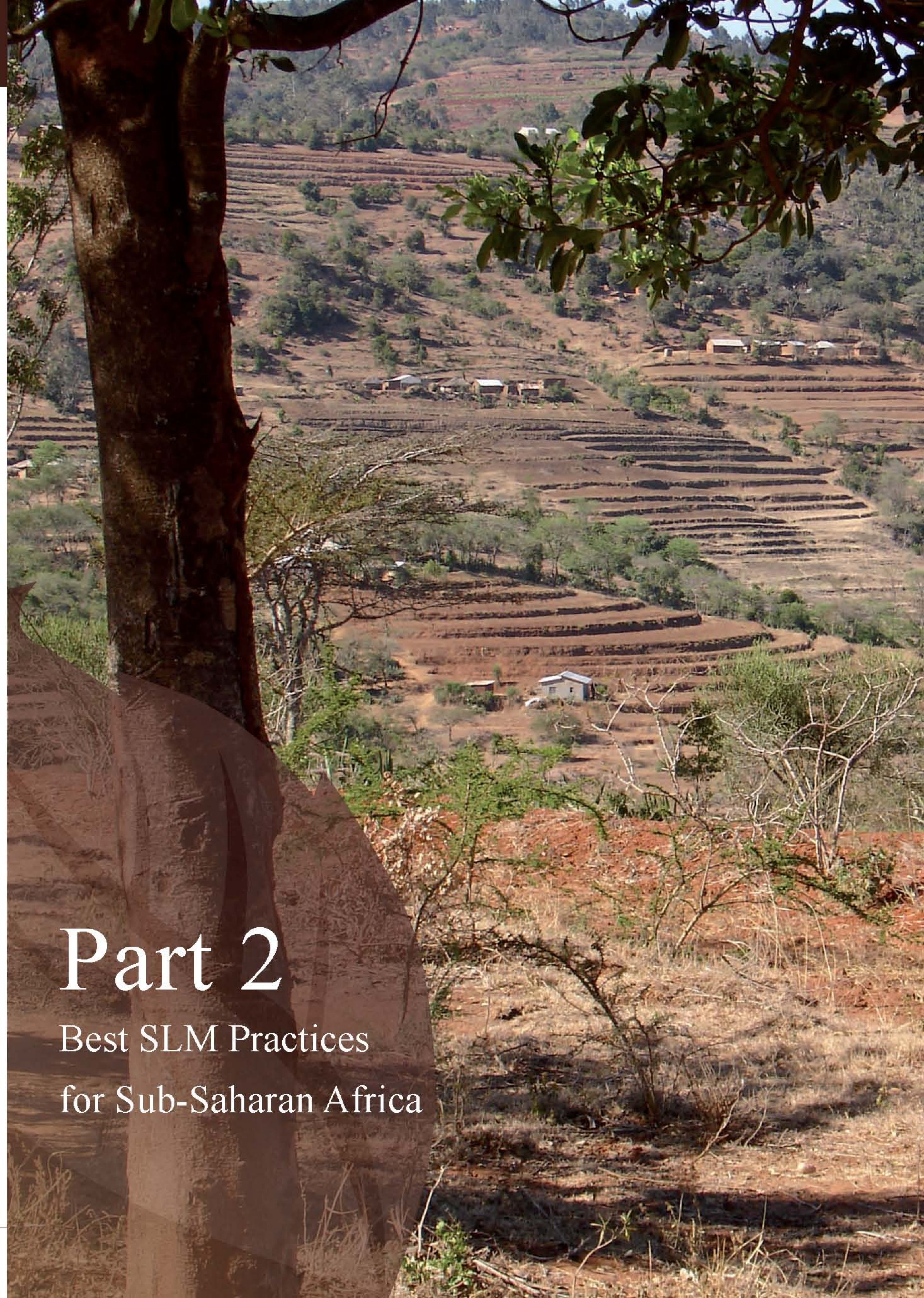
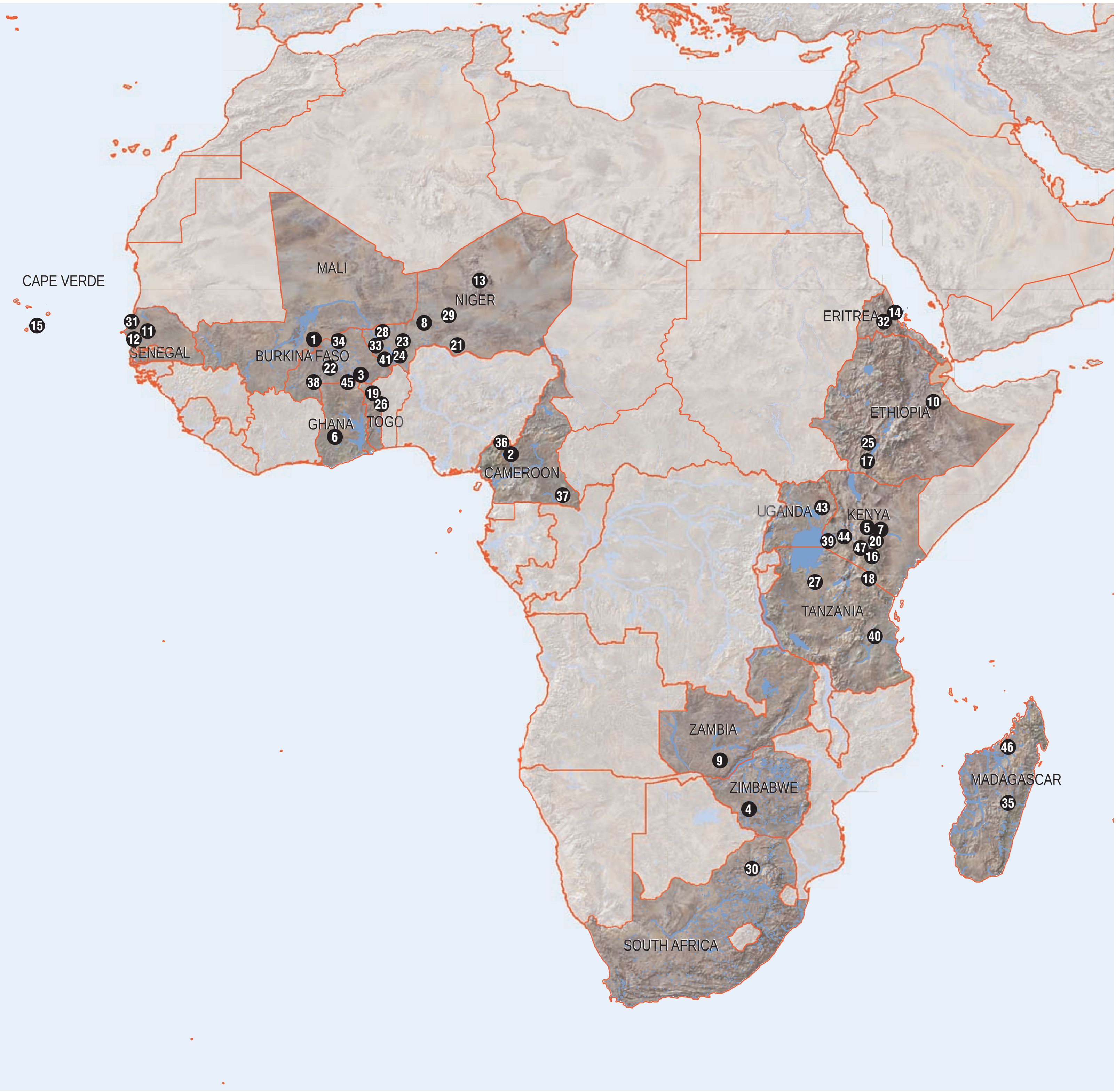


Part 2

Best SLM Practices for Sub-Saharan Africa

OVERVIEW OF BEST SLM PRACTICES



SLM Group and definition	Case studies	
Integrated Soil Fertility Management benefits from positive interaction and complementarities of a combined use of organic and inorganic plant nutrients in crop production. p. 62	(1) Seed Priming and Microfertilization – Mali	p. 68
	(2) Green Manuring with Tithonia – Cameroon	p. 70
	(3) Compost Production – Burkina Faso	p. 72
	(4) Precision Conservation Agriculture – Zimbabwe	p. 74
Conservation Agriculture combines minimum soil disturbance (no-till), permanent soil cover, and crop rotation, and is very suitable for large- as well as small-scale farming. p. 76	(5) Small-Scale Conservation Tillage – Kenya	p. 82
	(6) Minimum Tillage and Direct Planting – Ghana	p. 84
	(7) Conservation Tillage for Large-Scale Cereal Production – Kenya	p. 86
Rainwater Harvesting is the collection and concentration of rainfall to make it available for agricultural or domestic uses in dry areas where moisture deficit is the primary limiting factor. p. 88	(8) *Tassa* Planting Pits – Niger	p. 94
	(9) Small Earth Dams – Zambia	p. 96
	(10) Runoff and Floodwater Farming – Ethiopia	p. 98
Smallholder Irrigation Management aims to achieve higher water use efficiency through more efficient water collection and abstraction, water storage, distribution and water application. p. 100	(11) African Market Gardens – Senegal	p. 106
	(12) Low-Pressure Irrigation System 'Californian' – Senegal	p. 108
	(13) Irrigated Oasis Gardens – Niger	p. 110
	(14) Spate Irrigation – Eritrea	p. 112
Cross-slope barriers are measures on sloping lands in the form of earth or soil bunds, stone lines, or vegetative strips, etc. for reducing runoff velocity and soil erosion. p. 114	(15) *Aloe Vera* Life Barriers – Cape Verde	p. 120
	(16) Grassed *Fanya Juu* Terraces – Kenya	p. 122
	(17) Konso Bench Terrace – Ethiopia	p. 124
Agroforestry integrates the use of woody perennials with agricultural crops and / or animals for a variety of benefits and services including better use of soil and water resources, multiple fuel, fodder and food products, habitat for associated species. p. 126	(18) Chagga Homegardens – Tanzania	p. 132
	(19) Shelterbelts – Togo	p. 134
	(20) Grevillea Agroforestry System – Kenya	p. 136
	(21) Farmer Managed Natural Regeneration – Niger	p. 138
	(22) Parkland Agroforestry System – Burkina Faso	p. 140
Integrated Crop-Livestock Management optimises the uses of crop and livestock resources through interaction and the creation of synergies. p. 142	(23) Night Corralling – Niger	p. 148
	(24) Rotational Fertilization – Niger	p. 150
	(25) Grazing Land Improvement – Ethiopia	p. 152
	(26) Smallstock Manure Production – Togo	p. 154
Pastoralism and rangeland management Grazing on natural or semi-natural grassland, grassland with trees and / or open woodlands. Animal owners may have a permanent residence while livestock is moved to distant grazing areas, according to the availability of resources. p. 156	(27) Ngitili Dry-Season Fodder Reserves – Tanzania	p. 162
	(28) *Couloirs de Passage* – Niger	p. 164
	(29) Improved Well Distribution for Sustainable Pastoralism – Niger	p. 166
	(30) Rotational Grazing – South Africa	p. 168
Sustainable planted forest management The purpose of planted forests can be either commercial or for environmental / protective use or for rehabilitation of degraded areas. The sustainability of new planted forests depends on what they replace, e.g. the replacement of a natural forest will hardly be sustainable. p. 170	(31) *Casuarina* Tree Belt for Sand Dune Fixation – Senegal	p. 176
	(32) Afforestation and Hillside Terracing – Eritrea	p. 178
	(33) Sand Dune Stabilisation – Niger	p. 180
Sustainable Forest Management in drylands encompasses administrative, legal, technical, economic, social and environmental aspects of the conservation and use of dryland forests. p. 182	(34) Assisted Natural Regeneration of Degraded Land – Burkina Faso	p. 188
	(35) Indigenous Management of Tapia Woodlands – Madagascar	p. 190
Sustainable Rainforest Management encompasses administrative, legal, technical, economic, social and environmental aspects of the conservation and use of rainforests. p. 192	(36) Forest Beekeeping – Cameroon	p. 198
	(37) Community Forests – Cameroon	p. 200
Trends and new opportunities SLM measures which have not yet widely spread and / or provide additional sources of income for land users, such as ecotourism, payments for ecosystem services, organic agriculture, etc. p. 202	(38) Organic Cotton – Burkina Faso	p. 206
	(39) Push-Pull Integrated Pest and Soil Fertility Management – Kenya	p. 208
	(40) Equitable Payments for Watershed Services – Tanzania	p. 210
	(41) Conservation Approach for Kouré Giraffes – Niger	p. 212
SLM approaches 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 more sustainable land management. p. 216	(42) *Stratégie Energie Domestique* – Niger	p. 222
	(43) Promoting Farmer Innovation – Kenya, Tanzania and Uganda	p. 224
	(44) Farmer Field Schools – Kenya	p. 226
	(45) Participatory Negotiated Territorial Development – Burkina Faso and Ghana	p. 228
	(46) Participatory Learning and Action Research approach to Integrated Rice Management PLAR-IRM – Madagascar	p. 230
	(47) 'Catchment' Approach – Kenya	p. 232


Hanspeter Liniger

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.

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

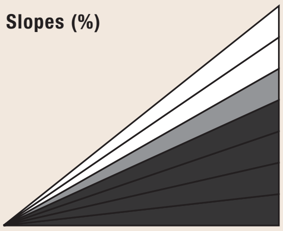
Climate

▦	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

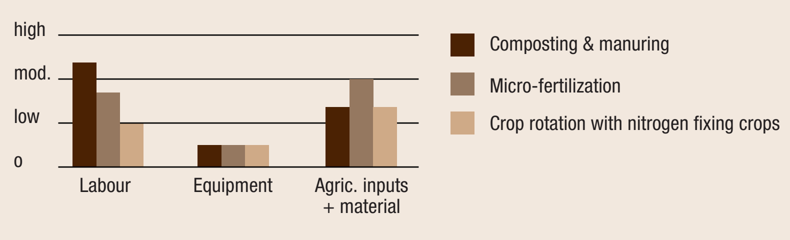
■	High
▨	Medium
□	Low

Required know-how

□	High
■	Medium
□	Low

Economics

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	500–800	1100-1800[1]	900-1500[2]	30-50%[1]	70-84%[2]
Pearl millet	200	300-370[1]	400-500[2]	48-70%[1]	123-143%[2]
Zai+Micro-fertilizing,					
Sorghum (Burkina Faso)	552	900-1200		50-100%	
Sorghum (Ghana)	290	400-650			
Cowpea (Burkina Faso)	590	950-1200			
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 fertiliser)	➜ 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 smallholders 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

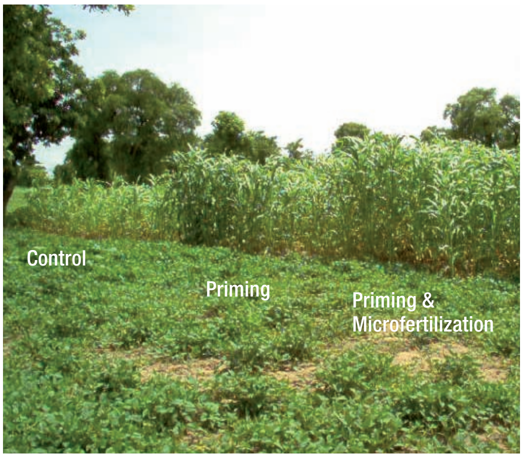
Woodfine, A. 2009. Using sustainable land management practices to adapt to and mitigate climate change in Sub-Saharan Africa: resource guide version 1.0. TerrAfrica. www.terrafrica.org

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

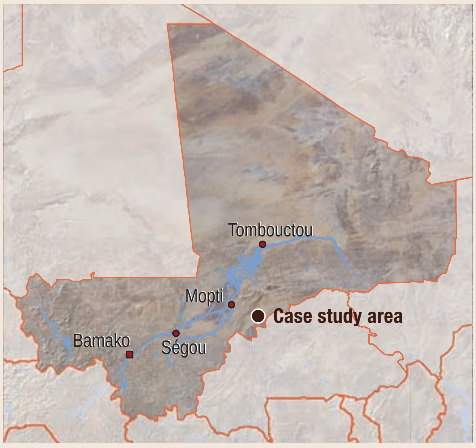
For establishment: na
For maintenance: low

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.

Main contributors: Jens B. Aune, Noragric/Department of International Environment and Development Studies; Norwegian University of Life Sciences; As, Norway; jens.aune@umb.no, http://www.umb.no

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.

Main contributors: Fabienne Thomas; fabienne.thomas@volkart.ch ■ Urs Scheidegger, Swiss College of Agriculture SHL, Head International Agriculture, Switzerland; urs.scheidegger@bfh.ch.
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

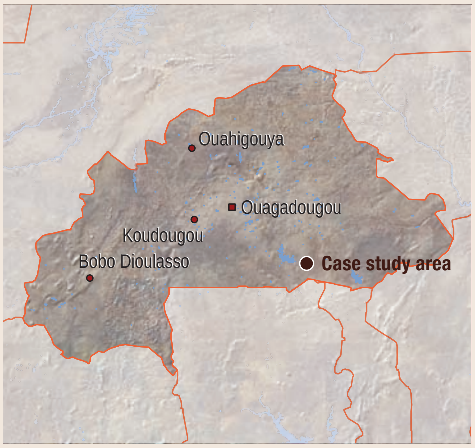
For establishment: low
For maintenance: medium

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 m^3)	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 km^2. 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.

Main contributors: Steve Twomlow, UNEP, Nairobi, Kenya; stephen.twomlow@unep.org; www.unep.org

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.

CONSERVATION AGRICULTURE

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 intercropping which allows permanent cover and also replenishment of nutrients – when nitrogen-fixing legumes are included in the mixture.

For successful adaptation in SSA, CA needs to evolve to suit the biophysical and socio-economic conditions, 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).

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

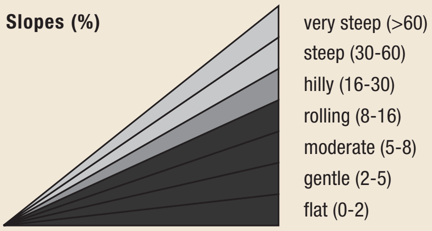
Climate

■	Humid
■	Subhumid
■	Semi-arid
□	Arid

Average rainfall (mm)

■	> 3000
■	2000-3000
■	1500-2000
■	1000-1500
■	750-1000
▩	500-750
░	250-500
□	< 250

Slopes (%)



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

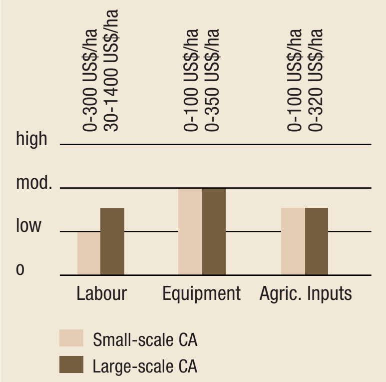
■	High
□	Medium
□	Low

Economics

Establishment 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, herbicides, 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 livestock 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 institutions 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/km^2
- 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.

Main contributors: Martin Kisima, Farmer, Meru, Kenya; martin@kisima.co.ke ■ Kithinji Mutunga, FAO, Nairobi, Kenya; Kithinji.Mutunga@fao.org
Key references: WOCAT. 2009. WOCAT database on SLM Technologies; www.wocat.net.