (e.g. plough) ➜ access to credits for small-scale farmers.
- Lack of water ➜ establish water retention structures.

Adoption

Cotton is the top export product in Burkina Faso and other West-African countries (50-60 % of export revenues). The proportion of organic cotton is growing. Actually 1% is produced organically. Around 7,000 farmers are producing organic cotton in Burkina Faso, of whom 28% are women.

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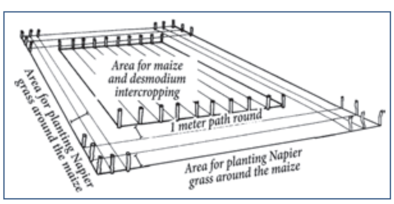
Key references: Helvetas. 2008. Guide de production - Un manuel de reference (Authors: Ouedraogo A, Yombi L, Doumbia S, Eyhorn F, Dischl R) ■ Eyhorn F., S.G. Ratter, M. Ramakrishnan. 2005. Organic Cotton Crop Guide – A Manual for Practitioners in the Tropics; Research Institute of Organic Agriculture FiBL, Frick, Switzerland

PUSH-PULL INTEGRATED PEST AND SOIL FERTILITY MANAGEMENT – KENYA

In the Lake Victoria region - like in many other parts of Sub-Saharan Africa – stemborer pests, striga weeds and poor soil fertility are the main constraints to efficient production of cereals. In combination they often lead to complete crop failure. The 'Push-Pull' technology efficiently controls the pests and progressively improves soil fertility. It involves intercropping maize with a repellent plant, such as desmodium ('push'); an attractant trap plant, such as napier grass (*Pennisetum purpureum*) is planted as a border crop around this intercrop ('pull').

The stemborer moths are attracted to volatile compounds emitted by the napier grass which at the same time serves as a haven for the borers' natural enemies. When moths lay eggs on napier grass a sticky substance secreted by the grass physically traps the moths' larvae. Napier is also an important carbohydrate-rich fodder grass. Desmodium, a perennial cover crop, produces repellent volatile chemicals that push away the moths, and the plant effectively suppresses striga weeds through its root exudates. Furthermore, desmodium fixes nitrogen, conserves soil moisture, enhances arthropod abundance and diversity and improves soil organic matter, thereby making cereal cropping systems more resilient and adaptable to climate change. Being a low-growing plant it does not interfere with the crops' growth.

Push-pull simultaneously improves cereal productivity; enables production of year-round quality fodder - thereby allowing for integration with livestock husbandry; diversifies income streams and enables smallholders to enter into the cash economy. It also improves soil fertility; protects fragile soils from erosion and enables a minimum tillage system. The technology is appropriate to resource-poor smallholder farmers as it is based on locally available plants, affordable external inputs, and fits well with traditional mixed cropping systems practiced in SSA.



SLM measure	Vegetative
SLM group	Trends and New Opportunities
Land use type	Annual cropping
Degradation addressed	Fertility decline and reduced organic matter content; Increase of pests / diseases
Stage of intervention	Prevention and mitigation
Tolerance to climate change	Technology is tolerant to climatic extremes

Establishment activities

1. Plant 3 consecutive rows of napier grass (*Bana* variety) around the plot: make planting holes, apply fertilizer (or manure), place 3-node canes or root splits, cover with soil (before rains).
2. Land preparation for desmodium: plough and harrow the land (to get fine soil), make furrows between the rows where the maize will be planted (using strong pointed stick; before rains).
3. Mix desmodium seed with super phosphate fertilizer (ratio 1:2), or alternatively with fine soil. Sow into the furrows and cover with soil (onset of rains).
4. Plant maize.
5. Weeding of maize, desmodium and napier grass (3 and 5-6 weeks after planting maize).
6. Manage napier grass: 1st harvest after 3 months (plants are 1-1,5 m high), leave stem height of 10 cm for quick regrow, start with inner row.
7. Cut desmodium for livestock fodder, leave a stubble height of 6 cm; or let it flower for seed production (and cut at a later stage for fodder).

Maintenance / recurrent activities

1. Land preparation for maize: carefully dig / plough between desmodium lines not to disturb / uproot the desmodium.
2. Plant maize.
3. Trim the desmodium so that it does not overgrow in between the maize plants (after 3 and 6 weeks).
4. Repeat activities 5.-7. listed under establishment.

Labour requirements

For establishment: medium
For maintenance: low

Knowledge requirements

For advisors: medium
For land users: low

Photo 1: A dense barrier of napier around the maize plot; Spacing of napier plants should be 75 cm between rows and 50 cm between plants within a row.
Photo 2: Desmodium is drilled in between maize rows at 75 cm row to row distance.
Photo 3: Overview of a push-pull plot (max 50 m x 50 m). (All photos by ICIPE)
Technical drawing: Layout of push-pull plot with1 m spacing between napier border and maize field. (ICIPE)

Case study area: Lake Victoria region, East Africa

Establishment inputs and costs per plot

Inputs	Costs (US$)
Labour: 8 person-days	10
Equipment / tools: planting stick / hoe	0
Agricultural inputs: 1,200 napier root splits or canes; 0.5 kg desmodium seeds; 47 kg superphosphate fertilizer	200
TOTAL	**210**
% of costs borne by land users	100 %

Maintenance inputs and costs per plot per year

Inputs	Costs (US$)
Labour: 6 person-days	7
Equipment / tools: planting stick / hoe	0
Agricultural inputs: 47 kg superphosphate fertilizer	32
TOTAL	**39**
% of costs borne by land users	100%

Remarks: Size of push-pull plot for the cost calculations above = 0.25 ha.
Input prices (in US$): 1 person-day = 1.2 US$; 1 napier root split / cane = 0.14 US$.; 1 kg desmodium seeds = 18.9 US$.; 1 kg superphosphate fertilizer = 0.68US$.

Benefit-cost ratio

Inputs	short term	long term
Establishment	positive	very positive
Maintenance	positive	very positive

Adoption

The technology is based on low external inputs and is adapted to the traditional mixed cropping systems in Africa. To date it has been adopted by over 29,000 smallholder farmers in East Africa, mostly without incentives. Where the technology is being introduced for the first time, farmers only need demonstration and technology information.

Ecological conditions

- Climate: mainly subhumid; bi-modal rainfall pattern, with main rainy season March-May; short rainy season October-November
- Average annual rainfall: 700-1,100 mm per year
- Soil parameters: low fertility, low to medium depth, medium drainage, low organic content; texture is mostly loamy clay, partly sandy
- Slope: < 10 %.
- Landform: mainly valleys, plains, and footslopes.
- Altitude: 1,200 – 1,250 m a.s.l.

Socio-economic conditions

- Size of land per household: 2 ha; production area: 0.9 ha
- Type of land user: small-scale; very poor to poor; mainly Individual farmers, some organised in informal groups
- Population density: 440-850 persons/km^2
- Land ownership: mainly individual (titled or not titled); communal; state
- Land use rights: mainly individual, leased; seldom communal (organised)
- Level of mechanisation: equally manual labour, and animal traction
- Market orientation: mainly subsistence (self-supply), starting small-scale commercial

Production / economic benefits

+++ Increased crop production: maize yields increase by 25-50% where stemborer is the only problem and by 300% in areas affected by stemborer and striga weed
+++ Increased fodder production: all-year round quality fodder for cattle (napier grass and desmodium)
+++ Increased income: selling cereal grains, desmodium seed, napier grass (if not fed to own livestock), and milk
+++ Reduced financial constraints: reduced fertilizer inputs thanks to nitrogen-fixing by desmodium
++ Reduced workload: weeding is minimised

Ecological benefits

+++ Increased soil fertility
+++ Increased soil organic matter
+++ Reduced soil loss: soil protected from erosion through desmodium (cover crop) and napier grass (barrier)
+++ Increased ground cover (cover crop, live mulch)
+++ Increased soil moisture (cover crop, live mulch)
+++ Reduced wind impacts due to napier barriers

Socio-cultural benefits

+++ Social capital generated through common learning and implementing agricultural 'best practices'

Off-site benefits

+++ Improved nutrition and both on-farm and off-farm employment

Weaknesses ➜ and how to overcome

- Napier grass is an aggressive plant that spreads through rhizomes under the ground ➜ regular control and weeding.
- The older napier stems and leaves are less palatable for livestock ➜ regularly cut young, tender leaves and stems.
- Minor adjustment of the smallholder farming system to introduce desmodium in traditional maize-bean intercrops ➜ desmodium (fodder crop) and beans (food crop, important protein source) can both be intercropped with maize. In areas where striga weed is not a problem, farmers can plant desmodium after every 3 or 5 rows of maize, and use the other rows for beans. Stemborers will still be repelled.

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Key references: Biovision. 2010. www.biovision.ch ■ icipe - African Insect Science for Food and Health. 2010. www.push-pull.net ■ Khan Z.R. et al. 2007. A Primer on Planting and Managing 'Push-Pull' Fields for Stemborer and Striga Weed Control in Maize ■ Fischler M. 2010. Impact assessment of Push-pull technology . Intercooperation, Switzerland.

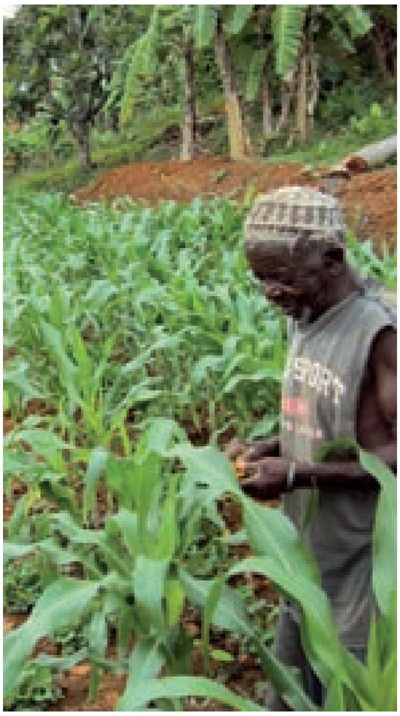
EQUITABLE PAYMENTS FOR WATERSHED SERVICES - TANZANIA

Equitable Payments for Watershed Services (EPWS) is a programme using Payments for Ecosystem Services (PES) to improve rural livelihoods. Incentive mechanisms are used to reward upstream landowners for maintaining a beneficial land use or for adapting a particular land use practice which affects the availability and / or quality of downstream water resources. The EPWS approach has enormous potential to advance a new conservation revolution based on a compensation mechanism encouraging and financing conservation efforts as well as improving the livelihoods of the rural poor.

Equitable Payments for Watershed Services (EPWS) aims to spread SLM technologies to communities, to raise awareness of the benefits of SLM and to improve land productivity. Farmer groups are formed to lead the implementation of SLM. The approach includes supervision, support and training of farmers to ensure appropriate implementation of SLM and efficient soil erosion control. Methods include demonstration plots and farmer-to-farmer extension. Capacity building to farmers (on gender mainstreaming, good governance and relevant laws and policies) and monitoring of hydrological and livelihood status are important components of the approach. Efforts to ensure good women integration resulted in a relatively high proportion within the farmer groups (>35%).

A payment mechanism has been established to compensate farmers for delivering watershed services (in form of freshwater) through implementation of SLM. Compensation payments – paid in cash and through material support – are made first to establish land use changes, and thereafter for service delivery and maintenance. They are mainly covered through international donors (DANIDA) and 'buyers' from the private sector, investing in watershed management.

This PES approach is very new in the country and there is little expertise within the government – which therefore needs to take deliberate efforts to groom experts through seminars and courses on PES mechanisms and its operationalisation. The EPWS team consisting of CARE International, WWF staffs and short term workers (such as students) is always involving government staff in various activities to induce them to knowledge on EPWS in particular and the PES concept at large.



Type of approach
Traditional / indigenous and project / programme based.

Problems / constraints addressed
– Land cover changes due to extensive cultivations
– Deforestation and forest degradation
– Soil erosion, loss of soil fertility
– Low storage capacity of the Uluguru Mountains due to land cover change
– Declining amount of available water in the river coming from Uluguru Mountains
– Increase run-off and sediment load in water system due to bare lands

Aims and objectives
– Improve livelihoods through SLM
– Improvement of hydrological system
– Mechanism to ensure effectiveness, growth and sustainability of EPWS
– Enhance quality of program implementation

Target groups
Land users and land use groups (village farmers, women), SLM specialists (experts on hydrology, GIS, SWC, economics, forests, etc.), politicians and policy makers (district commissioners, ward councillors)

Participation and decision-making
– Interactive implementation and decision making
– Participatory feasibility studies to identify the core problems
– PRA to identify and agree on SLM technologies
– Government staff was involved in various activities e.g. planning, training, data collection and analysis, extension, etc.

Implemented SLM / other activities
Excavation of terraces (esp. *Fanya juu / chini*, bench terraces), agroforestry and reforestation, agronomic practices (intercropping, legume crops), grass strip planting, applications of manure and indigenous pesticides.
Apart from SLM sustainable livelihoods activities were implemented.

Implementing bodies
Care International Tanzania, WWF Tanzania Country Office, DAWASCO and Coca Cola KLtd, Morogoro district council through agriculture officers, communities

Land users' motivation for implementing SLM
Affiliation to the project, environmental consciousness, well-being and livelihoods improvement, payments according to PES.

Photo 1: Man observing maize growth after changing his practices to *Fanya juu* terraces. (Erasto Massoro)
Photo 2: Farmers excavating *Fanya juu* terraces to reduce run off and improve crop production. (Erasto Massoro)

Case study area: Uluguru Mountains, Morogoro, Tanzania; 10-100 km^2 covered by EPWS Approach

Costs and subsidies

Annual budget: 100,000 -1,000,000 US$

Approach costs were met by the following contributors / donors:

International (DANIDA)	60 %
Private sector (buyers)*	9 %
Local community (through labour power)	31 %
TOTAL	**100%**

**'buyers' are downstream beneficiaries who pay or provide rewards for managers of the watershed upstream (='sellers')*

Subsidies financed under the approach:
Farmers are being compensated (paid in cash) for labour and area provided for the implementation of SLM (opportunity costs). Material support through manure, seeds and working tools is given as well.

Externally financed inputs	
Labour	fully financed (paid in cash)
Agricultural inputs (seeds, fertilizers)	partly financed
Equipment	partly financed

Remarks: The PES system pays for delivering of watershed services which is freshwater (quantity and quality). Payments are made first as compensation to establish land use changes, later for service delivery. EPWS Tanzania is currently facilitating payments for establishment and maintenance of the land use change.

Training and awareness raising

Training was provided to land users by SLM specialists and agricultural advisors. Farmer-to-farmer exchanges with neighbouring communities have improved the capacity of local leaders and farmers' representatives on practical skills on SLM measures, leadership skills, governance, gender mainstreaming, policies and laws to ensure their understanding on the implementation of the EPWS project in their locality.

Advisory service

Included: technical support on monitoring, provision of extension services for improved land use, situation analysis, awareness creation, capacity building on legal issues and mapping of interventions.
People involved: University, foresters, hydrologists, Ministry of Agriculture, land use planners.

Research

Research is a main part of PES as an approach to facilitate SLM adoption and has been very effective in guiding programme design; it included SLM assessment, hydrological analysis, economic analysis, social and livelihoods assessment, etc. All interventions applied were proposed by research conducted before and during implementation.

Organisation / capacity development

Country with limited experts to operationalise the new PES approach. Government needs to take deliberate efforts to groom experts through courses. Government staff is involved in various activities to induce them with knowledge on EPWS.

Benefits of SLM Approach

The project is still in initial stage - impacts can not be fully assessed yet

++ Improved sustainable land management: increased production

++ Improved livelihoods / human well-being

++ Improved situation of socially / economically disadvantaged groups: women have gained training in improving land use practices

++ Poverty alleviation: through change of crop production

Strengths

- Approach rewards land users for providing watershed services
- PES as an additional argument for supporting property claims
- To ensure services are delivered and payments are made and a reliable monitoring mechanism has been put in place
- Poor people are in the centre of the objectives
- PES as an incentive for conservation, helping to change

Weaknesses ➜ and how to overcome

- May reduce the effectiveness of non-incentive based approaches as people will now demand rewards / payments ➜ awareness creation is important to all players including government and local communities.
- Payments / rewards are realised before service delivery ➜ ensure integration of PES with other approaches to ensure effectives short and long term benefits. Paying labour cost upfront while waiting for the service delivery rewards.

Sustainability of activities

Participant land users can continue the activity without additional support- maintenance costs are low and the technologies will improve productivity and resilience of the farming system. Upscaling to neighbouring villages will be facilitated by the establishment of networks of farmers groups to receive training by local extension services. A steering committee, with representatives of the farmers, investors and government offices will facilitate replication in other parts of the country.

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CONSERVATION APPROACH FOR KOURÉ GIRAFFES - NIGER

The giraffe population in Kouré, Niger is unique because: (1) it includes the last representatives of white giraffes (*Giraffa camelopardalis peralta*) worldwide; (2) it thrives in an unprotected environment without any natural enemy (besides man); (3) it is in direct contact with rural communities and its livestock. The giraffe, reduced to only 49 individuals in 1996, was in danger of extinction due to a variety of reasons, the main one being the progressive deforestation in their habitat: the *brousse tigré* savanna vegetation. From 1996-2000, a government programme funded by international development agencies (SNV*, FFEM and the EU) has been carried out to sustainably protect the giraffes and their habitat. This program is based on a participatory approach which actively involves local people in conservation activities, while simultaneously strengthening local development and promoting ecotourism. Its revenues are redistributed to all local actors. A main pillar of the approach was the transfer of responsibilities in natural resources management to local organisations. User groups, a guides' association, a project steering committee, etc. were formed and its members were trained.

Tourism and wildlife observation infrastructure was established – including a visitor's centre, lodging, watch towers, etc. – and tourism activities were organised: Guides are trained, registered and organised into an association. They receive a fixed salary and accompany tourists in turns. Furthermore they support project technicians and researchers in monitoring giraffes and collaborate with the network of government-employed foresters, which has been set up to control the conservation of the habitat.

Tourists pay an entry fee for wildlife watching tours. The revenues and donations are partly used for management and conservation of the giraffe habitat and partly for socio-economic development of the villages (such as infrastructure projects). These revenues are managed directly by the '*communes*' (municipalities).

Thanks to the protection of the savanna vegetation through enclosures for regeneration, prohibition of cutting and closing down of rural wood markets the giraffe population has recovered considerably, comprising 200 individuals in 2008.

**SNV: Netherlands Development Agency; FFEM: French Fund for World Environment; EU: European Union*

Photo 1: Giraffes around the village of Kouré. (Ahmed Oumarou and ECOPAS*) * ECOsystèmes Protégés en Afrique Sahélienne

Type of approach
Project based (PURNKO - *Projet Utilisation des Ressources Naturelles de Kouré*)

Problems / constraints addressed
- Conflicts between giraffes and local population (damage to crops)
- Extinction of giraffes
- Deforestation (giraffe habitat deterioration)
- Rural poverty
- Negative perception of fauna by the population
- Absence of titled land ownership and of adapted forestry laws

Aims and objectives
- Durable and sustainable conservation of the giraffe population in the Kouré area and protection of their habitat.
- Building organisational and management capacity of the local population for protecting the giraffes.
- Fight against poverty by offering supplementary revenue to population through ecotourism (diversification of income).

Target groups
- Agropastoral land users (individuals / groups)
- SLM specialists / advisors
- Planners and decision-makers
- Tourists, women, artisans, teachers and students, national visitors

Participation and decision-making
Initiation: Ministries of planning, environment, tourism and artisan, EU, Association of French Volunteers for Progress (AFVP), SNV, beneficiaries
Planning / implementation: Kouré Guides Association (AGK), groups of beneficiaries, project advisors and animators
Monitoring / evaluation: AGK, groups of beneficiaries, project advisors and animators, department of Environmental Protection
Research: French Center for Agricultural Research for Development (CIRAD), University of Niamey, National Agricultural Research Institute of Niger (INRAN), International Union for Conservation of Nature (IUCN) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)

Implemented SLM / other activities
SLM measures: planting of palatable trees, semi-circular micro-catchments and planting pits for water harvesting, rill and gully rehabilitation, trenches, small dams, stone lines, enclosures and assisted natural regeneration
Other activities: health, education, infrastructure, trade, micro-credit, river works, forest surveillance

Implementing bodies
International institutions / agencies, national and local government, local communities, land users, researchers

Land users' motivation for implementing SLM
Increased revenue, profitability, improved livelihood

Case study area: Kouré, Tillabéri / Dosso region, Niger; 840 km² covered by approach

Costs and subsidies

Annual budget: US$ 189,000

Approach costs were met by the following contributors / donors:

International: EU	63,3%
International NGO: SNV	18,9%
International: FFEM	17,8%
TOTAL	**100%**

Remarks: Contribution of local populations hadn't been estimated.

Subsidies financed under the approach:

Externally financed inputs	
Labour of populations	not financed
Labour of project technicians	fully financed
Agricultural inputs & construction material	fully financed
Infrastructure (tourism, etc.)	fully financed
Village development funds	fully financed
Giraffe habitat management	fully financed

Access to credits

Through village development fund; micro-credit was allocated without interest to women of women groups for agriculture or livestock production. Repayment occurred after six months. After termination of the project, 'Care International' continued giving credit however with interest.

Repartition of revenues (2007)

Repartition of tourism revenues: 50% for local communities / villages, 30% for giraffe habitat management and 20% for the government.

Training and awareness raising

- Beneficiaries of training program: members of community management committee, land users (women and men), professional guides, advisors
- Form: on-the-job, farmer to farmer, demonstration areas, public meetings, courses, site visits and field trips
- Topics: Conservation technologies and SLM, ecotourism, professional guide skills, organisation of associations, accountancy, agriculture

Advisory service

Dissemination of the approach was by rural animation tools (village planning, rapid PRA, etc.). The Youth Association for Preservation of Natural Resources (AJPREN), U.S. Peace Corps, AFVP and local departments for Environmental Protection ensured a continuous programme of training, environmental education and awareness raising of guides and local people.

Research

Research had been conducted on-farm in collaboration with local populations. Research topics treated were socio- economical, ecological, technical, giraffe habitat and genetics and agricultural.

Organisation / capacity development

The second phase of the project (1996-1998) was entirely dedicated to organisational development including creation of a Monitoring Committee, a decentralised Development Board, a professional Association of Guides, an Informants Network, an Association of Artisans, women groups, 20 management committees of village development funds, etc. On one hand partners have implemented capacity building programmes to train the different stakeholders and on the other hand for financial and logistic support.

Benefits of SLM Approach

+++ Improved sustainable land management: one director for the planning and management of the giraffe area was appointed

+++ Adoption of Approach by other land users / projects: the *ECOsystèmes Protégés en Afrique Sahélienne* (ECOPAS) project adopted (2002) this approach which became the basis for national planning action for giraffes in Niger

+++ Improved livelihoods / human well-being: 3,811 €/village had been distributed to the population of 20 villages through village development funds

+++ Improved situation of socially / economically disadvantaged groups: financial support to women for agricultural production

+++ Poverty alleviation: creation of 13 permanent guide jobs; 900 woman developed agriculture production for marketing

+++ Other: conflicts mitigation (between giraffes and population)

Strengths

- Populations organisation and mobilisation
- Economic, financial and ecological impacts
- Scientific research tools for decision making

Weaknesses ➜ and how to overcome

- Absence of local and national financial contribution ➜ provide regressive grants and promote endogenous funding of activities.
- Approach resulted from exterior initiatives ➜ awareness raising and environmental education to develop 'conservation behaviour' in Niger.
- Uncontrolled fast growth of giraffe population ➜ transfer of giraffes to other protected habitats in West Africa.

Sustainability of activities

After the project was terminated, land users continued this approach without external support based on local development organisations, *Association pour la Sauvegarde des Giraffes du Niger* (ASGN) and Kouré Guides Association (AGK). Since 2002, the research component is being continued by ECOPAS / EU.

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Key references: Oumarou A. 2006. Elaboration d'une stratégie de conservation à long terme de la girafe au Niger, communication à l'atelier organisé du 22-24 novembre 2006 à Niamey (Niger) par le Ministère de l'environnement et de la lutte contre la désertification en partenariat avec ECOPAS / Union Européenne. ■ Compte rendu de l'atelier international sur la cogestion faune sauvage et bétail, organisé par Abdoulaye Sambo Soumaila et Marlis Lindecke, DED Niger et GTZ Eschborn, février 2001 ■ Graham R.T.1999. Rapport de consultation sur l'évaluation et l'appui à la cellule Faune du projet PURNKO, août 1999, Niamey, Niger

Hanspeter Liniger

SLM APPROACHES AND CASE STUDIES

Awareness of the best SLM technology options is a precondition for spreading SLM. However, how to implement and adapt these practices on the ground and how to create an enabling environment to facilitate this process is a major challenge. Despite continuous efforts over many years the spread and upscaling of SLM practices in SSA has been slow.

In the following section, successful experiences and promising current trends in approaches are presented, in order to assist land users under their specific conditions, and to help indicate what are the most favourable enabling environments for uptake of SLM practices. This is supported by six selected case studies illustrating the variety of approaches that underpin the trend towards successful implementation and adoption of SLM.

Land users and technicians planning SLM interventions in a watershed, Kenya. (Hanspeter Liniger)

In a nutshell

Definition: A SLM Approach defines the ways and means used to promote and implement a SLM Technology - be it project / programme initiated, an indigenous system, a local initiative / innovation - and to support it in achieving better and more widespread sustainable land management. It may include different levels of intervention, from the individual farm, through the community level, and the extension / advisory system at regional or national levels. It may be set within an international framework. Critical analyses of approaches should assist in answering questions about how land users learn about improvements or 'new' technologies, how they obtain skills to apply them, how they are stimulated to adapt technologies and innovate, and how they gain access to required inputs, equipment and financial resources.
A successful approach is usually characterised by being people-centred, responsive and participatory, practical, multilevel and multi-stakeholder, part of a partnership, sustainable (in its socio-economic, institutional and ecological dimensions) and dynamic.
An effective SLM Approach comprises the following elements: (1) participants / actors at all levels: policy-makers, administrators, experts, technicians, land users; (2) inputs: labour, material and financial, etc.; (3) know-how: technical, scientific, practical; and (4) the enabling environment: socio-cultural, legal and political (discussed in Part 1).
Approaches that have demonstrated success in SSA include: community-based natural resource management (*gestion des terroirs*), farmer field schools, *animation rural*, various approaches that support farmers' innovations, and the 'Landcare' Approach based on its success in Asia and Australia.

Problems addressed: Lack of technical knowledge, lack of cash to invest in SLM, limited access to inputs, conflicts over resource use, poverty, social inequity, lack of a supporting environment such as markets, prices, infrastructure and services, institutional support, with appropriate laws and regulations. These are intended to address the root causes of low agricultural production through stimulating the adoption and spread of improved SLM.

Intended beneficiaries: Individuals, communities, common interest groups, watershed / catchment / village associations.

Adoption and upscaling: Clearly identified causes of degradation and corrective measures, an enabling policy and regulatory environment are basics for the adoption of the most appropriate SLM measures. Furthermore, the extent of community involvement at different stages from problem identification to decision making and implementation will influence adoption and the potential of an approach to be upscaled. Land users or communities need to feel ownership or identify with the approach and the technology. Approaches and technologies need to go hand in hand and be matched: technologies influence the approach needed and vice-versa.

Development issues addressed are: Food security, rural, urban and peri-urban poverty alleviation, preventing and reversing land degradation, biodiversity and adaptation to climate change.

Distribution:
Participatory Research and Development: Ethiopia, Ghana, Kenya, Senegal, Sierra Leone, Tanzania, Uganda, Zambia;
Participatory Catchment Approaches and Community Based Natural Resource Management (CBNRM): Burkina Faso, Ghana, Kenya, Lesotho, Malawi, Niger, Tanzania, and Zambia;
Information and Communication Technologies (ICT): Kenya and Uganda;
Contracting Extension Services to NGOs and other third parties: promising in Madagascar and Mali;
Farmer Field Schools (FFS): large number of countries, recent developments in Eastern Africa;
Payment for Ecosystem Services: Ghana, Kenya, Tanzania and Uganda.

Evolution of SLM approaches

Approaches can be grouped into three major types: top-down interventions, farmer-first and trans-disciplinary. This typology reflects the broad evolution of approach types and methods over time.

Top-down interventions: Most of the early soil and water conservation - the forerunner of SLM - approaches in SSA during the colonial and immediate post-independence era focused on top-down interventions. These were characterised by lack of land user's participation and 'forced' implementation of externally developed measures (typically coercive terracing and compulsory destocking). In the associated conventional research and extension systems, a form of linear *Transfer of Technology* (ToT) indicated the one-way flow from researcher to extension worker to land users. This model viewed land users, extension agents and researchers as three separate levels with links in one direction only, and no feedback mechanism. In the 1950s and 1960s, the common explanation of non-adoption of technologies was that land users were ignorant. The answer was more *extension teaching*. In the 1970s and early 1980s non adoption by land users was attributed to farm level constraints. The 'cure' was to remove the constraints by input supply and introduction of *Farming Systems research* (FSR). During the late 1980s, and early 1990s the central role of land users was recognised and their non-adoption was explained by technologies that do not fit. The solution was to emphasise *land user participation*.

Farmer first: The new approach made the land user central to programme design and implementation of soil and water conservation activities. It stressed small-scale and bottom-up participatory interventions, often using indigenous technologies and largely rejected the 'conventional' transfer of technology (ToT) model (see above). New approaches based on collaboration between people with local knowledge and researchers developed and were put into practice. The difficulties of implementing land user-led participatory approaches have in turn led to a more focussed approach, in which farmer innovation is driven by the economic, social, institutional and policy environment. In the last few years, the concept has moved from soil conservation towards SLM both at the farm and landscape level. The focus now is on *empowerment of local community groups* by delegating authority, accountability and resources to the most appropriate level and focusing on local technologies.

Trans-disciplinary approach: Research and development is now widely seen as a 'holistic' learning process suggesting that it is a joint process requiring the participation of a wider range of stakeholders (*multi-level and multi-stakeholder*). More importantly, it redefines the role of local people from being merely recipients and beneficiaries to actors who influence and provide key inputs to the process; it links scientific and local knowledge in an interdisciplinary mode, emphasises multi-agency collaboration and is problem- and impact-driven.
However, SLM is often beyond the means, responsibility and decision-making power of single resource users. Instead of solely considering local needs the focus has to be expanded towards regional (watershed / landscape, upstream, downstream) and even national needs (for example irrigation schemes), which might restrict individual freedom of decision-making. At this higher level of intervention, interagency collaboration and the responsibilities of different ministries and institutions should be clearly defined and strengthened.

Main principles

Participatory (collaborative): Involving and giving land users / communities responsibility at all stages.
A participatory approach serves a number of important purposes:
– builds trust and understanding among stakeholders at local, regional and even national level;
– ensures that the perspectives and realities of the intended beneficiaries are accurately reflected;
– empowers marginalised and disadvantaged groups (downstream 'end' users, female land users, disaffected youth, members of minority ethnic groups, etc.);
– fosters ownership of both resources and the process – and thus increases the prospects for adoption.

Participatory methods are relevant from initial policy formulation and programme appraisal, through the different evaluation stages including implementation and improvement, and monitoring and impact assessment at later stages. Key elements are: awareness raising / capacity building, research, extension / advisory service, and organisational development. There is increased use of participatory methods in organisational strengthening, understanding and negotiation of stakeholders' perceptions and increased public accountability. Participatory methods attempt to deal with issues of ownership and control of knowledge, and to reach clarity or consensus between stakeholders as to how, by whom, and against what criteria, the programme is to be measured. Examples of approaches that are underpinned by a strong participatory philosophy are: participatory rural appraisal, participatory technology development and learning for sustainability.

Integrated (multilevel and multi-stakeholder): An integrated approach places people and supportive institutions at the centre of the management and development process, sustaining and enhancing both human and natural capital. Integrated approaches imply a shift from simply bringing together representatives of each sector or projects, towards having them absorb each others' messages and integrating these ideas into their own core work. It must involve researchers, extension agents, communicators and land users in a continuous and interactive way, with the objective of solving land users' problems, using local resources and personnel, and using equipment and buildings in a low-cost manner. Experience has also shown that integrated processes are assisted enormously when they are supported at the highest levels of government. Examples of integrated approaches are: landscape approach (integrated watershed management), livelihoods approach (integrated rural community development), and multi-stakeholder decision-making.

Partnership-based: In a collaborative approach the role of partnerships, platforms and coalitions is to mobilise scientific knowledge for agricultural investments that are pro-poor, pro-growth and pro-environment, to have more equitable partnerships by coupling science and traditional knowledge, achieve a common vision about SLM, provide the right framework to work together to develop policy, govern programs and share information and to target a broad spectrum of stakeholders: policymakers, civil society (NGOs), land users / owners, community-based organisations, research institutions, mass media, and the private sector. TerrAfrica is such a platform.
In addition to these principles and as with technologies, important criteria for an approach to be adopted, adapted and upscaled are that it should be relatively cheap, practical, flexible and sustainable.

Types

Approaches are basically social processes; they do not necessarily follow any systematic classification and there is no absolute best approach - though clearly some work better in certain situations than others. Approaches need to be developed - not selected, transferred or copied - depending on the situation, the people involved, objectives, possible solutions and resources available. In the following, established and contemporary, proven and promising approaches are briefly described:

Participatory Research and Development (PRD) is a pool of concepts and practices that enable people to enhance their knowledge of SLM and strengthens land users' innovative capacity. It is bottom-up, demand-driven and has partly evolved from efforts to improve technology development and dissemination. Participatory approaches are envisioned to (1) respond to problems, needs and opportunities identified by users; (2) identify and evaluate technology options that build on local knowledge and resources; (3) ensure that technical innovations are appropriate for local socio-economic, cultural and political contexts; and (4) promote wider sharing and use of agricultural innovations.

Participatory Learning and Action (PLA): This is a new, alternative name for what was initially (and still often is) termed PRD. Instead of outsiders trying to understand the knowledge of the local people, PLA tries to facilitate local people to develop their capabilities. The emphasis is on participation as a systemic learning process linked to action and change. PLA is the latest term for the basket of 'P' technologies including those that follow below.

Participatory Rural Appraisal (PRA): PRA is an approach developed mainly by NGOs. The approach aims at analysis by people themselves of their own realities and thus the incorporation of the knowledge and opinions of rural people in the planning and management of projects. It includes the use of transect walks, maps, calendars, matrices, and diagrams using locally available materials. PRA evolved from Rapid Rural Appraisal (RRA) - which was modified more in name than in nature as 'participation' was not thought to be compatible with 'rapid'.

Participatory Monitoring and Evaluation (PME) is primarily used in impact assessment and project management. Local people, community organisations, NGOs and other stakeholder agencies decide together how to measure results and what actions should follow once this information has been collected and analysed. It goes beyond the choice of particular methods and techniques to who initiates and undertakes the evaluation process and who learns or benefits from the findings.

Participatory Land Use Planning (PLUP) for planning of communal or common property land, which is particularly important in many communities where communal lands are the most seriously degraded and where conflicts over land use rights exist. Rather than trying to regulate communal lands through national policy, new arrangements can be regulated through negotiation among all stakeholders and communally binding rules for SLM, based on planning units, such as social units (e.g. village) or geographical units (e.g. watershed) can be developed.

Gestion des Terroirs is the best-known example of a **participatory catchment approach** in francophone West Africa. It associates groups and communities with a traditionally recognised land area, aiding these communities in building skills and developing local institutions for the implementation of sustainable management plans. It has focused on natural resource management at the village or community level through: (1) technical projects, such as those related to the conservation of soil, etc; (2) socio-economic factors related to the organisational structures within which people arrange their livelihood strategies; and (3) the legal system and its administration, by which use rights are enforced in practice.

Participatory and Negotiated Territorial Development (PNTD) is rural development through negotiation, participation and dialogue. Developed by FAO, the dialogue process starts with the establishment of international partnerships between the FAO and local government that will lead to the consolidation of a territorial social pact to overcome the social and economic inequalities that affect rural populations, for the eradication of hunger, and for the promotion of social inclusion.

Example: Zimbabwe

An Intermediate Technology Development Group project is located in southern Zimbabwe, where drought occurs in three out of every five years. The approach combines low-cost technologies (water harvesting and subsurface irrigation) with building farmers' capacities to participate in research, extension and within group structures. The benefits of the project, beside doubling the yield, include farmers having acquired new skills for food production; local institutions having been strengthened in tackling their own problems; training has increased confidence among local people, particularly poorest groups; there is increased involvement of women in community decision-making; there is also greater capacity amongst farmers to articulate their needs to service providers, and research and extension systems have become more responsive to farmers' needs (Pretty, 2001).

Top: *Gestion des Terroirs* meeting of village members and technical staff of a SLM project, Niger. (Hanspeter Liniger)
Middle: Participatory Planning with drums in a village, Ghana. (William Critchley)
Bottom: Community's participation at all stages. Treasurer of a forest management project in Niger. (Hamadou Mamoudou)

Community-Based Natural Resource Management (CBNRM): The nature of CBNRM is not simple to define. The concept is related to, and embraces, a variety of terms, including participatory, community, community-based, collaborative, joint and popular natural resource management. It tends to be associated with approaches where the focal unit for joint natural resource management is the local community and resources are subject to communal rights.
Decentralisation is a promising means of institutionalising and scaling-up the popular participation that makes CBNRM effective. However, most current 'decentralisation' reforms are characterised by insufficient transfer of powers to local institutions. Decentralisation reforms present the opportunity to move from a project-based approach toward legally institutionalised popular participation.

Landcare is a community-based approach focused on building social capital to voluntarily resolve local problems affecting the community while preserving land resources. The unique aspect of 'Landcare' is its effective partnership with government and the broader society, including the business sector, in the form of financial and technical advice. In this way, technical knowledge from scientific sources can be integrated with indigenous knowledge and the skills of local people. Although not yet common in SSA (found only in South Africa and Uganda) it is very promising.

Community development / investment funds: Part of a decentralisation policy often includes making funds available to communities for their own development efforts. Depending on the specific situation - which is a function of the donor, the country, and the local needs - the funds may be open or earmarked for specific purposes. The basic concept is that the community has sovereignty over these funds - in other words within a specific domain (for example agricultural intensification), the community decides how to use the funds. Commonly, when allocated to individuals they are paid back into the pool after a number of years, and thus form a local 'revolving fund'. Some such schemes broaden their scope and become, effectively, savings and credit schemes benefiting the community as a whole.

Extension, advisory service and training can be devided into:
1) 'Multiple strategy' which includes several or all of the following: awareness-raising, extension worker to farmer visits, training workshops and seminars around specific themes, exposure visits, hands-on training, and the use of demonstration plots. This is what is adopted by the majority of the project / programme-based approaches.
2) Informal farmer-to-farmer extension and exchange of ideas. Farmer-to-farmer transmission was the only form of 'extension' for thousands of years, and not only has it not died out, but it is being rejuvenated through progressive projects.
3) Trained 'local promoters' that become facilitators / extension workers under a project.
None of these are mutually exclusive. Investment in training and extension to support the capacity of land users and other local and national stakeholders is a priority to adapt better to changing environmental, social and economic conditions, and to stimulate innovation. Examples of innovative extension approaches are: Participatory Technology Development (PTD), Promoting Farmer Innovation (PFI), Participatory Innovation Development (PID) (an umbrella term now covering PFI); Training and Visit (T&V) for promoting technology packages developed by subject matter specialists, Information and Communication Technologies (ICTs), market driven extension, entrepreneurship to support value chains, etc.

Contracting extension services to NGOs and other third parties: NGOs are playing an evolving role in linking and bridging sectors. Many NGOs are forming strategic partnerships with government agencies, private sector and grassroots organisations, and strengthening their technical capacities for scaling-up successful initiatives while continuing to pilot innovative approaches. Over the past few decades, governments in SSA have shifted considerably, from viewing NGOs as a threat, to recognising their valuable role in grassroots implementation of public agendas, often filling gaps in government services and capacity.

Example: Community-Based Natural Resource Management (CBNRM)
In practice, CBNRM is mostly about ways in which the state can share rights and responsibilities regarding natural resources with local communities. At one end of the scale is community participation in protecting, for instance, a national park, without actually involving them in park management. At the other end of the scale is a complete handover of ownership of land and natural resources from the state to communities. Between these two extremes are joint management models, where representatives of the state, acting within the terms of negotiated contracts, manage a state-owned natural resource (for example a lake or forest reserve) together with one or several communities (DANIDA, 2007).

Example: Agroforestry Extension project, Malawi
The Agroforestry Extension project (MAFE) works with some 20,000 farmers on 4,200 hectares to encourage the adoption of various agroforestry practices within farms (e.g. undersowing of pigeon pea and sesbania in maize for soil fertility improvement). The project uses participatory approaches. Farmers are formed into farmer associations, trained as trainers and can ask for specific services from government and non-governmental organisations. As a result, maize yields have improved from 700 kg/ha to 1,500-2000 kg/ha, farmers have become less dependent on fertilizers and more households have become both food and woodfuel secure. Some 6.98 million trees were planted in 1999 by 1,155,900 households, and the project expects to see reduced pressure on natural forests as these mature (Pretty, 2001).


Savings and loans: micro-finance in Burkina Faso. (William Critchley)

Learning for Sustainability (LforS) is an innovative extension approach for facilitating group learning processes concerned with issues relevant to sustainable development. Its main characteristics are: group learning, learning in the local context, a multi-level and multi-stakeholder approach and an active, process-oriented and situated learning. LforS fosters an in-depth understanding of the local context by linking information, knowledge, perspectives and experience from different sources, and by focusing on the dynamics of a given system. LforS is a process-oriented approach that encourages participants to share with each other, to discover common interests and goals, and to develop their own visions.

Farmer Field Schools (FFS) for SLM (and 'farmer study circles' which are more informal) is a group learning approach which builds knowledge and capacity among land users to enable them diagnose their problems, identify solutions and develop plans and implement them with or without support from outside. The school brings together land users who live in the similar ecological settings and socio-economic and political situation. FFS provides opportunities for learning-by-doing. Extension workers, SLM specialists or trained land users facilitate the learning process.

Initiatives for supporting local innovators identify traditional practices with a SLM potential and support recent innovations (e.g. self-help groups, self teaching). Here the 'approach' is basically through transfer of knowledge within a community and through generations. Land users continuously adapt and experiment with new seeds and plants, as well as new practices and technologies, in order to cope with changing environments and new problems. Spontaneous spread may have occurred either recently or through the ages as a tradition. Adoption can be supported by local institutions / community organisations such as land user groups, marketing cooperatives, irrigation and range management associations, women's groups, land user to land user extension groups etc. More attention and support should be given to local innovation as well as to traditional systems, rather than focusing solely on project-based SLM implementation of standard technologies.

Integrated watershed management (IWM) approach aims to improve both private and communal livelihood benefits from wide-ranging technological and institutional interventions. The concept of IWM goes beyond traditional integrated technical interventions for soil and water conservation, to include proper institutional arrangements for collective action and market related innovations that support and diversify livelihoods. This concept ties together the biophysical notion of a watershed as a hydrological landscape unit with that of community and institutional factors that regulate local demand and determine the viability and sustainability of such interventions (i.e. SLM).

Payment for Ecosystem Services (PES) is a rather new approach and carbon markets in particular, offer incentives to mobilise investments to conserve or rebuild forests and vegetative cover, in favor of higher biomass, higher productivity, sustainable agriculture and resilience to climate change. A UNDP and UNEP CDM capacity-building project includes Ethiopia, Kenya and Tanzania.
The Clean Development Mechanism (CDM) allows emission-reduction (or emission removal) projects in developing countries to earn certified emission reduction (CER) credits, each equivalent to one tonne of CO_2. These CERs can be traded and sold, and used by industrialised countries to meet a part of their emission reduction targets under the Kyoto Protocol. The mechanism stimulates sustainable development and emission reductions, while giving industrialised countries some flexibility in how they meet their emission reduction / limitation targets.
Other projects are: payments for Reduced Emissions from Deforestation and Degradation (REDD), pro-Poor Rewards for Environmental Services in Africa (PRESA) is providing technical and policy support to small-holder PES projects.

Top: Participants of a training workshop in Mali playing the LforS simulation game 'Sustainable household strategies and community development'. (Ernst Gabathuler)
Middle 1: Learning for Sustainability workshop in a shifting cultivation, Madagascar. (Andreas Kläy)
Middle 2: Farmer Field School on fertilizer micro-dosing in upper east Ghana. (William Critchley)
Bottom: A Farmer Field School group in Bassodawish, Tanzania reflecting on Conservation Agriculture. (Photo CPAR)

Adoption and upscaling

Adoption rate

Participation of land users / communities has often remained wishful thinking due to conflicts and a habitude to adopting a passive role. Under pressure of success, institutions fall back into instruction-oriented behaviour and a lack in confidence in the rural population. Almost the only field of sustained effective extension has been with single commodity approaches for cotton, maize, tea, etc. Nonetheless, participatory approaches are gradually gaining ground across the institutional landscape – from research and academic organisations to NGOs, development agencies, and local government units.

Upscaling

Field experiences show that for innovations to be sustainable there is a need to address not only the technological but also the socio-cultural, political, economic dimensions such as: community structures, gender, collective action, property rights, land tenure, power relations, policy and governance.

However, public sector research and extension, due to several constraints - including financial - are generally unable to develop technologies tailored to a set of individual local conditions (agro-ecological and cultural preferences) hence often produce poorly focused recommendations. The future of extension is in decentralisation of technology testing in highly diverse environments, or in participatory research with land users (inter-disciplinary).

Continuous innovation has been carried out by farmers for millennia. Enabling external institutions, such as NGOs, can play a supportive role in stimulating processes of open discussion and conflict resolution. Researchers and extension workers can further stimulate the ongoing process of innovation and give it a new dimension.

Methods and key elements of technical support

- *Awareness raising*
- *Creating opportunities for information exchange*
- *Using appropriate technologies for information and communication*
- *Training and capacity building*
- *Organisational development*
- *Advisory service*
- *Research*
- *Networking*

Participatory rural appraisal: sharing experiences between Ethiopia, Ghana and Uganda. (William Critchley)

References and supporting information:

Asiabaka, C. C., 2002. Promoting sustainable extension approaches: Farmer field school (FFS) and its role in sustainable agricultural development in Africa. Int. J. of Agri. and Rural Dev.; 3(46-53).

Bass, S., S. J. Scherr, Y. Renard, S. Shames. 2009. New Directions for Integrating Environment and Development in East Africa: Key Findings from Consultations with Stakeholders in Ethiopia, Kenya, Tanzania, and Uganda. Ecoagriculture Discussion Paper no. 3. Washington, D.C., Ecoagriculture Partners.

Baumann, P., M. Bruno, D. Cleary, O. Dubois and X. Flores. 2004. Applying people centred development approaches within FAO - Some practical lessons. LSP Working Paper 15. FAO.

Curtis, M., 2007. Deadly Combination: The Role of Southern Governments and the World Bank in the Rise of Hunger. Understanding the Issue (2/2007).

Critchley, W., 2007. Working with Farmer Innovators. CTA.

DANIDA., 2007. Community-based natural resource management. Technical Note. http://www.danidadevforum.um.dk/en/servicemenu/News/CommunityBasedNaturalManagement.htm

Eicher, C. K., 2007. Agricultural extension in Africa and Asia. Staff Papers 7431, Michigan State University, Department of Agricultural, Food, and Resource Economics.

FAO. 2008. Farmer field schools on land and water management in Africa. Proceedings of an international workshop in Jinja, Uganda. 24–29 April, 2006.

Gonsalves, J., T. Becker, A. Braun, D. Campilan, H. De Chavez, E. Fajber, M. Kapiriri, J. Rivaca-Caminade and R. Vernooy (eds). 2005. Participatory Research and Development for Sustainable Agriculture and Natural Resource Management: A Sourcebook. Volume 1: Understanding Participatory Research and Development. International Potato Center - Users' Perspectives with Agricultural Research and Development, Laguna, Philippines and International Development Research Centre, Ottawa, Canada.

Hatcher, J., 2008. Dialogue, consensus and vision – PNTD more than a methodology: a strategy for territorial interaction and integration (edited by P. Groppo, FAO). Land and Water Division, FAO.

Hurni, H., 1996. Precious Earth - From soil and water conservation to sustainable land management. Geographica Bernensia.

Liniger, H.,1995. Endagered water, a global overview of degradation, conflicts and strategies for improvement. CDE.

Pretty, J., 2001. Compendium of Land and SARD Cases: Supporting Document to Task Managers' Report to CSD+10 on the Land and Agriculture Cluster for Chapters 10, 12 and 14 of Agenda 21. Compendium of Land and SARD Cases: April 2001.

Shiferaw, B. A., J. Okello and R. V. Reddy. 2009. Adoption and adaptation of natural resource management innovations in smallholder agriculture: reflections on key lessons and best practices. Environ Dev Sustain (2009) 11:601–619.

WOCAT. 2007. Where the land is greener-case studies and analysis of soil and water conservation initiatives worldwide. Editors: Hanspeter Liniger and William Critchley.

WOCAT. 2008. A Framework for documentation and evaluation of sustainable land management Approaches – basic. WOCAT questionnaire.

STRATÉGIE ENERGIE DOMESTIQUE - NIGER

The SED approach (*Stratégie Energie Domestique*: domestic energy strategy) aims at sustainable management of forest resources by delegating responsibility to the communities and increasing their sense of stewardship. The approach was used within PAFN (*Project d' Aménagement des Forets Naturelles*) a long term project in Niger for the management of natural forests. The local people are organised to manage and protect forest resources. On the one hand they carry out controlled, intensive cutting of trees and use of other forest products (gum arabic, honey, fruits, doum palm leaves etc). On the other hand the communities are committed to sustainably managing the forests through SLM technologies, ensuring long term preservation and regeneration of forest resources and maintenance of ecosystem services. Rural wood markets created by the project facilitate wood supply for urban centres and generate permanent income for the rural communities, thus improving their livelihoods. Part of the income is reinvested in sustainable forest management practices. The main aims of the approach are to simultaneously expand woodland areas, enhance controlled cutting, assure provision of urban centres with wood, and guarantee a permanent source of income for rural communities living near the forests. The approach is based on participatory methods, involving local actors at all stages of the project and handing over of major responsibilities to the communities.

The main operational unit of the approach is the so-called SLG (*structures locales de gestion*), a committee at community level, which is responsible for resource management, execution of development activities, monitoring and evaluation and sustainability of investments. Setting-up these organisational structures, as well as training and capacity building of its members is carried out by the project. Once the SLGs are established, planning of development activities and elaboration of forest management plans (PAF) and village forest management plans (PVAF) is done. Then, concrete activities are implemented: establishment of rural wood markets; commercialisation of wood and forest products; establishment of village development funds; implementation of SLM activities. Local people implement project activities at field level. The SLGs are the institutional beneficiaries of the approach, they participate in the management of generated income (e.g. taxes on products sold) and in turn support the mobilisation of local communities. The project provides technical and financial support (for village development funds earmarked for infrastructure projects). A Committee for Science and Technology (CST) with experts from CIRAD France and University of Niamey supervised programme implementation.

Type of approach
Project / programme based

Problems / constraints addressed
– Overuse of fragile natural resources through uncontrolled cutting of trees
– Conflict over natural resources between pastoralists (*Peulhs*) and agropastoralists, lack of social cohesion, exclusion of women
– Lack of financial resources
– Lack of land titles and inadequate laws
– Weak organisational capacity and technical expertise

Aims and objectives
– Stop uncontrolled exploitation of forest resources and increase the population's stewardship of their land
– Ensure fuelwood supply for large population centres (e.g. Maradi, Niamey)
– Combat poverty by providing additional sources of income in the form of new rural wood markets

Target groups
– Land user(s), pastoralists, women, loggers and local merchants
– SLM specialists and advisors, planers and decision makers, teachers and students

Participation and decision-making
National and sub-regional governmental institutions, partnering national NGOs and communities were in charge of managing the project. Planning as well as monitoring and evaluation was done by regional and sub-regional committees (*comités de suivi et évaluation*), NGOs and SLGs. Decision regarding choice of SLM technologies was taken by specialists, after consulting with communities and land users. The implementation was done by the SLG with support from field technicians.

Implemented SLM / other activities
SLM measures: enclosures, natural regeneration (e.g. *Acacia alibida*), vegetative strips (trees / shrubs, fodder plants, grass), stone lines, half-moons, passage ways, mulching with straw and branches, selective clearing, fire control, etc.
Other activities: health, education, infrastructure, trade and markets, micro-credits, gardening, poultry farming, beekeeping

Implementing bodies
International institutions together with national / local government, national NGOs, private sector, local communities and land users

Land users' motivation for implementing SLM
Increased revenue, improved livelihoods, payments / subsidies, environmental awareness / health

Photo 1: *Marché de bois* – firewood market of Awanchalla,Illéla,Tahoua.
Photo 2: Training of SLG members. (All photos by Hamadou Mamoudou)

Case study area: natural forests in Niger; 3,723 km² covered by the approach

Costs and subsidies

Annual budget: 1,915,061 US$/year

Approach costs were met by the following contributors / donors:

International institution / agency	89,9%
National government	9%
Local community, land users	1,1%
TOTAL	**100%**

Remarks: African Development Fund, Niger Ministry of Environment / national departments of environment, beneficiaries (SLG)

Subsidies financed under the approach:

Externally financed inputs	
Labour	partly financed
Agricultural inputs	partly financed
Construction material	fully financed
Infrastructure	fully financed
Training, research	fully financed
Project management (technicians, advisors, monitoring, steering, etc.)	fully financed

Remarks: Labour for SLM technologies is an in-kind contribution from the local people. But labour of development activities was paid by the project. Agricultural inputs: seeds, seedlings, imported fertilizers were paid by the project. Seeds collected in the forest and organic fertilizers were supplied by the beneficiaries.

Access to credits

Credits were (mainly) given to women for 'income-generating activities' (fodder, buying of fertilizers, marketing and small trade activities). They were set for six months with an annual interest rate of 20%. Credits were managed by two micro-finance institutions (SICR Kokari, MCPEC).

Training and awareness raising

- Training was provided for the managers of SLGs, advisors, field technicians (NGOs and government) and land user(s). Twelve by the project trained rural animators continued to train SLG members and local animators in the villages.
- Form: On-the-job learning, site visits, farmer-to-farmer, demonstration areas, public meetings, courses, field trips.
- Topics: SLGs approach and organisation, planning at village level, forest law, principles and measures of sustainable forest resource management, management of rural wood markets and of village development funds, methods of rural animation and literacy campaigns.

Advisory service

Extension is provided by NGOs (Karkara, ABC Ecologie) and governmental technical services (at regional and sub-regional level) who work directly with the land users. The methods used are training workshops, training of trainers, monitoring and evaluation as well as Rapid Rural Appraisal (RRA). Financial and material support for inputs are offered.

Research

Research was conducted by the *Institut National de Recherche Agronomique du Niger* (INRAN), University of Niamey, CIRAD France, and local communities. It covered: agro-economy, institutional and energy aspects, training and communication, sociology, forestry and pastoral infrastructure, environmental monitoring, credit systems.

Organisation / capacity development

In each village a local forest management body (*Structure Locale de Gestion* - SLG) was established. All in all there are 113 SLGs. In addition 12 rural markets (9 for doum palm leaves and 3 for gum arabic) were established, each managed by a SLG.

Benefits of SLM Approach

+++ Improved sustainable land management: 6 PAF and 110 PVAF were elaborated and applied by the communities.

+++ Adoption of approach by other land users / projects: The SED has become an integrated part of '*Programme National pour un Environnement et un Développement Durable*' funded by UNDP. Since 2005, all environmental projects have a SED component.

+++ Improved livelihoods / human well-being: 24 school rooms and 4 wells were financed; more than US$ 200,000 of credits were distributed to 2,660 men and women from 2004-2006, etc.

+++ Improved situation of socially / economically disadvantaged groups: pastoralists, women, loggers.

+++ Poverty alleviation: Production and commercialisation activities increased income in the project zone by over 100%.

Strengths

- Organisation and training of local communities
- Enhancing local income and level of economic activity
- Decision support for sustainable management of natural resources (e.g. maps, scientific monitoring methods)

Weaknesses ➜ and how to overcome

- Requires substantial financial and technical means ➜ enhance in-kind contributions from local communities.
- Energy and deforestation problems are not solved sustainably ➜ substitute fuelwood by a more sustainable source of energy.
- Long term control of forest exploitation is needed ➜ establish permanent bodies for ecological monitoring.

Sustainability of activities

The local communities continue implementing the approach without external support; cutting of trees is controlled by the water and forestry department to avoid uncontrolled logging.

Main contributors: Abdoulaye Sambo Soumaila, Groupe de Recherche d'Etude et d'Action pour le Développement (GREAD), Niamey, Niger ; leffnig@yahoo.fr

Key references: Rapport d'achèvement du projet PAFN, Cellule de gestion du PAFN, Décembre 2006 ■ Rapport d'évaluation du PAFN, document de projet soumis au FAD, Rapport de mission internationale, Juin 1998 Manuel de planification et de suivi-évaluation, Cellule de gestion PAFN, Novembre 2002 ■ fiches de suivi du projet, 2002-2006 ■ Kimba Hassane. 2003. Talatou Harouna: Protocole de suivi environnemental, septembre 2003 ■ Bützler W. 2003. Expertise en Faune et Biodiversité, Rapport de la mission d'appui Août - Septembre 2003.

PROMOTING FARMER INNOVATION - KENYA, TANZANIA, UGANDA

The objective of Promoting Farmer Innovation (PFI) is to stimulate technical innovation, in the field of land management, by farmers. The PFI approach seeks to build on technical initiatives – 'innovations' in the local context - developed by farmers themselves in dry / marginal areas where the conventional approach of 'transfer of technology' from research to extension agents, and then on to farmers, has so often failed.

The approach basically comprises identifying, validating and documenting local innovations / initiatives. Simple monitoring and evaluation systems are set up amongst those innovative farmers who are willing to co-operate. Through contact with researchers, extra value is added to these techniques where possible. Farmer innovators are brought together to share ideas. Finally, 'best-bet' technologies, in other words those that are considered to be good enough to be shared, are disseminated through farmer-to-farmer extension. This takes two forms. First, farmers are brought to visit the innovators in their farms. Secondly, farmer innovators are used as teachers / trainers to visit groups of farmers – including FAO's 'farmer field schools' in some cases. Only in this second form of extension is an allowance payable to the innovator. A ten-step field activity methodology has been developed (see figure 1).

At programme level, there is capacity building of in-line extension and research staff, who are the main outside actors in the programme. In each of the countries the approach has been implemented through a government ministry and with NGOs in the field. The principle, and practice, is not to create separate project enclaves, but to work through existing personnel, sharing buildings and vehicles that are already operational in the area. A 'programme development process' methodological framework shows how the ultimate goal of institutionalisation can be achieved (see figure 2). PFI's first phase, completed in 2000, was financed by the Government of The Netherlands, through UNDP, and was active in Kenya, Tanzania and Uganda.

PFI is a potentially important direction for research and extension in SSA. Its principles have been taken up by, amongst others, the UNEP-GEF funded 'Stimulating Community Initiatives in Sustainable Land Management' project.

Figure 1

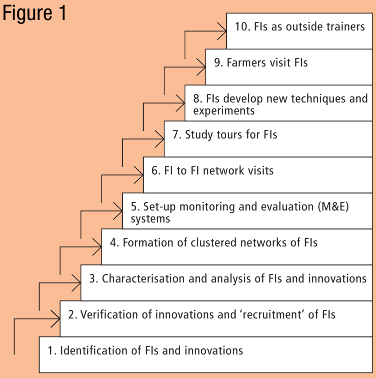
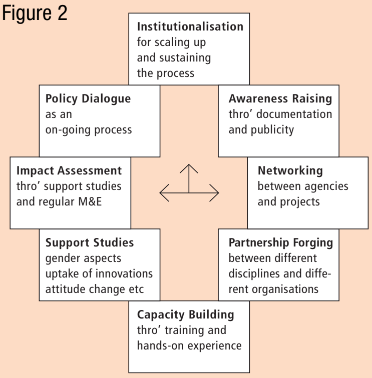


Figure 2



Type of approach
Recent local innovation (stimulated by project)

Problems / constraints addressed
– Poor supply of relevant recommendations from research for small-scale farmers in marginal areas
– Poor delivery of SLM technologies (where they exist) to farmers
– Lack of motivation of research and extension staff
– Isolation of promising 'innovative' SLM ideas which address low crop yields, land degradation and poverty
– Lack of exchange of innovative knowledge

Aims and objectives
Improve rural livelihoods through an increase in the rate of diffusion of appropriate SLM / water harvesting technologies.
– Promotion of farmer-farmer exchange
– Capacity building of farmers and supporting organisations
– Promotion of policy dialogue

Target groups
Land users, SLM specialists / agricultural advisors, planners, politicians / decision-makers

Participation and decision-making
'Best –bet' technologies were pre-selected by extension agents / researchers based on innovative farmers' technologies identified in the field – but the farmers chose which technology to implement.

Implemented SLM / other activities
– SLM measures: runoff harvesting, gully control, composting, etc.
– The approach focussed on SLM only

Implementing bodies
National governments, national NGOs, and land users

Land users' motivation for implementing SLM
Increased production, profitability; improved livelihoods; learning from innovative colleagues

Photo 1: 'Stimulating Community Initiatives in Sustainable Land Management' – a project that follows the PFI methodology: active in Ghana (pictured), Morocco, South Africa and Uganda. (William Critchley)
Figure 1: Field activities: the ten steps - from identification through to using innovators as trainers. (Critchley, 2000)
Figure 2: Programme development processes: the framework of a farmer innovation programme. (Critchley, 2000)
Acronyms: FI: Farmer Innovator, M&E: Monitoring and Evaluation

Case study area: East Africa (parts of Kenya, Tanzania and Uganda); 15,000 km² covered by the approach. Map shows case study area in the districts of Soroti, Kumi and Katakwi, Uganda.

Costs and subsidies

Annual budget: No estimates available

Approach costs were met by the following contributors / donors:

International institution / agency	60%
National government	20%
International NGO	–
National NGO	–
Private sector	–
Local government	–
Local community, land users	20%
TOTAL	**100%**

Subsidies financed under the approach:

Externally financed inputs	
Labour	not financed
Equipment / tools	not financed
Agricultural inputs	partly financed (planting material)
Construction material	not financed
Infrastructure	na
Other	meals during field days, small allowances on study tours

Access to credits

Credits were not provided.

Training and awareness raising

Staff seconded from Ministries of Agriculture / NGOs provide: (1) methodology training for participating staff; (2) presentational skill training for farmer innovators and; (3) training in gender aspects. Training has proved very effective – partially because it was provided on a 'response to need' basis and not predetermined.

Advisory service

Under this approach there are new roles for government / NGO extension staff - as trainers and facilitators. Substantive extension work is carried out by the innovators themselves, through (a) other farmers visiting their plots / homes, and (b) the innovators going outside to act as trainers themselves, either to individual farmers or to train groups as happens under PFI Kenya, through FAO supported 'farmer field schools'. Farmer-to-farmer extension has been a main strength of the programme.

Research

Apart from process monitoring of the methodology, which has led to improvements, technical research into the innovations has been relatively weak.

Organisation / capacity development

The approach had an articulated 'Programme Development Process' procedure, starting with capacity building and moving upwards through networking, impact assessment and awareness raising, towards the final goal of 'Institutionalisation'.

Benefits of SLM Approach

+++ Improved sustainable land management: leads to improved production and soil and water conservation.

++ Adoption of approach by other land users / projects: In each of the three countries Government and NGOs adopted at least certain elements of the approach. UNDP and FAO in Kenya set up a joint 'PFI-Farmer Field School' project.

+++ Improved livelihoods / human well-being: All the innovations were directly related to better livelihoods (as demonstrated in an 'monitoring & assessment' exercise).

+++ Improved situation of socially / economically disadvantaged groups: After evaluation at the end of the first phase a gender-proactive policy (which worked well) was put in place to increase the number of women innovators involved.

+++ Poverty alleviation: The project focussed on poor, small-scale farmers in dry areas.

Strengths

- Builds on local ideas
- Revitalises the extension service
- Is attractive to stakeholders at all levels
- Gives land users more confidence in their own abilities
- Offers new locally tested ideas / technologies which work

Weaknesses ➜ and how to overcome

- Dependent on individual commitment and flexibility; does not follow the conventional institutional chain of command ➜ training in skills and methodologies.
- Sometime confers too much prestige on a particular group of 'favoured farmers' ➜ 'rotate' farmers who are the focus of attention.
- Researchers reluctant to respond to farmers' agenda ➜ effort to convince researchers of benefits of joint research with farmers.

Sustainability of activities

There are examples of spontaneous voluntary continuation of farmer innovator groups in all three countries – but on a reduced level after initial project support ended.

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Key references: Critchley W. 2000. Inquiry, initiatives, and inventiveness: farmer innovators in East Africa. Phs Chem Earth (B), Vol 25, no3, pp 285-288 ■ Critchley W. and K. Mutunga. 2003. Local innovation in a global context: documenting farmer initiatives in land husbandry through WOCAT. Land Degradation and Development (14) pp 143 – 162.

FARMER FIELD SCHOOLS - KENYA

A Farmer Field School (FFS) is a community-based practically-oriented field study programme. It is usually a time-bound activity (generally one agricultural production cycle), involving a group (commonly 20-30) of farmers, facilitated by agricultural advisors or – increasingly – by other farmers. The FFS provides an opportunity for farmers to learn together, using practical, hands-on methods of discovery-based and participatory learning. The methods emphasise observation, discussion, analysis, collective decision-making, presentation and taking appropriate action. Discussion and analysis are important ways to combine local indigenous knowledge with new concepts and bring both into decision-making. The aim is to develop participants' decision-making and problem solving capacity among farmers. The process builds self-confidence (particularly for women), encourages group control of the process, and builds management and leadership skills. Although FFS are time-bound, many groups formalise their relations and continue study or action projects, including FFS on other subjects, after the FFS learning cycle is completed.
The Farmer Field Schools on Integrated Land and Water Management (ILWM) in eastern and central Kenya focus on learning about how to improve management of land and water resources both on individual plot and farm level and within 'landscapes' and communal lands; including local watersheds, river-valleys, forested hill-tops, grazing lands, eroded gullies etc. Each FFS group experiments practically on selected SLM practices / measures. All learning takes place in the field and farmers usually meet once per week at a selected host farm in their locality to monitor their field experiments and to discuss emerging issues. Trained facilitators, usually agricultural advisors, guide farmers in their observation and analysis of what is taking place in the field. Local farmer innovations are identified to feed indigenous knowledge into the FFS process: Innovators visit FFS groups or FFS members visit innovators farms to share their knowledge. The FFS process combined with the promotion of farmer innovation has proven to contribute to strong and cohesive groups that are able to make informed decisions and change cultural and practical behaviour in order to improve their production and land management. The process also builds self-confidence, and empowers especially women to take on leadership roles in the community. The impacts observed of FFS thus have strong biophysical and social dimensions.

Type of approach
Project / programme based

Problems / constraints addressed
- Land degradation, climatic variability and loss of agricultural biodiversity
- Farmers focus on their own farms and income and lack of interest for wider watershed / environment

Aims and objectives
- Support farmers' knowledge levels and decision-making capacity in relation to sustainable land and water management
- Raise farmers' yields in a sustainable manner and ultimately contribute to increased net farm income
- Strengthen community organisation and collective efforts

Target groups
Land users and small-scale farmers / SLM specialists / public rural and agricultural advisors

Participation and decision-making
The land users are actively involved in all phases of the approach and the learning curriculum is based on the problems identified by the group. Each group has its own leadership and management structure and handles its own funds. Extension staff serves as facilitators rather than teachers and focus on methodological aspects of the FFS approach. The technical scope of the learning is determined by the group and specific technical support brought in as needed.

Implemented SLM / other activities
- SLM measures: conservation agriculture, water harvesting, mulching, green manures, improved pasture, composting, integrated plant nutrient management, enhancing on farm biodiversity, etc.
- The approach focuses also on community organisational building for collective action and collective storage and marketing of products.

Implementing bodies
The Food and Agriculture Organisation (FAO) of the UN in collaboration with the Ministry of Agriculture in Kenya

Land users' motivation for implementing SLM
Increased production levels; increased income; also prestige and status in the community (affiliation to a group / network); friendship and collective spirit among group members (especially women)

Photo 1: A FFS group in Nakuru Kenya, monitoring their water harvesting trials in maize during a regular learning session.
Photo 2: A FFS group on a study visit to the Kenya Institute of Organic Farming, Thika.
Photo 3: Training of facilitators in Mwingi and practice on how to use the infiltration ring for measurement of the soil infiltration rate. (All photos by Deborah Duveskog)

Case study area: Eastern and Central Kenya; Mwingi, Kitui and Nakuru Districts

Costs and subsidies

Annual budget: about 100,000 US$

Approach costs were met by the following contributors / donors:

International institution / agency	60 %
National government	20 %
International NGO	–
National NGO	–
Private sector	–
Local government	–
Local community, land users*	20 %
TOTAL	**100%**

Remarks: Community contributions included provision of land, manure, fencing materials, tools etc. and weekly contributions to the group savings account.

Subsidies financed under the approach:

Externally financed inputs	
Labour	not financed
Equipment / tools	fully financed
Agricultural inputs	partly financed
Construction material	not financed
Infrastructure	not financed
Learning materials	partly financed

Remarks: Funding for group level learning; materials and farm inputs were given directly to the group as a grant for them to manage.

Access to credits

No access to credits provided through the approach.

Training and awareness raising

- Agricultural advisors were trained in the FFS approach and in ILWM topics through a total of four weeks of training.
- Farmers were trained in FFS through season-long FFS learning where farmers meet at a 'host-farm' weekly to carry study activities.
- All the training was of practical nature with hands-on practice in the field on the learning subjects, including site visits to farmers and tours to centres of expertise.
- All aspects of ILWM topics were covered in the training.

Advisory service

- Participatory extension with season-long regular interaction between farmers and agricultural advisors. At a later stage also strong farmer-to-farmer extension.
- The approach requires an attitude shift among agricultural extension workers to become more client-orientated.

Research

- Local researchers were involved at the start-up of FFS groups for the sake of providing technical advice as well as to capture farmers' demands for future research priorities.

Organisation / capacity development

- Through the FFS cycle participants develop skills in financial management, leadership, organisational management etc. that form the basis for effective institutional capacity.
- FFS groups regularly interact and visit each other which has led to the creation of networks of federated FFS groups that in many cases have developed into local farmer associations or producer organisations.

Benefits of SLM Approach

+++ Improved sustainable land management: yield increase of more than 200% has been recorded frequently.

+++ Improved livelihoods / human well-being: improved gender relations and division of farm workload, resistance to drought and improved livelihoods and life satisfaction in general.

++ Adoption of approach by other land users / projects: the applied practices have spread from participants to neighbours in the community.

++ Poverty alleviation: all participants fall in the poor or medium poor category and therefore the project has contributed to reduced poverty levels.

Strengths

- The collective action created in communities to deal with and manage their own resources.
- Improved capacity of farmers for problem solving and innovation in ILWM.

Weaknesses ➜ and how to overcome

- A top-down and patronising attitude towards farmers is common among agricultural staff and experts, which prevents equal and trustful relationships ➜ institutionalisation of participatory extension is thus needed with a change in mindset among government and other agricultural support staff.
- The various government bodies and ministries responsible for land and water issues often operate individually without strong synergies ➜ a stronger collaboration is needed between ministries especially Ministry of Water and Ministry of Agriculture in order to deal effectively with land and water aspects in an integrated manner.

Sustainability of activities

Graduated FFS groups have organised themselves into a network and farmer organisations that have taken on collective activities following the end of the initial project. In some cases this has included starting-up self-financed new FFS groups.

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Key references: Duveskog D. 2001. Adapted from A Study Guide for Farmer Field Schools: Water Harvesting and Soil Moisture Retention. ■ FAO-IIRR. 2006. Discovery-based Learning on Land and Water Management: Practical Guide for Farmer Field Schools.

PARTICIPATORY NEGOTIATED TERRITORIAL DEVELOPMENT - BURKINA FASO AND GHANA

Participatory Negotiated Territorial Development (PNTD) is a rural development approach developed by FAO. It offers a structure to build consensus among individual communities and development partners on natural resources / territorial management and development issues. PNTD facilitates consensus based planning within a team that represents different actors at different levels, including sector offices / technical services (agriculture, environment, etc.) and NGOs (involved in community-based rural development) at district / department / municipality level; and traditional authorities, user groups and associations at community / village level.

During the diagnostic phase of the PNTD process, local territorial issues are analysed based on the viewpoints of the different actors and on a historical analysis. This step contributes to a coherent, shared understanding of the territorial system, thus providing the basis for collective agreements on development. These are referred to as Social Territorial Agreements. They are based on negotiation within the PNTD team. Main activities of PNTD include: (1) Facilitation of the planning process; (2) Provision of technical expertise; (3) Linkages to relevant institutions; (4) Technical advisory to assess viability and costs of joint development proposals; (5) Reporting back to communities and provision with final plans and resource maps; (6) Signing of 'Social Territorial Agreements' and endorsement by local government; (7) Establishment of a joint monitoring and evaluation system; and (8) Follow-up meetings between government institutions and NGOs.

Independent external support by territorial facilitators is essential to assist in various aspects of the process. A PNTD approach was piloted within a project in the Onchocerciasis (riverblindess) Freed Zone along the Burkina Faso-Ghana border. This newly opened zone lacked a well defined, accepted management structure to support the development process, while cross-border aspects further complicated development, requiring cooperation among the communities and development partners from both countries. The PNTD team was supported by facilitators from the Netherlands Development Organisation (SNV). The team's capacity to carry out inclusive planning processes has improved significantly, in terms of proposal development, negotiation and consensus building, and in placing the findings of the diagnostic phase in the larger geographical context. Joint development plans were elaborated and agreed upon from the perspective of the communities. FAO has been supporting the exercise through technical backstopping.

Conceptual principles of PNTD	
Territorial based:	Social territories (shaped by the social and historical relations between the actors and the territory) are the spatial units of analysis.
Actor based:	Recognition of the heterogeneity of the actors' interests and vision of the territory.
Dynamic:	Understanding of and learning from the changing context and complexity of interactions to support positive patterns and mitigate negative patterns.
Systemic:	Appreciation of the interdependencies within and between territories and their components.
Multi-sectoral:	Integration of environmental, social, economic, political and cultural aspects.
Multi-level:	Recognition of different territorial levels and administrative levels.
Participatory and negotiated	Agreements are developed on the basis of consensus and equal representation of all stakeholders.

Type of approach
Project based

Problems / constraints addressed
– Limited commitment from central governments
– Cross-border planning proved to be considerably more expensive than regular planning activities

Aims and objectives
– Testing a PNTD approach for local (transboundary) territorial planning
– Refining the methodological process
– Preparing a joint development plan for the two areas in Ghana and Burkina Faso

Target groups
Local government (district / department), NGO trainers, community leaders; OFZP national coordinators plus ECOWAS-FAO (Economic Community of West African States) project managers

Participation and decision-making
Initial stakeholder meeting with government representatives, traditional authorities and NGOs was held to introduce PNTD, define pilot area, set composition and tasks of the PNTD team, revise timeframe. Decisions on priority activities were negotiated first within each community and then among communities of the two countries. The PNTD team members acted as facilitators of this process.

Implemented SLM / other activities
– SLM measures: re-forestation, improved livestock rearing, soil conservation, dam construction (between two communities)
– Other activities: a road to link two communities directly

Implementing bodies
SNV (Netherlands Development Organisation) Burkina Faso, SNV Ghana, international and national NGOs

Land users' motivation for implementing SLM
Social pressure (avoiding potential transboundary conflicts) and improving natural resources and land management

Photo left: PNTD can help tackle problems related to territorial disputes and natural resource management. (SNV, Ghana)
Photo right: Dialogue, negotiation and consultation the most significant elements of PNTD. (SNV, Burkina Faso)

Case study area: pilot area covering four communities: Barre and Narquia in the Zecco and Ziou Departements, Nahouri Province, Burkina Faso; and Namoo and Feo, Bongo district in the Upper East Region of Ghana.

Costs and subsidies

Annual budget: No estimates available

Approach costs were met by the following contributors / donors:

International institution / agency	100%
National government	–
International NGO	–
National NGO	–
Private sector	–
Local government	–
Local community, land users	–
TOTAL	**100%**

Subsidies financed under the approach:
No subsidies were given. Labour was not rewarded and inputs were not financed by the project.

Access to credits

No access to credits provided through the approach

Training and awareness raising

A local NGO (BADECC) conducted training of PNTD teams on territorial diagnosis, proposal development, negotiation and conflict resolution. All activities were jointly conducted and attended by participants from Ghana and Burkina Faso. Capacity development took place within the pilot area through a combination of formal training sessions and – preferably – on-the-job training. Training focused on: (1) the PNTD process and its application in the context of cross-border natural resource management; (2) PRA tools relevant to the diagnostic phase; (3) participatory resource mapping (a tool to support the negotiation on development proposals).

Advisory service

This approach focuses on establishing and maintaining social dialogue within the territory and restructuring and / or strengthening territorial institutions.

Organisation / capacity development

The PNTD team's capacity to carry out inclusive planning processes has improved significantly, particularly referring to proposal development, negotiation and consensus building, and in placing the findings of the diagnostic phase in a larger geographical context (interactions between communities). Less impact was achieved from the diagnostic phase as many team members had used the PRA tools before. As PNTD team members work for local (non-) government organisations, the capacity of these institutions to facilitate consensus based planning has also enhanced.

Benefits of SLM Approach

+++ Invoked a high level of interest within the targeted communities; increased active participation, planning and consensus building capacity at community level.

\+ Improved sustainable land management: improved soil conservation and livestock rearing.

Strengths

- Provides a suitable framework for cross-border planning in the West African context.
- PNTD process raised the level of participation of local government institutions and NGOs in a negotiated territorial development process through the PNTD team which comprised technical staff of these organisations.
- PNTD enabled (and stimulated) the communities on both sides of the border to interact, and joint development plans were elaborated and agreed upon from the perspective of the communities.
- Looking beyond community boundaries, and consensus building between communities and stakeholders were new aspects of planning to the team members.

Weaknesses ➜ and how to overcome

- It took time for team members to grasp the conceptual approach of PNTD. They were used to working within individual communities, and if they were involved in planning then mostly at a diagnostic level.
- Language problems required almost continuous translation, and thus effectively doubling the time required ➜ recruitment of linguistic mediator(s) needs to be considered in the project budget.

Sustainability of activities

The PNTD-approach has shown applicability. Yet, there are some aspects which need to be considered: (Local) governments need to take ownership of the cross-border planning and development processes. This could be realised by structuring external support differently: (1) Local government (districts, municipalities) supported by NGO's are responsible to carry out all activities; (2) External (project) support focuses on overall coordination, the provision of technical advice, the provision of operational budgets, and building of partnerships.

Main contributors: Paolo Groppo and Carolina Cenerini, FAO; Rome, Italy; paolo.groppo@fao.org, carolina.cenerini@fao.org
Key references: FAO. 2005. An approach to rural development: Participatory and Negotiated Territorial Development (PNTD). Rural Development Division, FAO. OFZ Project (Socio Economic Development Programme for the Transborder Onchocerciasis Freed Zone of Burkina Faso and Ghana) ■ SNV Burkina Faso - SNV Ghana. 2007. X-border Participatory, Negotiated, Territorial Development (PNTD) – pilot phase report.

PARTICIPATORY LEARNING AND ACTION RESEARCH APPROACH TO INTEGRATED RICE MANAGEMENT - MADAGASCAR

The Participatory Learning and Action Research approach to Integrated Rice Management (PLAR-IRM) is a bottom-up, social and experiential learning approach, leading to sustainable agricultural improvements, based on mutual support and communication among farmers. Innovation and agricultural change is aimed for, through capacity strengthening of all major stakeholders involved in the rice sub-sector. IRM refers to the production system and value chain as a whole. Innovation is not limited to technological change; it also includes time management and the building of social networks and institutions for mutual collaboration between farmers and other stakeholders within the rice value chain. A step-wise, self-discovery learning mode encourages the stakeholders to find solutions for their own site-specific problems. During the first years, groups of 25-30 producers are supported by a programme facilitator who animates the learning and innovation sessions. The main instruments are the learning modules dealing with specific crop management practices, harvest and post-harvest practices (involving processors and entrepreneurs also), as well as the agro-ecological and socio-economic conditions of rice production. The sessions aim to strengthen farmers' and other rice stakeholders' capacity to observe, analyse, interpret, make decisions, innovate and share knowledge and experiences. PLAR is based on locally relevant knowledge, practices and skills. Exchanges about current practices, and their logic or justification, are the starting point in all modules.

In a learning-by-doing approach farmers are encouraged to try out any new ideas identified during PLAR sessions on some parts of their fields reserved for new practices ('innovation space'). This allows them to assess the impact of such innovations on their rice yield, or on the profitability of rice growing and the rice business as a whole, and consequently to adapt and fine-tune the measures taken according to their needs. These innovation spaces are regularly visited as part of learning sessions for knowledge sharing between farmers. Since 2005, innovations in land preparation, early transplanting of seedlings, weeds and water management - basically without external inputs - have resulted in three times higher yields, benefitting thousands of farmers. Rice value chain activities started in 2008 with a view to empowering farmers' position within the chains and improving the competitiveness. Groups are unifying into PLAR centres with common marketing of rice, and contract input providers and rice processors.

Type of approach
Programme based

Problems / constraints addressed
- Low yields in rice production; most farmers live below subsistence level
- Absence of government and NGO support
- Limited access to markets, lack of infrastructure

Aims and objectives
- Sustainably improving food security, livelihoods and incomes of poor rice farmers by boosting the profitability of rice production and increasing the efficiency and competitiveness of the rice sub-sector
- Capacity strengthening of all stakeholders involved in the rice-subsector

Target groups
Mainly: land user groups (rice farmers); in 2nd phase: private service providers (e.g. input suppliers), rice processors and buyers

Participation and decision-making
Land users are actively involved in all phases of the approach. The curriculum is based on needs assessment. Decisions on SLM activities to be implemented are taken by individual farmers, and collectively. SLM implementation is done by farmers with technical support from programme officers. Gradually farmers take more responsibility, through the so-called weaning process: decisions on curriculum of training modules are taken by PLAR groups; Farmers' Facilitators (FF) are trained and lead the groups (from the 3rd year on). 5-10 weaned PLAR groups unify in the form of a PLAR centre, mainly dealing with rice value chain related activities.

Implemented SLM / other activities
- SLM measures: land preparation; nursery management; transplanting of young seedling in rows; new rice varieties; improved seed multiplication and conservation practices
- Other activities: value chain development: collective storage and marketing of rice; contractual arrangements with input providers and rice processors

Implementing bodies
International institution / agency (Aga Khan Foundation) operating as a local NGO with support of the local government, local communities and private sector

Land users' motivation for implementing SLM
Production, profitability and affiliation to movements / groups / networks

Photo 1: Farmers discussing development priorities on the basis of the lowland map.
Photo 2: Transplanting rice in lines using a '*fomby*'.
Photo 3: Farmer weeding using a rotative weeder.
(All photos by PSSDRI - *Programme de soutien de la region Sofia pour le développement rural intégré*)

Case study area: Sofia Region, Madagascar; about 10,000 km² covered by approach.

Costs and subsidies

Annual budget: 400,000 US$

Approach costs were met by the following contributors / donors:

International institution / agency	10 %
National government	–
International NGO	–
National NGO	30 %
Private sector	10 %
Local government	–
Local community, land users	50 %
TOTAL	**100%**

Subsidies financed under the approach:

Externally financed inputs	
Labour	not financed
Equipment	fully financed
Agricultural inputs	not financed
Construction material	not financed
Infrastructure	not financed

Remarks: Two *sarcleuses* (weeding equipment) per starting group are provided for free and remain property of the group.

Access to credits

Was supported by the approach in collaboration with an existing microfinance institution; loan period: 6-8 months; monthly interest rate: 2.5%

Training and awareness raising

- Training was given to groups of land users and facilitators
- Form: compulsory and optional PLAR learning modules; on-site experimentation (learning by doing) and farmer-to-farmer exchange during site visits
- Topics: crop management practices, harvest and post-harvest practices (incl. storage, marketing), socio-economic and ecological conditions of rice farming; curriculum based on needs assessment
- Current and planned: expansion of numbers of groups, unification into Centres, value chain activities and extending training sessions for non PLAR-group farmers

Advisory service

- Method and key elements: modular learning sessions guided by a facilitator, farmer-to-farmer extension
- Approach is based on indigenous knowledge

Research

- Local researchers were involved at the start-up of FFS groups for the sake of providing technical advice as well as to capture farmers' demands for future research priorities.

Organisation / capacity development

PLAR groups are formed (new formation or based on already existing entities) for mutual support and exchange of knowledge. In 2nd phase PLAR groups are weaned into higher-level learning and innovation platforms (=PLAR centres) for exchange between farmers facilitators and SLM specialists from the programme.

Benefits of SLM Approach

+++ Improved sustainable land management: yields have increased by > 200% (on innovation spaces).

+++ Adoption of approach by other land users / projects: from 2005-2009 PLAR groups have increased from 6 up to 102, involving 3,782 families and extended to 4,200 non grouped farmers.

+++ Poverty alleviation / improved livelihoods / human well-being: SLM practices result into a net benefit of > 700 US$/ha.

+++ Improved situation of socially / economically disadvantaged groups: marginalised poor rice farmers are targeted.

Strengths

- Farmers learn basic principles of rice management and develop their own locally adapted options for improvements; the innovation comes from inside the groups.
- Farmers build up individual and organisational capacity to find out solutions to their problems and build confidence as efficient partners with other value chain actors.

Weaknesses ➜ and how to overcome

- Labour intensive improvements ➜ provision of group credit to PLAR group members in collaboration with a local microfinance institution.
- Learning intensive approach, with regular group learning sessions ➜ PLAR groups elaborate their own learning programmes and curricula according to their availability and needs.

Sustainability of activities

In a 2nd phase farmers who are organised in PLAR groups gradually build up the capacity to manage the innovation and mutual learning approach on their own without programme support: Farmers' facilitators are trained to take over the lead of PLAR groups with backstopping from programme facilitators.

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Key references: Defoer T., M. Wopereis, S. Diack, and P. Idinoba. 2008. Apprentissage participatif et recherche action pour la gestion intégrée du riz à Madagascar: Manuel du facilitateur AKF, Genève, Suisse. ■ Defoer T., M. Wopereis, P. Idinoba T. and Kadisha. 2006. Participatory Learning and Action Reseaerch (PLAR) for Integrated Rice Management in inland valleys in sub-Saharan Africa: Facilitators' manual. WARDA- the Africa Rcie Center, Bouaké, Côte d'Ivoire.

Case study

'CATCHMENT' APPROACH - KENYA

The 'catchment' approach promotes sustainable land management systems by conservation of defined areas (termed 'micro-environments') through the active participation of the communities living there. It was launched in Kenya in 1988 to achieve greater technical and social impact - at a more rapid pace, than the previous focus on individual farmers. This case focuses on a single 'catchment' in a subhumid area of Central Kenya. The emphasis is on structural measures – especially *fanya juu* terraces - but vegetative systems are promoted also. Other activities are supported such as spring protection, improved crop and animal husbandry, agroforestry, fodder production, fish ponds and others. The specific objectives are to stimulate the implementation of a variety of SLM measures leading simultaneously to improved production.

Each approach area is defined by cultural / administrative boundaries rather than strict hydrological watersheds or catchments (as its name confusingly implies). A conservation committee is elected from amongst the focal community before problem identification begins. Technical staff from relevant government and non-government agencies (NGOs) are co-opted onto the committee. The approach then involves participatory methods of appraisal and planning of solutions. Land users, together with the co-opted subject matter specialists, pool their knowledge and resources. Common Interest Groups (CIGs) are formed, with the aim of self-help promotion of specific farm enterprises. Training is given to the members of the CIGs by the Ministry of Agriculture. The farmers carry out the majority of the work themselves: monetary or other tangible incentives are few.

The end result is the micro-environment (catchment area) conserved for improved production, and left in the hands of the community to maintain and sustain. The 'catchment' approach was developed under the National Soil and Water Conservation Programme – supported by the Swedish International Development Cooperation Agency (Sida) – and continues to be promoted as the Focal Area Approach (FAA) under the National Agricultural and Livestock Extension Programme (NALEP), which is again supported by Sida. However, under NALEP there is less emphasis on soil and water conservation than under the previous programme, and more focus on promotion of productive enterprises.

Type of approach
Project based

Problems / constraints addressed
- Lack of tangible and assessable impact of SLM activities, technically or socially
- Slow implementation of SLM programme
- Underlying problems of poverty, declining soil fertility, soil erosion and fuelwood shortage
- Lack of capital hinders farmers from investing in structures
- Lack of conservation / SLM knowledge

Aims and objectives
To contribute to increased and sustained environmental conservation and improved agricultural production at farm level, through participatory approaches for better land husbandry / SLM.

Target groups
Land users, SLM specialists / advisors, teachers / students, planners, politicians / decision makers

Participation and decision-making
The approach was designed by national specialists. The community was involved in the initiation, planning (public meetings, PRA) and implementation phase. Choice of the technology was mainly by land users supported by SLM specialists and partly by SLM specialists alone. Decision on the method of implementing the technology was mainly by land users supported by SLM specialists.

Implemented SLM / other activities
- SLM measures: *fanya juu* terraces, level bench terraces, agroforestry, fodder production, improved crop and animal husbandry
- Spring protection
- Fish ponds

Implementing bodies
Implemented by community members

Land users' motivation for implementing SLM
Increased production, profitability and improved livelihood

Photo 1: An extension officer showing members of a women group how to protect young mango seedlings in the catchment area of Sololo Division, Moyale District, Kenya. (James Njuki)

Case study area: Muranga District, Kenya; 1 km² covered by the approach

Costs and subsidies

Annual budget: US$ 4,000-5,000

Approach costs were met by the following contributors / donors:

International institution / agency	70%
National government	20%
International NGO	–
National NGO	–
Private sector	–
Local government	–
Local community, land users	10%
TOTAL	**100%**

Subsidies financed under the approach:

Externally financed inputs	
Labour	not financed
Equipment / tools	fully financed
Agricultural inputs	partly financed
Construction material	not financed
Infrastructure	not financed

Remarks: Incentives (other than education and motivation) have been used at very low levels. Common Interest Groups (CIGs) were then required to solicit help and assistance as need arises.

Access to credits

Credit was not provided directly, though a 'stakeholder kitty' revolving fund (savings and credit) was promoted and developed.

Training and awareness raising

Training included layout of conservation measures; agroforestry; energy conservation; food preservation – as well as specific farm enterprises. It was carried out for groups and mainly through farm visits by Ministry of Agriculture extension agents. Impact was good for farmers and extension workers.

Advisory service

Extension methods include farm visits; field demonstrations; field days; on-farm demonstrations. The extension service was 'quite adequate' to take this process forward into the future. The impact of the advisory service for farmers and teachers was rated as good, and as excellent for technicians.

Research

Specific problems were researched as they arose. A strong research-extension linkage was / is being built up. Monitoring of the progress of the overall programme is part of the approach.

Organisation / capacity development

A conservation committee is formed including elected members from focal communities and technical staff from relevant government and non-government agencies (NGOs). Common Interest Groups (CIGs) are formed. Support to local institutions was given through training.

Benefits of SLM Approach

++ Improved sustainable land management: mainly through *fanya juu* and level bench terraces.

\+ Adoption of approach by other land users / projects: the further spread of the approach has been limited to one NGO within the case study area.

+++ Improved livelihoods / human well-being: more income generating activities identified and implemented through common interest groups (CIGs) for crop production, marketing and livestock.

++ Others: some enhanced collaboration between agencies; Partners understand each other and avoid activity duplication.

Strengths

- Genuine community participation
- 'Ownership of approach' by the community: feeling that what has been achieved is due to communal efforts and belongs to them
- Improved linkages between extension / training and research
- Promotion of new and productive farm enterprises alongside better SLM

Weaknesses ➜ and how to overcome

- Technologies tend to be implemented uniformly, not site-specifically ➜ match SLM to each particular situation (e.g. promote structural measures only where necessary, i.e. where agronomic and vegetative measures do not provide sufficient protection).
- Uncertainty about continuation in specific areas if direct support stops after only one year ➜ continue approach for at least two or three years in each catchment (approach area).
- Limited area covered by National Agricultural and Livestock Extension Programme ➜ more staff required and more effective use of staff.
- In many places there is a lack of availability of inputs ➜ provide better credit facilities for CIGs / farmers generally.

Sustainability of activities

Interventions are likely to continue and be maintained, but this depends on common interest groups continuing to function actively.

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Key references: Yeraswarq A. 1992. The Catchment Approach to Soil Conservation in Kenya. Regional Soil Conservation Unit (now: Regional Land Management Unit, RELMA, a project under ICRAF, The World Agroforestry Centre, Nairobi. ■ Pretty JN., Thompson J. and Kiara JK. 1995. Agricultural Regeneration in Kenya: The Catchment Approach to Soil and Water Conservation. Ambio 24, no 1, pp 7-15.

ANNEX:
BEST SLM PRACTICES COMPARED

For a concise overview, the 12 SLM technology groups that are presented in Part 2 of the guidelines are compared in the following tables:
Table 1: development issues addressed, e.g. production, biodiversity, water, climate change mitigation and climate change adaptation.
Table 2: Benefit-cost ratio.
Table 3: Benefits and impacts at land user and community level, e.g. yields, labour input, improvement of sol and water, community and institutional strengthening, etc.
Table 4: Key factors for adoption including inputs, materials, training and education, land tenure, access to markets, research.

Annex table 1: development issues addressed

	Integrated Soil Fertility Management	Conservation Agriculture	Rainwater Harvesting	Smallholder Irrigation Management	Cross-Slope Barriers	Agroforestry	Crop-Live-stock Management	Pastoralism and Range-land Management	Sustainable Planted Forest Management	Sustainable Forest Management in Drylands	Sustainable Rainforest Management
Development issues addressed											
Preventing / reversing land degradation	++	++	++	+	++	+++	++	++	+++	+++	+++
Maintaining and improving food security	+++	++	++	+++	+	+++	++	++	+	+	+
Reducing rural poverty	++	++	+	++	+	+++	++	++	++	++	+
Creating rural employment	+	++	+	++	+	+	+	+	++	++	++
Supporting gender equity / marginalised groups	++	++	+	++	+	++	++	+++	na	++	+
Improving crop production	+++	++	+++	+++	++	++	++	+	+	+	na
Improving fodder production	+	+	++	+	++	++	++	+++	++	++	+
Improving wood / fibre production	+	na	++	na	+	++	+	++	+++	++	+++
Improving non wood forest production	na	na	na	na	na	+	+	++	++	+++	+
Preserving biodiversity	+	+	+	na	+	+++	++	+++	+	+++	+
Improving soil resources (OM, nutrients)	+++	++	+	+	+	+++	++	++	+	+++	+
Improving of water resources	+	++	+++	-/+	++	++	+	++	na	++	+/ –
Improving water productivity	++	+++	+++	+++	++	+++	++	++	na	++	+
Natural disaster prevention / mitigation	+	++	+	+	++	+++	+	++	+	+++	++
Climate change mitigation / adaptation	++	++	+++	-/+	++	+++	++	++	++	+++	++
Climate change mitigation											
C Sequestration (t/ha/yr) (figures for first 10-30 years of changed land management)	no data	0.57 (+/- 0.141)	0.26-0.46 (+/-0.35) (Pretty et al. 2006)	0.15 (+/- 0.012) (Pretty et al. 2006)	0.5-1 (estimation)	0.3 - 6.5	0.11- 0.81 up to 3 in silvo/ agro-forestry systems (Woodfine, 2009)	0.1 - 0.3 (Schumann et al, 2002 in FAO, 2004)	1.2 – 2 for afforestation in drylands (FAO, 2004 and GTZ, 2009)	no data	no data
C Sequestration: above ground	+	+	+	+	+	++	++	+	++	++	+++
C Sequestration: below ground	+	++	+	+	+	++	++	++	++	++	++
Climate change adaptation											
Increase resilience to extreme dry conditions	++	++	+++	+	++	++	++	+++	+	++	+
Increase resilience to extreme wet conditions	++	++	+++	++	+	+++	++	++	+	+++	++
Increase resilience to variable rainfall	+	+	+	no data	+	++	+	++	+	+++	++
Increase resilience to rising temperatures and evaporation rates	+	++	++	+	+.	++	+	+++	+	++	++
Reducing risk of production failure	++	+	+	++	+	++	++	++	+	+++	+

-- negative; - slightly negative; -/+ neutral; + slightly positive; ++ positive; +++ very positive; na: not applicable

Annex table 2: Benefit-cost ratio

	Benefit-cost ratio		
	short term	**long term**	**Comments**
Integrated Soil Fertility Management	++	+++	A small input in the form of organic and / or inorganic fertilizer can have a significant and immediate impact on crop production. However the profitability depends closely on price and availability of fertilizer.
Conservation Agriculture	+	+++	The short term benefit-cost ratio is mainly affected by the initial cost of purchasing new machinery and tools. The availability and the affordability of these tools can be major obstacles, especially for small-scale land users.
Rainwater Harvesting	– /+ +	++ / +++	RWH techniques can include high initial labour and material input – though there is a wide range. In the long term the benefit-cost ratio depends on the level of maintenance work needed.
Smallholder Irrigation Management	+ / ++	+++	The establishment costs for smallholder irrigation management (SIM) vary considerably. Micro-irrigation systems like drip irrigation require relatively high initial investments, which need to be covered though micro-credit. SIM can help farmers to move towards a mixed subsistence and more commercial system.
Cross-Slope Barriers	–	++	Usually require high initial investment and labour input, therefore the short term profitability is often negative. However vegetative strips can be used as cheap cross-slope barriers option, with much lower establishment costs than terraces, stone lines, etc. Vegetative strips often develop into terraces over time.
Agroforestry	– /+ +	++	Analyses mostly take direct utility values of integrated trees into account, because indirect use values, such as environmental functions, are much more difficult to evaluate. Furthermore, benefit-cost estimates are complicated by the many sources of annual variation affecting tree and crop production and tree-crop interactions. Hence benefits may be in general underestimated. Impact over different temporal scales is an issue that is especially relevant to agroforestry.
Integrated Crop-Livestock Management	+	++ / +++	Integration of livestock with crops improves farm productivity and income; and the benefits can be observed quite rapidly as well as appreciating over time.
Pastoralism and Rangeland Management	no data	no data	Pastoralism has considerable economic value and latent potential in the drylands but little is known or has been quantified. Multiple products and species can make pastoral systems significantly more cost-effective and productive than meat-focused ranching. The value of livestock production in the drylands is probably greatly underestimated in official statistics.
Sustainable Management of Planted Forests	– / – –	+ / ++	Short-time benefits from planted forests are usually negative due to the long establishment period of the trees. Environmental plantations are usually outside the financial perspective of small-scale land users and need therefore financial incentives and / or support for their establishment. The efficiency of plantation management and success in achieving sustainable wood supply depends mainly on whether a plantation is publicly, or privately, owned and managed.
Sustainable Forest Management in Drylands	–	++	Sustainable forest management in drylands is mainly based on community forest management, therefore an estimation of the benefits-costs ratio is very difficult.
Sustainable Rainforest Management	–	++	Once again this is mainly based on community forest management, therefore an estimation of the benefits-costs ratio is very difficult.

– – negative; – slightly negative; – /+ neutral; + slightly positive; ++ positive; +++ very positive

Annex table 3: Benefits and impacts at household and community level

Benefits		Integrated Soil Fertility Management	Conservation Agriculture	Rainwater Harvesting	Smallholder Irrigation Management	Cross-slope Barriers	Agroforestry	Crop-Livestock Management	Pastoralisms and Rangeland Management	Sustainable Planted Forest Management	Sustainable Forest Management in Drylands	Sustainable Rainforest Management
Production benefits	Increased crop yields	+++	++	+ +	+++	++	++	+++	+	na	na	na
	Increased fodder production	++	na	++	na	++	na	++	++	na	na	na
	Increased wood production	na	na	+	na	+	++	na	na	+++	+	+
	Increased production of NWFP	na	na	na	na	na	+	na	na	+	++	++
	Production diversification	+	+	+	++	+	+++	++	++	+	++	++
Economic benefits	Labour reduction	+/ –	+(+)	–	+	–	+/ –	+	+/ –	na	na	na
	Farm income	++	++	++	+++	+	++	++	++	+	+	+
Ecological benefits	Improved soil cover	++	++	+	+	+	++	++	++	++	++	+++
	Reduced soil erosion (by wind / water)	++	++	++	+	++	+++	++	++	++	++	+++
	Improved water availability	+	+++	+++	+/-	++	++	+	+	+/-	+	+++
	Increased organic matter/ soil fertility	+++	++	+	+	+	+++	+++	++	+	++	+++
	Biodiversity enhancement	++	+	+	+	+	+++	++	++	+	+++	+++
	Improved micro-climate	+	++	+	+	+	+++	+	+	++	+++	+++
Socio-cultural benefits	Improved SLM/ conservation/ erosion knowledge	++	++	++	na	+++	++	++	+++	na	++	++
	Changing the traditional gender roles of men and women	+	+	+	++	na	na	na	na	na	na	na
	Community institution strengthening	+	na	++	na	+	+	na	+	+	+++	+++

-- negative; - slightly negative; -/+ neutral; + slightly positive; ++ positive; +++ very positive
na: not applicable

Annex table 4: Key factors for adoption

Enabling environment: Key factors for adoption	Integrated Soil Fertility Management	Conservation Agriculture	Rainwater Harvesting	Smallholder Irrigation Management	Cross-Slope Barriers	Agroforestry	Crop-Livestock Management	Pastoralisms and Rangeland Management	Sustainable Planted forest Management	Sustainable Forest Management in Drylands	Sustainable Rainforest Management
Inputs, material incentives, credits	+++	++	++	+++	++	++	++	+	+	+	+
Training and education	++	++	++	++	++	na	++	+	++	++	++
Land tenure, secure land use rights	++	++	+++	+++	++	++	+++	+++	+++	+++	+++
Access to markets	++	++	++	+++	+	+	++	++	++	++	++
Research	+	++	++	+	++	+++	++	++	+	++	++

-- negative; - slightly negative; -/+ neutral; + slightly positive; ++ positive; +++ very positive
na: not applicable

References to Part 1

Note: Only references used for Part 1 are listed here. References of Part 2 are listed after each SLM group and case study.

AfDB, UNECA and OECD. 2009. African Economic Outlook 2008/09. Paris and Tunis: AfDB and OECD.

Alliance for a Green Revolution in Africa (AGRA). 2010. Statement from chairman: Africa's breadbaskets: key to achieving food security. http://www.agra-alliance.org/section/news/chairman_speech/; accessed 22 March 2010.

Aune, J. B. and A. Bationo. 2008. Agricultural intensification in the Sahel: the ladder approach. Agricultural Systems 98: 119–125.

Bonkoungou, E.G. 2001. Biodiversity in the drylands: Challenges and opportunities for conservation and sustainable use. Challenge Paper. The Global Drylands Initiative, UNDP Drylands Development Centre, Nairobi, Kenya.

Bot, A. and J. Benites. 2005. The importance of soil organic matter: key to drought-resistant soil and sustained food production. FAO soils bulletin 80. FAO, Rome, Italy.

Castillo, G. E., R. E. Namara, H. M. Ravnborg, M. A. Hanjra, L. Smith, M. H. Hussein, C. Béné, S. Cook, D. Hirsch, P. Polak, D. Vallée and B. van Koppen. 2007. Reversing the flow: agricultural water management pathways for poverty reduction. In: Molden, D. (Ed.), Comprehensive Assessment of Water Management in Agriculture: Water for Food, Water for Life. International Water Management Institute (IWMI)/ EarthScan, London/ Colombo, (Chapter 4), pp. 149–191.

Crepin, C., S. Danyo and F. Sperling. 2008. Land management and climate change. Draft issues paper. World Bank.

Critchley, W., 2007. Working with farmer innovators. CTA, Wageningen. The Netherlands.

Desanker, P.V., 2002. The impact of climate change on life in Africa: climate change and vulnerability in Africa. World Wide Fund for Nature (WWF), Washington DC, USA.

Desanker, P.V. and C. Magadza. 2001. Africa. In McCarthy J. J., et al. (Eds.), Climate change 2001: impacts, adaptation and vulnerability. Cambridge University Press, pp. 487–531.

Dixon, J., A. Gulliver and D. Gibbon. 2001. Farming systems and poverty: improving farmers' livelihoods in a changing world. FAO, Rome, Italy.

Drechsel, P., A. Olaleye, A. Adeoti, L. Thiombiano, B. Barry and K. Vohland. 2005. Adoption driver and constraints of resource conservation technologies in Sub-Saharan Africa. 21pp. http://www.iwmi.cgiar.org/africa/west_africa/projects/AdoptionTechnology/AdoptionConstraints-Overview.pdf

Envirotrade. 2010. Carbon trading: the market. http://www.envirotrade.co.uk/html/resources_market.php

Eswaran, H., R. Lal and P.F. Reich. 2001. Land degradation: an overview. Responses to land degradation. Proc. 2nd. International Conference on Land Degradation and Desertification. New Delhi, India: Oxford Press. http://soils.usda.gov/use/worldsoils/papers/land-degradation-overview.html.

Eswaran H., R. Almaraz, E. van den Berg and P. Reich. 1997. An assessment of the soil resources of Africa in relation to productivity. Geoderma 77:1–18.

Falkenmark, M., C. M. Finlayson, L. J. Gordon, E. M. Bennett, T. M. Chiuta, D. Coates, N. Ghosh, M. Gopalakrishnan, R.S. de Groot, G. Jacks, E. Kendy, L. Oyebande, M. Moore, G. D. Peterson, J. M. Portuguez, K. Seesink, R. Tharme and R. Wasson. 2007. Agriculture, water, and ecosystems: avoiding the costs of going too far. In: Molden, D. (Ed.), Comprehensive Assessment of Water Management in Agriculture: Water for Food, Water for Life. International Water Management Institute (IWMI)/ EarthScan, London/ Colombo, (Chapter 6), pp. 233–277.

Falkenmark, M. and J. Rockström. 2006. The new blue and green water paradigm: breaking new ground for water resources planning and management. Journal of water resources planning and management May/ June.

FAO, 2004. The State of Food and Agriculture 2003-2004 – Agricultural Biotechnology. Meeting the Needs of the Poor? FAO Agricultural Series No. 35.

FAO. 2009a. Food security and agricultural mitigation in developing countries: options for capturing synergies. FAO, Rome, Italy.

FAO, 2009b. FAO - Profile for climate change. ftp://ftp.fao.org/docrep/fao/012/i1323e/i1323e00.pdf

FAO. 2008a. TerrAfrica – A vision paper for Sustainable Land Management in Sub-Saharan Africa. FAO, Rome, Italy.

FAO. 2008b. Water and the rural poor: interventions for improving livelihoods in Sub-Saharan Africa, edited by Faurès J. M. and G. Santini. FAO, Rome, Italy.

FAOSTAT. 2008. Agricultural statistics. Available at http://faostat.fao.org/

FAOSTAT, 2004. Agricultural statistics. Available at http://faostat.fao.org/

Fox, P., J. Rockström and J. Barron. 2005. Risk analysis and economic viability of water harvesting for supplemental irrigation in semi-arid Burkina Faso and Kenya. Agricultural Systems 83 (3), pp. 231–250.

Gitonga, J.N.L., 2005. Monitoring and modeling crop growth, water use and production under dry-land environment west and northwest of Mount Kenya. PhD thesis, Dept. of Geography, University of Bern, Switzerland.

Harrison, S.G., G.B. Masefield, M. Wallis, and B.E. Nicholson. 1969; 1985. The Oxford Book of Food Plants. Oxford University Press, Oxford.

Henao, J. and C. Baanante. 2006. Agricultural production and soil nutrient mining in Africa: implication for resource conservation and policy development. IFDC Tech. Bull. International Fertilizer Development Center. Muscle Shoals, Al. USA.

Hurni, H. 1997. Concepts of sustainable land management. ITC Journal Vol. Nr. 3/4, 210-215.

ILEIA - the Centre for Learning on sustainable agriculture and the secretariat of the global AgriCultures network. 2001. http://ileia.leisa.info/index.php?url=show-blob-html.tpl&p%5Bo_id%5D=239119&p%5Ba_id%5D=211&p%5Ba_seq%5D=1; accessed 15.1.2010.

International Assessment of Agricultural knowledge, Science and Technology for Development (IAASTD). 2009a. Synthesis report - A synthesis of the global and sub-global IAASTD reports, edited by Beverly D. McIntyre, H. R. Herren, J. Wakhungu and R.T. Watson. http://www.agassessment.org/reports/IAASTD/EN/Agriculture%20at%20a%20Crossroads_Synthesis%20Report%20(English).pdf

International Assessment of Agricultural knowledge, Science and Technology for Development (IAASTD). 2009b. Sub Saharan Africa (SSA), sub-global IAASTD reports.

International Federation of Organic Agriculture Movements (IFOAM). 2009. The principles of organic agriculture. http://www.ifoam.org/about_ifoam/principles/index.html; accessed 22 March 2010.

International Food Policy Research Institute (IFPRI). 2010. SLM Advisory Services: Key Institutional, Financing, and Economic Elements for Scaling Up Sustainable Land Management in Nigeria. Synthesis Report.

International Soil Reference and Information Centre (ISRIC). 2010. Green Water Credits. http://www.isric.org/UK/About+ISRIC/Projects/Current+Projects/GWC+Introduction.htm; accessed 17 January 2010.

IPCC. 2007. Climate change 2007 – Impacts, adaptation and vulnerability. Contribution of working group II to the fourth assessment report of the IPCC. Available from: http://www.ipcc.ch/ipccreports/ar4-wg2.htm

ISRIC - World Soil Information. 2010. Green Water Credits. http://www.isric.org/UK/About+ISRIC/Projects/Current+Projects/Green+Water+Credits.htm, accessed on 14 June 2010.

Lastarria-Cornhiel, S. 2006. Feminization of Agriculture: Trends and Driving Forces (version 1.0). This document is part of a series of contributions by Rimisp for Rural Development (www.rimisp.org) to the preparation of the World Development Report 2008 'Agriculture for Development'.

Liniger, H.P. and W. Critchley. 2008. Safeguarding water resources by making the land greener: knowledge management through WOCAT. In: Bossio D. and K. Geheb (Eds), Conserving Land, Protecting Water (Comprehensive Assessment of water management in agriculture series). CABI, IWMI, CGIAR Challenge Program on Water & Food.

Liniger, H.P., 1995. Endangered water, a global overview of degradation, conflicts and strategies for improvement. Centre for Development and Environment (CDE), Bern, Switzerland.

Liniger, H.P., J. Gikonyo, B. Kiteme and U. Wiesmann. 2005. Assessing and managing scarce tropical mountain water resources - The case of Mount Kenya and the semi-arid Upper Ewaso Ng'iro Basin. Mountain Research and Development 25(2); 163-173.

McCann, J.C., 2005. Maize and grace: Africa's encounter with a new world crop 1500-2000. Harvard Univ. Press, Cambridge, US.

Molden, D., T. Y. Oweis, P. Steduto, J. W. Kijne, M. A. Hanjra, P. S. Bindraban, B. A. M. Bouman, S. Cook, O. Erenstein, H. Farahani, A. Hachum, J. Hoogeveen, H. Mahoo, V. Nangia, D. Peden, A. Sikka, P. Silva, H. Turral, A. Upadhyaya, and S. Zwart. 2007. Pathways for increasing agricultural water productivity. In: Molden, D. (Ed.), Comprehensive Assessment of Water Management in Agriculture: Water for Food, Water for Life. International Water Management Institute (IWMI)/ EarthScan, London/ Colombo, (Chapter 7), pp. 279-310.

Mortimore, M. with contributions from S. Anderson, L. Cotula, J. Davies, K. Faccer, C. Hesse, J. Morton, W. Nyangena, J. Skinner and C. Wolfangel. 2009. Dryland opportunities: a new paradigm for people, ecosystems and development, IUCN, Gland, Switzerland; IIED, London, UK and UNDP/DDC, Nairobi, Kenya. x + 86p.

Nkomo, J.C., A. Nyong and K. Kulindwa. 2006. The impacts of climate change in Africa. Report prepared for the Stern Review. Available from: www.sternreview.org.uk

Oldeman, L.R., 1998. Soil degradation: a threat to food security?, Report 98/01. The Netherlands: International Soil Reference and Information Centre (ISRIC), Wageningen, The Netherlands.

Oldeman, L.R., 1994. The global extent of land degradation. In Greenland D.J. and I. Szabolcs (Eds.), Land Resilience and Sustainable Land Use, pp. 99–118. Wallingford, UK, CABI.

Oweis, T., and A. Hachum. 2001. Reducing peak supplemental irrigation demand by extending sowing dates. Agric. Water Manage. 50:109–123.

Pender, J., C. Ringler, M. Magalhaes and F. Place. 2009. The Role of Sustainable Land Management for Climate Change Adaptation and Mitigation in Sub-Saharan Africa. A TerrAfrica partnership publication, Washington, D.C.

Pender, J. F., 2008. The world food crisis, land degradation and sustainable land management: linkages, opportunities and constraints. Mimeo. International Food Policy Research Institute (IFPRI), Washington, D.C.

Reich, P.F., S.T. Numbem, R.A. Almaraz and H. Eswaran. 2001. Land resource stresses and desertification in Africa. In: Bridges, E.M., I.D. Hannam, L.R. Oldeman, F.W.T. Pening de Vries, S.J. Scherr, and S. Sompatpanit (Eds.), Responses to Land Degradation. Proc. 2nd. International Conference on Land Degradation and Desertification, Khon Kaen, Thailand. Oxford Press, New Delhi, India.
Rockström, J., N. Hatibu, T. Oweis, S. Wani, J. Barron, A. Bruggeman, J. Farahani, L. Karlberg, and Z.Qiang. 2007. Managing water in rainfed agriculture. In: Molden, D. (Ed.), Comprehensive Assessment of Water Management in Agriculture: Water for Food, Water for Life. International Water Management Institute/EarthScan, London/Colombo, (Chapter 8), pp. 315–352.
Rockström, J., J. Barron and P. Fox. 2003. Water productivity in rainfed agriculture: challenges and opportunities for smallholder farmers in drought prone tropical agro-ecosystems. In: Kijne, J.W., R. Barker and D. Molden (Eds), Water Productivity in Agriculture: Limits and Opportunities for Improvements, CABI, Wallingford, U.K., pp. 145–161.
Rockström, J. 2003. Water for food and nature in drought-prone tropics: vapour shift in rain-fed agriculture. Royal Society Transactions B Biological Sciences 358 (1440): 1997–2009.
Sanchez P.A., 2002. Soil fertility and hunger in Africa. Science 295, 2019- 2020. Available from: http://www.sciencemag.org/cgi/content/summary/295/5562/2019?siteid=sci&ijkey=EMQmOjsSVVbg6&keytype=ref
Sanchez P.A., K.D. Sheperd, M.J. Soule, F.M. Place, R.J. Buresh, A.-M.I. Izac, A.U. Mokwunye, F.R. Kwesiga, C.G. Ndiritu and P.L. Woomer. 1997. Soil fertility replenishment in Africa: an investment in natural resource capital. In: Buresh R.J., P.A. Sanchez and F. Calhoun (Eds.), Replenishing Soil Fertility in Africa. Soil Science Society of America, Madison, Wisconsin.
Scherr, S.J. and S. Sthapit. 2009. Farming and land use to cool the planet. In: Starke, L. et al (Eds.) State of the World 2009 – Confronting Climate Change. Earthscan, London, UK.
Schwilch G., F. Bachmann and H.P. Liniger. 2009. Appraising and selecting conservation measures to mitigate desertification and land degradation based on stakeholder participation and global best practices. Land Degradation & Development 20: 308-326.
Smith, F., 2008. Women: guardians of West Africa's crop diversity. Geneflow'08: 27. Bioversity.
Stern, N., 2007. The economics of climate change - The Stern Review. Cambridge University Press, UK.
Stotz, S., 2009. Identification of SLM best bet practices in Sub-Saharan Africa and an analysis of the upscaling potential of different technologies. Bachelor study 03-907-185. University of Bern, Switzerland.
Studer, C., 2009. Management der limitierten Ressource Wasser in der Land- und Forstwirtschaft. Script, Swiss College of Agriculture.
Sustainable Agriculture and Rural Development (SARD). 2007. Conservation agriculture in Africa. SARD policy brief 18.
Tanner, C.B., and T.R. Sinclair. 1983. Efficient water use in crop production: research or re-search? In Taylor H.M., W.A. Jordan and T.R. Sinclair (Eds.), Limitations to Efficient Water Use in Crop Production. American Society of Agronomy, Madison, Wisconsin.
TerrAfrica. 2009. Sustainable land management in Sub-Saharan Africa. Draft TerrAfrica overview paper.
TerrAfrica. 2008. Policies for scaling up sustainable land management: resource guide for policymakers. Final draft. A TerrAfrica partnership publication.
TerrAfrica. 2007. Assessment of the barriers and bottlenecks to scaling-up SLM investments throughout Sub Saharan Africa. TerrAfrica SIP Activity 1.4.
UNESCO. 2006. Curriculum rationale. Understanding sustainable development. http://www.unesco.org/education/tlsf/TLSF/theme_a/mod02/uncom02t02.htm; accessed 3 March 2010.
UN-REDD Programme. 2009. The United Nations collaborative programme on Reducing Emissions from Deforestation and forest Degradation in Developing countries. http://www.un-redd.org/
Verchot, L., F. Place, K. Shepherd and B. Jama. 2007. Science and technological innovations for improving soil fertility and management in Africa. A report for the NEPAD Science and Technology Forum. Working Paper of World Agroforestry Centre.
Versfeld, D.B., D.C.Maitre, and R.A. Chapman. 1998. Alien invading plants and water resources in South Africa: a preliminary assessment. Water Research Commission Report No. TT 99/98.
Wikipedia. 2010. Integrated pest management. http://en.wikipedia.org/wiki/Integrated_pest_management; accessed 22 March 2010.
WOCAT. 2008. A framework for documentation and evaluation of sustainable land management: technologies basic questionnaire. www.wocat.net
WOCAT. 2007. Where the land is greener – case studies and analysis of soil and water conservation initiatives worldwide. Editors: Hanspeter Liniger and William Critchley.
Woodfine, A. 2009. Using sustainable land management practices to adapt to and mitigate climate change in sub-Saharan Africa: resource guide version 1.0. TerrAfrica. www.terrafrica.org.
World Bank (WB). 2010. Managing land in a changing climate: an operational perspective for Sub-Saharan Africa. Draft version Report No.: 54134-AFR. WB, Washington D.C.
World Resources Institute (WRI) in collaboration with United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP), and World Bank (WB). 2005. World Resources 2005: The Wealth of the Poor—Managing Ecosystems to Fight Poverty. WRI, Washington, D.C.
Zhi You, L., 2008. Africa infrastructure country diagnostic: irrigation investment needs in Sub-Saharan Africa. Summary of background paper 9. Produced by the International Food Policy Research Institute (IFPRI) for the World Bank (WB).

Supporting information:

Bennett, G. W., J. M. Owens, R. M. Corrigan. 2004. Truman's Scientific Guide to Pest Management Operations, 6th edition. Purdue University/ Questex Press.

Dixon, J., A. Gulliver and D. Gibbon. 2001. Farming systems and poverty - Improving farmers' livelihoods in a changing world. FAO and World Bank, Rome and Washington D.C.

FAO. 2009. Country support tool for scaling-up Sustainable Land Management in Sub-Saharan Africa. Version 1.0. A TerrAfrica partnership publication.

Gabathuler, E., F. Bachmann and A. Kläy (2011). Reshaping Rural Extension. Learning for Sustainability (LforS) - An Integrative and Learning-based Advisory Approach for Rural Extension with Small-Scale Farmers. Margraf Publishers: Weikersheim.

GTZ. 2009. Running dry? Climate change in drylands and how to cope with it. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), GmbH. Oekom Verlag, München.

Hurni, H., 2000. Assessing sustainable land management (SLM). Agriculture, Ecosystems and Environment Vol. 81 Nr. 1-10.

Müller-Lindenlauf, M., 2009. Organic agriculture and carbon sequestration - Possibilities and constrains for the consideration of organic agriculture within carbon accounting systems. FAO, Rome, Italy. ftp://ftp.fao.org/docrep/fao/012/ak998e/ak998e00.pdf

Neuenschwander, P., C. Borgemeister and J. Langewald (eds). 2003. Biological Control in IPM Systems in Africa. CAB International.

Noble, A.D., J. Pretty, F.W.T. Penning de Vries and D. Bossio. 2005. Development of bright spots in Africa: cause for optimism. In: Penning de Vries, F.W.T. (Ed), Bright Spots Demonstrate Community Successes in African Agriculture. Working Paper 102. Colombo, Sri Lanka: International Water Management Institute (IWMI).

Oweis, T. and A. Hachum. 2006. Water harvesting and supplemental irrigation for improved water productivity of dry farming systems in West Asia and North Africa. Agricultural Water Management 1-3: 57-73.

Patel, R. and E. Holt-Giménez. 2008. The new green revolution and world food prices. http://www.foodfirst.org/en/node/2083; accessed 22 March 2010.

Reij, C. and A. Waters-Bayer. 2001. Farmer innovation in Africa. Earthscan Publication, London. UK.

Shiferaw, B. A., J. Okello and R. V. Reddy. 2009. Adoption and adaptation of natural resource management innovations in smallholder agriculture: reflections on key lessons and best practices. Environ Dev Sustain 11:601–619.

Sustainet Broschure. 2004. Combating World Hunger Through Sustainable Agriculture. http://www.sustainet.org/download/sustainet_broch_eng.pdf

Swift, M.J., K.D. Shepherd (Eds). 2007. Saving Africa's Soils: Science and Technology for Improved Soil Management in Africa. Nairobi: World Agroforestry Centre

Tripp, R., 2006. Is low external input technology contributing to sustainable agricultural development? Natural Resource Perspectives 102, Overseas Development Institute (ODI).

Würth, F., 2010. Sustainable Land Management in the Face of Climate Change in Sub-Saharan Africa. Bachelor study. University of Bern, Switzerland.

Zomer R., A. Trabucco, R. Coe and F. Place. 2009. Trees on farm: analysis of global extent and geographical patterns of agroforestry. ICRAF Working Paper no. 89. Nairobi, Kenya: World Agroforestry Centre. 60pp.

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