Part 2
Best SLM Practices for Sub-Saharan Africa
OVERVIEW OF BEST SLM PRACTICES
## SLM Group and definition

**Integrated Soil Fertility Management**
Benefits from positive interaction and complementarities of a combined use of organic and inorganic plant nutrients in crop production.  

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**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.  

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**Rainwater Harvesting**
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.  

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**Smallholder Irrigation Management**
Aims to achieve higher water use efficiency through more efficient water collection and abstraction, water storage, distribution and water application.  

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**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.  

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**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.  

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**Integrated Crop-Livestock Management**
Optimises the uses of crop and livestock resources through interaction and the creation of synergies.  

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**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.  

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**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.  

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**Sustainable Forest Management in drylands**
Encompasses administrative, legal, technical, economic, social and environmental aspects of the conservation and use of dryland forests.  

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**Sustainable Rainforest Management**
Encompasses administrative, legal, technical, economic, social and environmental aspects of the conservation and use of rainforests.  

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**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.  

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**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.  

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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

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.

<table>
<thead>
<tr>
<th>Development issues addressed</th>
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</thead>
<tbody>
<tr>
<td>Preventing / reversing land degradation</td>
<td>++</td>
</tr>
<tr>
<td>Maintaining and improving food security</td>
<td>+++</td>
</tr>
<tr>
<td>Reducing rural poverty</td>
<td>++</td>
</tr>
<tr>
<td>Creating rural employment</td>
<td>+</td>
</tr>
<tr>
<td>Supporting gender equity / marginalised groups</td>
<td>++</td>
</tr>
<tr>
<td>Improving crop production</td>
<td>+++</td>
</tr>
<tr>
<td>Improving fodder production</td>
<td>+</td>
</tr>
<tr>
<td>Improving wood / fibre production</td>
<td>+</td>
</tr>
<tr>
<td>Improving non wood forest production</td>
<td>na</td>
</tr>
<tr>
<td>Preserving biodiversity</td>
<td>+</td>
</tr>
<tr>
<td>Improving soil resources (OM, nutrients)</td>
<td>+++</td>
</tr>
<tr>
<td>Improving of water resources</td>
<td>+</td>
</tr>
<tr>
<td>Improving water productivity</td>
<td>++</td>
</tr>
<tr>
<td>Natural disaster prevention / mitigation</td>
<td>+</td>
</tr>
<tr>
<td>Climate change mitigation / adaptation</td>
<td>++</td>
</tr>
</tbody>
</table>

**Climate change mitigation**

<table>
<thead>
<tr>
<th>Potential for C Sequestration (tonnes/ha/year)</th>
<th>no data</th>
</tr>
</thead>
<tbody>
<tr>
<td>C Sequestration: above ground</td>
<td>+</td>
</tr>
<tr>
<td>C Sequestration: below ground</td>
<td>+</td>
</tr>
</tbody>
</table>

**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.

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.
INTEGRATED SOIL FERTILITY MANAGEMENT

Applicability

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

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

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

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

**Maintenance costs**

- **Composting & manuring**
- **Micro-fertilization**
- **Crop rotation with nitrogen fixing crops**

(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**

<table>
<thead>
<tr>
<th></th>
<th>Yield without SLM (kg/ha)</th>
<th>Yield with SLM (kg/ha)</th>
<th>Yield gain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-fertilization, (Mali) Sorghum</td>
<td>500–800</td>
<td>1100–1800$^1$</td>
<td>30–50%$^1$</td>
</tr>
<tr>
<td>Pear millet</td>
<td>200</td>
<td>300–370$^2$</td>
<td>48–70%$^1$</td>
</tr>
<tr>
<td></td>
<td>900–1500$^3$</td>
<td>400–500$^2$</td>
<td>70–84%$^2$</td>
</tr>
<tr>
<td>Zai+Micro-fertilizing, Sorghum (Burkina Faso)</td>
<td>552</td>
<td>900–1200</td>
<td>50–100%</td>
</tr>
<tr>
<td>Sorghum (Ghana)</td>
<td>290</td>
<td>460–650</td>
<td>50–100%</td>
</tr>
<tr>
<td>Cowpeas (Burkina Faso)</td>
<td>530</td>
<td>850–1200</td>
<td>50–100%</td>
</tr>
<tr>
<td>Tithonia - Green manure, (Cameroon) Beans</td>
<td>370</td>
<td>410–570</td>
<td>10–55%</td>
</tr>
<tr>
<td></td>
<td>30–50%$^1$</td>
<td>48–70%$^1$</td>
<td>70–84%$^2$</td>
</tr>
</tbody>
</table>
|                      | 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**

<table>
<thead>
<tr>
<th></th>
<th>short term</th>
<th>long term</th>
<th>quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-fertilizing</td>
<td>+++</td>
<td>+++</td>
<td>Value-cost ratio, Mali: 3.5–12 (for 0.3 g), Sorghum 0.4–1.2 (for 6 g), Pearl Millet</td>
</tr>
<tr>
<td>Manuring &amp; Fertilizer &amp; 50% Crop Residues</td>
<td>+++</td>
<td>+++</td>
<td>Value-cost ratio, Nigeria: 20.8, Rice 5.9, Maize 3.5, Millet</td>
</tr>
</tbody>
</table>
| Composting & Manuring | ++        | +++       | -- negative; – slightly negative; /+ neutral; + slightly positive; ++ positive; +++ very positive | (Sources: Aune, et al., 2007; WOCAT, 2009 and IFPRI, 2010)
| Green Manure         | ++        | +++       | -- negative; – slightly negative; /+ neutral; + slightly positive; ++ positive; +++ very positive |
| Overall              | ++        | +++       | -- negative; – slightly negative; /+ neutral; + slightly positive; ++ positive; +++ very positive |

**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

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

### Constraints

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

References and supporting information:

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 following and animal manure) often outpaces the use of mineral fertilizers (Place et al. 2003).
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.

**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

**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**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+++</td>
<td>Increased crop yield: combined effect of seed priming and microfertilization 50%, seed priming alone 25%</td>
</tr>
<tr>
<td>+++</td>
<td>Increased production of straw / biomass</td>
</tr>
<tr>
<td>++</td>
<td>Decreased financial resources needed for purchasing fertilizer, makes the technology feasible for poor small-scale farmers</td>
</tr>
<tr>
<td>++</td>
<td>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</td>
</tr>
<tr>
<td>++</td>
<td>No additional labour inputs (the technology does not significantly increase sowing time due to simultaneous application of seeds and fertilizer)</td>
</tr>
<tr>
<td>++</td>
<td>Increased land productivity / clearance of new land is avoided</td>
</tr>
<tr>
<td>+</td>
<td>Earlier harvest (food security)</td>
</tr>
</tbody>
</table>

**Ecological benefits**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+++</td>
<td>Reduced susceptibility to beginning-of-season droughts; less burning effect if drought after sowing</td>
</tr>
<tr>
<td>++</td>
<td>Reduced exposure of plants to droughts (compared to 6 g treatment)</td>
</tr>
<tr>
<td>++</td>
<td>Increased resistance to Striga (pest)</td>
</tr>
</tbody>
</table>

**Socio-cultural benefits**

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>Can be mechanised</td>
</tr>
<tr>
<td>+</td>
<td>Improved nutrition and both on-farm and off-farm employment</td>
</tr>
</tbody>
</table>

**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.

**Establishment inputs and costs per ha**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>0</td>
</tr>
<tr>
<td>Equipment</td>
<td>0</td>
</tr>
<tr>
<td>Agricultural inputs</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>

No establishment costs.

**Maintenance inputs and costs per ha per year**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: 6 person-days</td>
<td>1</td>
</tr>
<tr>
<td>Equipment / tools: planting stick / hoe</td>
<td>0</td>
</tr>
<tr>
<td>Agricultural inputs: 47 kg superphosphate fertilizer</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>3</strong></td>
</tr>
</tbody>
</table>

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

**Benefit-cost ratio**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Short term</th>
<th>Long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Maintenance</td>
<td>very positive</td>
<td>very positive</td>
</tr>
</tbody>
</table>

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 cap) cost-benefit ratio of 0.3 g treatment is 8-20 times higher.

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

**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 m² 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.

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**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 crop-land 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

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/km²
- 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 km².

Establishment inputs and costs per ha

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td></td>
</tr>
<tr>
<td>Equipment</td>
<td></td>
</tr>
<tr>
<td>Agricultural Inputs</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>no data</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: 6 person-days</td>
<td>80</td>
</tr>
<tr>
<td>Equipment / tools: planting stick / hoe</td>
<td>30</td>
</tr>
<tr>
<td>Agricultural inputs: 47 kg superphosphate fertilizer</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>110</td>
</tr>
</tbody>
</table>

% 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

<table>
<thead>
<tr>
<th>Inputs</th>
<th>short term</th>
<th>long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Maintenance</td>
<td>positive</td>
<td>positive</td>
</tr>
</tbody>
</table>

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

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

Integrated Soil Fertility Management

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 (zaï). 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.

**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

### 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)

### Establishment inputs and costs per ha

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: 2 person-days</td>
<td>2</td>
</tr>
<tr>
<td>Equipment: hoe, digging stick, bucket</td>
<td>10</td>
</tr>
<tr>
<td>Construction material: clay (0.5 m³)</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>12</strong></td>
</tr>
<tr>
<td>% of costs borne by land users</td>
<td>100%</td>
</tr>
</tbody>
</table>

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

### Maintenance inputs and costs per ha per year

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: 20 person-days</td>
<td>20</td>
</tr>
<tr>
<td>Equipment: wheelbarrow renting</td>
<td>6</td>
</tr>
<tr>
<td>Agricultural inputs: manure (100 kg)</td>
<td>2</td>
</tr>
<tr>
<td>Material: ash, straw</td>
<td>0</td>
</tr>
<tr>
<td>Compost transportation</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>30</strong></td>
</tr>
<tr>
<td>% of costs borne by land users</td>
<td>100%</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Inputs</th>
<th>short term</th>
<th>long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>very positive</td>
<td>very positive</td>
</tr>
<tr>
<td>Maintenance</td>
<td>very positive</td>
<td>very positive</td>
</tr>
</tbody>
</table>

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

### Ecological benefits
- + + Increased soil moisture
- ++ Increased soil fertility
- ++ Improved soil cover
- ++ Efficiency of excess water drainage
- + Reduced soil loss

### Socio-cultural benefits
- ++ Community institution strengthening
- ++ Improved conservation/ erosion knowledge
- ++ Integration of agriculturalists and pastoralists

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

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

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


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**Part 2: SLM Technology, Compost Production - Burkina Faso** 73
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.

**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).

For establishment: high
For maintenance: medium to low

**Labour requirements**

**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

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/km²
- 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 m² in 2004 to more than 3,500 m² in 2008.

Establishment inputs and costs per ha

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>0</td>
</tr>
<tr>
<td>Equipment</td>
<td>0</td>
</tr>
<tr>
<td>Agricultural inputs</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>0</strong></td>
</tr>
</tbody>
</table>

No establishment costs.

Maintenance inputs and costs per ha per year

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: 124 person-days</td>
<td>108</td>
</tr>
<tr>
<td>Equipment: hand hoes</td>
<td>7</td>
</tr>
<tr>
<td>Agricultural inputs: fertilizer</td>
<td>69</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>184</strong></td>
</tr>
</tbody>
</table>

% 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

<table>
<thead>
<tr>
<th>Inputs</th>
<th>short term</th>
<th>long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>positive</td>
<td>very positive</td>
</tr>
<tr>
<td>Maintenance</td>
<td>positive</td>
<td>very positive</td>
</tr>
</tbody>
</table>

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.

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

Key references:
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**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preventing/reversing land degradation</td>
<td>++</td>
</tr>
<tr>
<td>Maintaining and improving food security</td>
<td>++</td>
</tr>
<tr>
<td>Reducing rural poverty</td>
<td>++</td>
</tr>
<tr>
<td>Creating rural employment</td>
<td>++</td>
</tr>
<tr>
<td>Supporting gender equality/marginalised groups</td>
<td>++</td>
</tr>
<tr>
<td>Improving crop production</td>
<td>++</td>
</tr>
<tr>
<td>Improving fodder production</td>
<td>+</td>
</tr>
<tr>
<td>Improving wood/fibre production</td>
<td>na</td>
</tr>
<tr>
<td>Improving non wood forest production</td>
<td>na</td>
</tr>
<tr>
<td>Preserving biodiversity</td>
<td>+</td>
</tr>
<tr>
<td>Improving soil resources (OM, nutrients)</td>
<td>++</td>
</tr>
<tr>
<td>Improving water resources</td>
<td>++</td>
</tr>
<tr>
<td>Improving water productivity</td>
<td>+++</td>
</tr>
<tr>
<td>Natural disaster prevention/mitigation</td>
<td>++</td>
</tr>
<tr>
<td>Climate change mitigation/adaptation</td>
<td>++</td>
</tr>
</tbody>
</table>

**Climate change mitigation**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potential for C Sequestration</td>
<td>0.57 ± 0.14*</td>
</tr>
<tr>
<td>C Sequestration: above ground</td>
<td>+</td>
</tr>
<tr>
<td>C Sequestration: below ground</td>
<td>++</td>
</tr>
</tbody>
</table>

**Climate change adaptation**

<table>
<thead>
<tr>
<th>Issue</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resilience to extreme dry conditions</td>
<td>++</td>
</tr>
<tr>
<td>Resilience to variable rainfall</td>
<td>++</td>
</tr>
<tr>
<td>Resilience to extreme rain and wind storms</td>
<td>+</td>
</tr>
<tr>
<td>Resilience to rising temperatures and evaporation rates</td>
<td>++</td>
</tr>
<tr>
<td>Reducing risk of production failure</td>
<td>+</td>
</tr>
</tbody>
</table>

* 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 (0.5%), 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

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 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.
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, pulverisation) in drought-prone situations

Water degradation: acidification 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 sub-humid 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 plateaux and valley floors. Due to the reduced runoff and erosion it is particularly suitable for steeper slopes (under manual or animal traction), where crops are grown under these conditions.

Soils: Suitable for sandy loams to clay loams, but unsuitable for compacted hard soils or those at risk of waterlogging (poorly drained), shallow soils. Compaction due to previous tillage can be dealt with through sub-soiling.

Socio-economic conditions

Farming system and level of mechanisation: can be applied at all farm scales and implemented with different levels of mechanisation. Until recently there has been little emphasis on extending CA to the small-scale level.

Small-scale farms: hand or animal (oxen) draft implements such as animal (or sometimes tractor) drawn ripper, and ripper planter; hand jab planters for manual systems, etc.

Large-scale farms: direct seed drill, knife roller, sprayer, etc. with substantial reduction in time and energy use for tillage operations.

Market orientation: suitable for subsistence or commercial systems; access to markets is important to sell surplus and to purchase inputs.

Land ownership and land use / water rights: some communally-owned lands lack security of tenure and hence render land users reluctant to practise and invest in the shift to conservation agriculture.

Skill / knowledge requirements: medium to high for land users, extension agents and technical staff (rotations / crop sequence, planting dates, weed control / use of herbicides).

Labour requirements: significantly reduced (by 10% to more than 50%) compared to conventional tillage (reduced hired labour costs, family labour ➔ more time available for other activities).
Economics

Establishment and maintenance costs

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

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

(Source: WOCAT, 2009)

Production benefits

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

(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

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

(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 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

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

### Constraints

<table>
<thead>
<tr>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Low biomass production (for cover) in low precipitation areas and short growing seasons</td>
</tr>
<tr>
<td>• Scarcity of pertinent plant nutrients in humid areas due to high and fast decomposition rate (especially P)</td>
</tr>
</tbody>
</table>

**How to overcome**

- **African adapted** CA: reduce the mulch requirement, focus on no-tillage methods (including traditional low-till systems such as zai 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

<table>
<thead>
<tr>
<th>Economic</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Needs initial capital investment for adapted machinery and small scale equipment</td>
</tr>
<tr>
<td>• External input constraints: fertilizers, cover crop seeds, herbi cides, etc. (availability, access and costs)</td>
</tr>
<tr>
<td>• Availability and access to equipment on local markets</td>
</tr>
<tr>
<td>• Low capacity of local manufacturers of hand / animal-driven CA equipment</td>
</tr>
<tr>
<td>• Labour constraints for hand weeding (availability and costs in first years)</td>
</tr>
</tbody>
</table>

**How to overcome**

- 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

<table>
<thead>
<tr>
<th>Ecological</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Competition between soil cover and livestock feed (how to integrate livestock and mixed cropping smallholdings)</td>
</tr>
<tr>
<td>• Weed control in the early years of adoption</td>
</tr>
<tr>
<td>• Crop residues on the surface may favour disease and pests (micro-climate)</td>
</tr>
<tr>
<td>• Compacted soils require prior sub-soiling</td>
</tr>
</tbody>
</table>

**How to overcome**

- Stale-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

<table>
<thead>
<tr>
<th>Socio-cultural</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Uncertain land use rights</td>
</tr>
<tr>
<td>• Lack of laws and regulations for communal grazing</td>
</tr>
<tr>
<td>• Lack of supporting policies and implementing institutions</td>
</tr>
<tr>
<td>• Poorly developed infrastructure / restricted access to markets, requires information, locally specific knowledge, technical skills and innovation to find the most suitable system</td>
</tr>
<tr>
<td>• Difficult to introduce crop rotations on small portions of land (half a hectare or less)</td>
</tr>
<tr>
<td>• ‘Project’ approach to piloting CA (short time frames, availability of support, limited lead-time for institutionalising CA into existing institutions and policies</td>
</tr>
</tbody>
</table>

**How to overcome**

- 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. Production, market systems and supply chains must be developed for producing CA equipment and other inputs for smallholders.
Disseminate knowledge: Agricultural machinery producers and cultural, 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.).

References and supporting information:
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.

SLM Group: Conservation Agriculture
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).

### Establishment activities

Note: Conservation tillage is based on agromonic 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’ plough beam, plough unit, ripper / chisel (tindo) used for ripping / deep ripping.
Case study area: Umande, Laikipia District, Kenya

Establishment inputs and costs per ha

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>0</td>
</tr>
<tr>
<td>Equipment</td>
<td>0</td>
</tr>
<tr>
<td>Agricultural inputs</td>
<td>0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>0</td>
</tr>
</tbody>
</table>

No establishment costs.

Maintenance inputs and costs per ha per year

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: 3-5 person-days</td>
<td>25</td>
</tr>
<tr>
<td>Equipment</td>
<td>0</td>
</tr>
<tr>
<td>Agricultural inputs: seeds (50 kg), fertilizer (20 kg), compost / manure (4,000 kg)</td>
<td>68</td>
</tr>
<tr>
<td>TOTAL</td>
<td>93</td>
</tr>
</tbody>
</table>

% 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

<table>
<thead>
<tr>
<th>Inputs</th>
<th>short term</th>
<th>long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Maintenance</td>
<td>positive</td>
<td>very positive</td>
</tr>
</tbody>
</table>

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

Adoption

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

Ecological conditions

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

Socio-economic conditions

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

Production / economic benefits

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

Ecological benefits

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

Socio-cultural benefits

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

Off-site benefits

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

Weaknesses ➜ and how to overcome

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

Main contributors: Frederick Kihara, Nanyuki, Kenya; pdo@africaonline.co.ke

The traditional slash-and-burn land use system in the case study area—involv-
ing clearing natural vegetation followed by 2-5 years of cropping—has become unsustainable as land pressure has greatly increased, shortening fallow peri-
ods. 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.

### 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).

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

### Labour requirements

- **For establishment:** na
- **For maintenance:** low

### Knowledge requirements

- **For advisors:** moderate
- **For land users:** moderate

### 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.
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):

<table>
<thead>
<tr>
<th>Input</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: 83 person-days</td>
<td>142</td>
</tr>
<tr>
<td>Equipment</td>
<td>13</td>
</tr>
<tr>
<td>Agricultural inputs</td>
<td>65</td>
</tr>
<tr>
<td>Construction material</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>220</strong></td>
</tr>
</tbody>
</table>

Minimum tillage and direct planting:

<table>
<thead>
<tr>
<th>Input</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour: 48 person-days</td>
<td>83</td>
</tr>
<tr>
<td>Equipment</td>
<td>18</td>
</tr>
<tr>
<td>Agricultural inputs</td>
<td>111</td>
</tr>
<tr>
<td>Construction material</td>
<td>0</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>212</strong></td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Input</th>
<th>Short term</th>
<th>Long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Maintenance</td>
<td>neutral</td>
<td>positive</td>
</tr>
</tbody>
</table>

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/km²
- 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 km²). 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.
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.

Establishment activities
1. Purchasing no-till machinery.

Note: Conservation tillage is based on agromonic 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 establishment costs are less than half of the conventional tillage.

**Maintenance inputs and costs per ha per year**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Costs (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>10</td>
</tr>
<tr>
<td>Equipment: 4 machine hours / ha</td>
<td>70</td>
</tr>
<tr>
<td>Agricultural inputs: biocides</td>
<td>25</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>105</strong></td>
</tr>
</tbody>
</table>

% 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**

<table>
<thead>
<tr>
<th>Inputs</th>
<th>short term</th>
<th>long term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishment</td>
<td>slightly positive</td>
<td>positive</td>
</tr>
<tr>
<td>Maintenance</td>
<td>positive</td>
<td>very positive</td>
</tr>
</tbody>
</table>

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/km²
- Land ownership: company (Ltd)
- Land use rights: leased
- Market orientation: commercial
- Level of mechanisation: highly mechanised

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

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

**Off-site benefits**
+++ Reduced downstream siltation (the heavy rains in 2003 did not cause erosion)
+ Groundwater recharge during exceptional high rainfall seasons

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

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

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Kithinji Mutunga, FAO, Nairobi, Kenya; Kithinji.Mutunga@fao.org

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

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