Final Technical Report

Promoting Conservation Agriculture to Improve Land Productivity and Profitability among Smallholder Farmers in Western Kenya

Report submitted to Kilimo Trust

By

The African Network for Soil Biology and Fertility (AfNet) of the Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT)

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1 Executive Summary

Smallholder farmers in Africa are trapped in a vicious cycle of poverty and land degradation coupled with increasing population and demand for food. There is, therefore, need to harness appropriate and affordable agricultural technologies that are highly productive and at the same time positively contribute to environmental services as an element of sustainability.

Conservation agriculture (CA) is one such technology that holds the key not only to sustained food production but also improves soil properties and other ecosystems services, because it addresses missing components in the intensive tillage-based standardized approach to agriculture intensification. Despite its numerous benefits, the adoption of CA, especially in SSA, is still low.

Therefore, the aim of the project was to promote widespread adoption of conservation agriculture by smallholder farmers while protecting and improving soil conditions to achieve higher yields and enhanced environmental services in East Africa. The project has created widespread awareness of conservation agriculture to 4500 households in the target districts using the mother-baby approach, field days and demonstrations. Over 1200 farmers have been trained on the principles of CA technology. Farmers identified two CA technologies as most promising in the region: i) 80% preferred the Cereal-legume rotation (specifically the soybean-maize rotation) and ii) 20 % preferred cereal-legume intercrop, with desmodium as cover crop. Under the rotation system, the cereal component was grown during the long rains (March-June), while soybean during the short rains (September-November). The selection of the maize-desmodium intercrop was based on i) striga weed infestation, ii) need for alternative animal feed, and iii) production of desmodium seed for sale. For the intercrop plots, desmodium provided more than 70% ground cover, minimizing weed competition and surface run off.

Average maize grain yield was significantly higher than the control (1.2 t/ha) in both CA (2.8 t/ha rotation and 3.0 t/ha intercrop system) and conventional agriculture plots (2.8 t/ha). To promote development of manufacturing enterprises the project facilitated the training of key stakeholders in fabrication of CA tools (8 artisans), soybean processing and two farmer groups were strengthened for collective action. Under CA increase in crop yields was the benefit ranked highest by farmers. However, under the current fertility status in most farms, CA cannot be practiced effectively without addition of nutrients especially nitrogen and phosphorus to the system.

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5 Back ground

Smallholder farmers in Africa are trapped in a vicious cycle of poverty and land degradation. There is, therefore, need to harness appropriate and affordable technologies that can help break this cycle. Conservation agriculture (CA) is one such technology that holds the key not only to sustained food production but also improves soil properties and other ecosystems services. Across the world, CA has been observed to result in numerous direct impacts at farm level: higher yields, land use intensification, higher farm profits, better returns to labor, lower labor demands and reduced drudgery. Other indirect benefits include improved rural welfare, improved national food security, mitigation of de-forestation, soil conservation, less floods and silting, and higher aquifer re-charge. Despite these numerous benefits, the adoption of CA, especially in SSA, is still low, and limited to the southern Africa region with minimal cases in East Africa.

Therefore, this project aimed at promoting widespread adoption of conservation agriculture by smallholder farmers while protecting and improving soil conditions to achieve higher yields and enhanced environmental services in East Africa. Specific interventions were to develop effective "development pathways" or road maps on the practice of CA at the target benchmark sites. The smallholder farmers who form the majority of land users need to be convinced on the effectiveness of CA, to enable them adopt and adapt it as a sustainable agricultural practice. The goal was to bring the farmers out of poverty with no further impoverishment of soils and other natural resources.

5.1 Objectives

The specific objectives of the project were:

1. To build country multidisciplinary teams and evaluate the socio-economic and policy constraints and opportunities for adoption of CA.
2. To screen the most appropriate legumes for integration into conservation agriculture systems.
3. To develop, test, adapt and demonstrate various conservation agriculture practices.
4. To develop relevant agro-enterprises and build capacity of smallholder farmers in applying conservation agriculture practices.
5. To develop mechanisms for payment for environmental services (PES) to smallholder farmers.

5.2 Project Outline

This project recognized that past research efforts have generated numerous CA practices that, if adopted by smallholder farmers, could increase food production, contribute to higher incomes, improved nutrition/food security and contribute to the conservation of the natural resource base. Whereas these practices take into account the general principles of CA, there was need to adapt them to the local conditions for greater adoption, outcome, and impact on the livelihoods of millions of smallholder farmers. The aim of the project was to generate effective "development pathways" or road maps on the practice of CA. This included analysis of how CA contributed towards provision of environmental services for sustainable long-term productivity hence income generation.

The goal of this project was therefore to improve smallholder food security and income, and enhance ecosystem health. The purpose was to promote widespread adoption of conservation agriculture by smallholder farmers while protecting and improving soil conditions to achieve higher yields and enhanced environmental services in Kenya. The specific objectives of the project are highlighted above.

The project adopted an iterative process comprising participatory approaches and partnerships to develop linkages between all actors (farmers, researchers, extension agents, agro-dealers and other stakeholders) and develop CA technologies and innovations that suit the local biophysical environment and the farmers' socio-economic conditions. Through the mother-baby trial approach the potential benefits of CA were clearly visible and the rate of adoption by farmers was accelerated.

At the end of the project, participatory analysis of environmental impact of CA and other agricultural processes gave the farmers insight on how they can contribute to environmental sustainability for the future.

6 Methodology

6.1 Planning Meeting

An introductory Conservation Agriculture (CA) project planning meeting was successfully held at TSBF-CIAT offices in ICRAF campus Nairobi on the 25th Feb., 2008 attended by 9 participants (4 TSBF-CIAT, 3 KARI, and 2 CPWF-CIAT).
The main objectives of the workshop were to:

1. discuss and update the Program of Work
2. discuss and harmonize the methodologies and approaches for carrying out project activities (viz. field experiments, training, scaling up/out and participatory approaches, socio-economic issues, surveys, technologies, etc.)
3. clarify the roles and responsibilities of various partners in the project
4. finalize the selection of benchmark sites
5. define guidelines of self-monitoring and evaluation
6. discuss communication strategies between partners

The project coordinator Dr Andre Bationo gave a brief summary of the project, its purpose, objectives, outputs and the expected outcomes and impact.
The project establishment was delayed because of late securing of project funds and the unstable political situation in Kenya which mainly affected Western Kenya the site of the project. Nevertheless, it was agreed that project activities should commence immediately to catch up with the long rains season in mid-March.
The KARI team highlighted the success of previous CA work done by FAO with both small and large scale farmers in 5 districts in Kenya. The results showed that CA had more impact among the large scale farmers who mainly used tractor drawn implements and herbicides compared to small-scale farmers. .
During the planning meeting, the following vision of success for the project was set:

- *It is expected that successful implementation of the project will lead to at least 25% of farmers in 2 contrasting catchments in Siaya District exposed to, adapting and/or adopting sustainable CA technologies and 80% of adopters obtaining 100% increase in food security through increased yield, reduced labor input; and/or improved provision of environmental services by 2010.*

6.2 Site Selection & Treatments

Two contrasting catchments were selected in Siaya and Butere-Mumias districts where project activities would be implemented. In each of these catchments, one Mother trial experiment as a learning points for farmers and other stakeholders on the concepts of CA were set-up in a central position for easy access by most farmers preferably in a school compound. In each of the 2 catchments, 30 more farmers would be selected as representative of catchment conditions to lay out baby trials for the different CA practices.

The Mother trials would have the following initial treatments:

- T1 - Absolute Control - Farmers' practice
  - No input application
- T2 - No Till -cereal/legume rotation (maize/soybean)
  - Rip and subsoil, mulch, fertilizer
- T3 - No Till -maize/desmodium-intercrop
  - Rip and subsoil, fertilizer
  - Push-pull approach
- T4 – Conventional Tillage -Maize/bean intercrop,
  - Fertilizer

Each treatment plot would be 15m by 15m as shown in figure 1. The minimum data set agreed upon for each catchment monitoring (mother trial) site included gravimetric soil moisture, rainfall data and composite soil samples from all the plots before planting in each season.

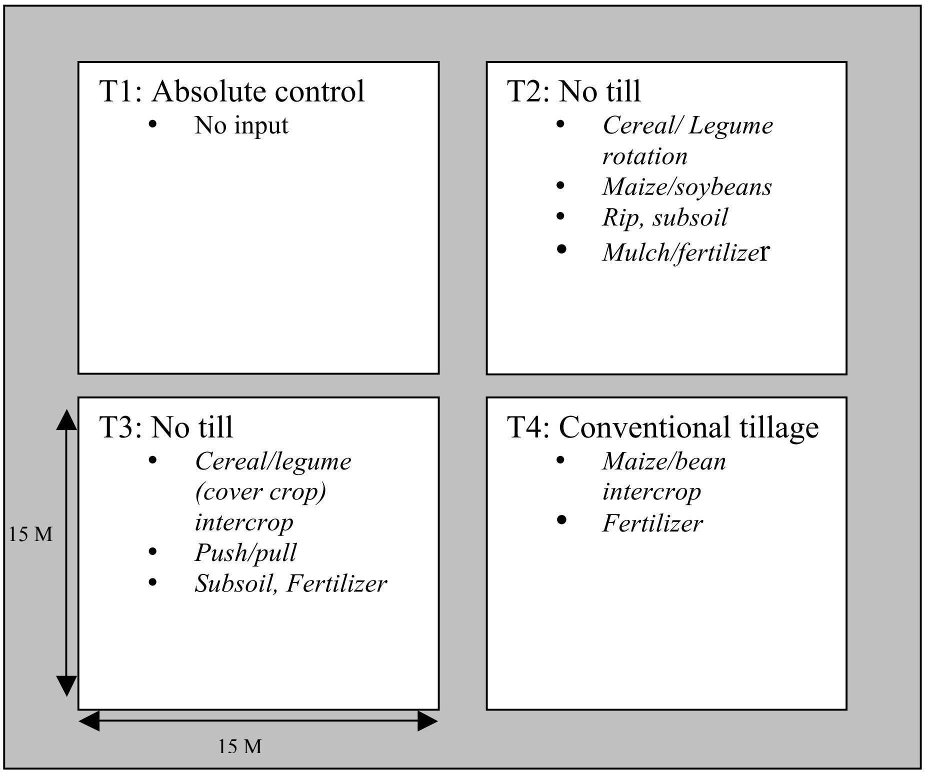

Figure 1: Experimental layout

PM&E would be done for the mother and baby trials as well on farmers fields to evaluate the impact of adopting CA on farmers' income. To verify whether the integration of mother-baby trials and Farmer Field School approach was the most effective mode of implementing the project, impact assessment would be determined by comparing the participating and non-participating farmers' data. Impact of CA on environmental services provision would also be determined.

6.3 Location of conservation agriculture experiments in Kenya

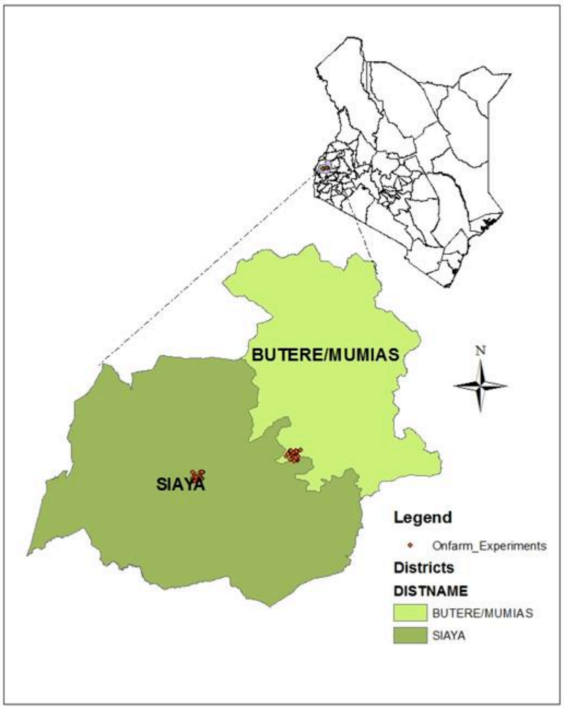

Figure 2: Experimental site map

6.4 Output 1: The state-of-art and practice of conservation agriculture evaluated

A baseline survey was conducted to identify and document success cases of CA use within the benchmark sites. This was supplemented with a desk study to inventory success cases at the national and regional levels. These cases gave the background information on CA in the region and formed the entry point for the project. Appropriate CA technologies and innovations were then designed to address these problems, taking into account the prevailing local biophysical, social, cultural, political and environmental conditions.

6.4.1 Activities

1.1 To make an inventory of CA practices currently in use in the benchmark sites
1.2 Undertake an ex-ante economic profitability analysis of the CA practices in place in the benchmark sites.
1.3 Identify constraints and opportunities facing smallholder farmers practicing CA
1.4 Conduct baseline studies to identify success and failed cases of CA practice at national and regional levels

A farmer survey was carried out in Manyala, Butere District and Uyoma, Siaya District (Figure 1) in western Kenya to evaluate the factors limiting the adoption of conservation agriculture technologies in this region.
A questionnaire and informal interviews were administered to a sample of 120 farmers (participants and non participants in TSBF CA trials) from Manyala and Uyoma locations to evaluate the factors limiting the adoption of conservation agriculture technologies in this region. For the informal interview the farmer described the practices on their farm, reasons for adopting them, source of the technology, and suggestions on improvement of the technology.
In the questionnaire the farmers described the actual practices on their farm, and also identified their training and products needs for CA practice.
Data collected was subjected to statistical analysis using excel and SPSS (12.0) applications. The descriptive statistics included frequencies, percentages and charts.

7 Results

7.1 Farming systems, seed and fertilizer use

From the survey the cereal-legume associations either as intercrops or rotation systems were the promising CA practices in the region with preference for the maize-soybean rotation system. On the other hand, the preference of legume cover crops among the smallholder farmers is still limited even with the multipurpose varieties such as desmodium.

Desmodium cover crop establishing under maize

One of the participating farmers in her field: Foreground: Soybean; Background (right), maize/desmodium intercrop; Background (left),farmer practice.

However, under the current fertility status in most farms, CA cannot be practiced effectively without addition of nutrients especially nitrogen and phosphorus to the system. Hence, for farmers to gain from CA it has to be practiced for several cropping seasons while adding sufficient nutrients from external sources to build the necessary soil conditions for sustained production.

Soybean and maize planted under CA without any fertilizer application

This created a need for information on the use of fertilizers in the region.
Most farmers in the region purchased fertilizer rather than obtaining the inputs on credit or as grants from research organizations or NGOs (figures 3 and 4).

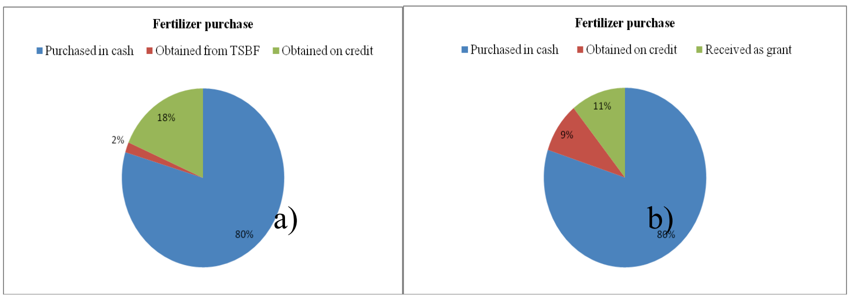

Figure 3: Fertilizer purchase among farmers in Siaya (a) and Butere (b) districts

Due to lack of linkage or access to credit services, only farmers with cash at hand during the planting season can access the inputs. Through this CA project some linkages with credit institutions have been established to ensure that farmers have access to some form of credit services that will enable them access inputs in a timely manner.

Table 1: Fertilizer expenditure in Siaya and Butere

	Amount spent on fertilizer by a farmer (Kshs.)		Total amount spent on fertilizer by a farmer (Kshs.)	Distance to nearest market (Km)
	1st fertilizer	2nd fertilizer		
Siaya	2039	1246	3285*	9
Butere	2319	1845	4164*	4
Average (Siaya & Butere)	2179	1545	3725	7

*No significant difference between the amounts.

Table 2: ANOVA single factor analysis of fertilizer expenditure by farmers in Siaya and Butere

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	528833.5	1	528833.5	0.173357	0.677832*	3.913989
Within Groups	3.97E+08	130	3050553			
Total	3.97E+08	131				

*Not significant

Most farmers in Siaya use bicycle transport to carry fertilizer to the farms to minimize cost of fertilizer and also several households can only be accessed through footbaths making use of bicycles the most appropriate means of transport locally.

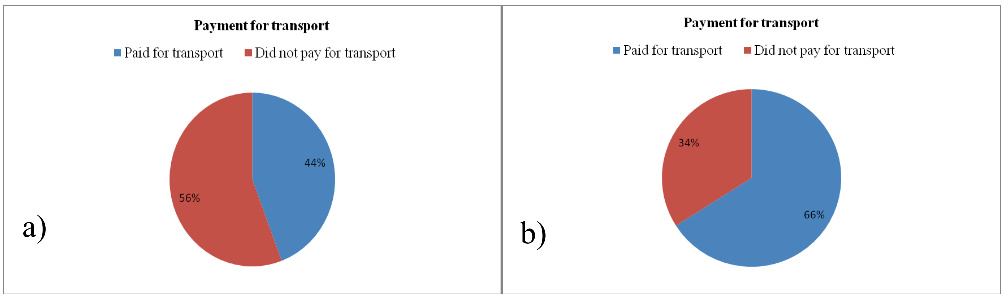

Figure 4: Farmer payment for fertilizer transport in Siaya (a) and Butere (b)

However in Butere most farmers paid for transport of fertilizer inputs from the market (Fig. 6b). This is due to the nature of topography in the region which is generally hilly with medium slopes making it difficult to use bicycles, hence, farmers have to seek alternative transport to ferry inputs to their farms. However, transportation services are more readily available in the area and are affordable.

7.2 Awareness and capacity building of CA practices

From the survey, majority of the smallholder farmers in the region are well informed on the practice of conservation agriculture and its potential in improving crop yields and sustaining productivity in the long run (Table 1). However, actual practice of the technologies is limited (Table 2) due to a number of constraints as highlighted below. The heightened awareness of conservation agriculture in the region is attributed to past and current project activities involving Kilimo Trust, TSBF-CIAT, KARI and other institutions promoting CA and related technologies.

Maize crop under no till system

Table 3: Farmers who are aware of conservation agriculture in western Kenya

Aware of conservation agriculture	Freq.	Percentage
Yes	98	75
No	33	25
Total	131	100

These projects have used demonstrations, farmer field days, exchange visits, mother-baby trials, farmer field schools, farmer-farmer learning and printed media (mainly brochures, leaflets and posters) to create awareness.

[redacted]

A group of farmers assessing the performance of the baby trials

Brochure on CA front (below) and back

[redacted]

Table 4: Farmers who practice conservation agriculture in western Kenya

Practices conservation agriculture	Freq.	Percentage
Yes	79	60
No	52	40
Total	131	100

2 Farmers in the two benchmark areas practice various CA technologies (Table 3), including reduced tillage or minimal soil disturbance mainly to open up planting holes only and where necessary weeds are removed through scrapping. The other practices are crop rotation (cereal/legume), soil cover (cover crops or crop residues), ripping and sub-soiling.

Ripping a farmer's field with 2 pairs of oxen

Display of CA oxen drown implements

Table 5: Number of farmers who are aware and use CA practices in western Kenya by district

CA practices	District	Aware	Use
Reduced Tillage	**Butere**	42	39
	Siaya	38	32
	Total	81	72
Crop rotation	**Butere**	38	34
	Siaya	42	28
	Total	81	63
Soil cover (residues)	**Butere**	39	37
	Siaya	41	34
	Total	81	72
Soil cover (cover crops)	**Butere**	37	33
	Siaya	37	28
	Total	75	62
Ripping	**Butere**	35	21
	Siaya	24	13
	Total	60	35
Sub-soiling	**Butere**	8	2
	Siaya	23	9
	Total	31	11

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7.3 Benefits and Constraints of CA

Table 6: The benefits of conservation agriculture highlighted by the farmers

Benefits	Frequency	%
Higher production and yield	48	59.5
Financial benefit- crop sales	6	6.8
Higher production and income	5	5.7
Less labour	5	5.7
Soil improvement	5	5.7
Sustain production and income	4	4.5
Less labour, high yield	3	3.4
Less production cost	2	2.2
Economic savings	1	1.1
Farm improvement	1	1.1
Food and finance sustainability	1	1.1
Less labour, high production	1	1.1
Moisture conservation	1	1.1

Pay fees	1	1.1
Save time and labour	1	1.1
School fees	1	1.1
Soil conservation	1	1.1
Use current knowledge	1	1.1
Total	88	100

The constraints to adoption and adaptation of CA (Table 7) include lack of enough capital for implements and other farm inputs at affordable costs. Adoption strategies developed will need to address this constraint besides others to realize the desired impact in terms of acreage and practice of CA technologies.

Table 7: Constraints of conservation agriculture experienced by farmers in western Kenya

Constraints	**Frequency**	**%**
Lack capital and finance	16	18
Labour intensive	15	16.9
Lack inputs	14	15.7
High costs	9	10.1
Weeds and pests, difficult weeding	5	5.6
Poor infiltration, aeration and drainage	4	4.5
Other	3	3.4
Weather	2	2.2
Purchase of inputs needed	2	2.2
Poor seeds	2	2.2
Poor germination rate	2	2.2
Training needed	1	1.1
Timing	1	1.1
Theft	1	1.1
Striga	1	1.1
Seeds expensive	1	1.1
Seed and fertiliser inadequate	1	1.1
Poor drought resistance	1	1.1
Much supervision	1	1.1
Low production	1	1.1
Livestock trespassing	1	1.1
Late planting	1	1.1
Lack of seeds	1	1.1
Labour cost	1	1.1
Input scarcity	1	1.1
Hardening of soils	1	1.1
Total	**89**	**100**

The two most used CA technologies include, reduced/minimum tillage and soil cover (crops residues). Lack of labour is the major constraint faced by farmers in using reduced or minimum tillage followed by lack of right input and high prices of the inputs (Table 6).

Similarly, labour constraints are the major hindrance to the use of soil cover (crop residues) followed by unavailability and high price of inputs (Table 7).

Table 8: Constraints faced by farmers in using reduced or minimum tillage

Constraints	Frequency	%
Lack of labour	28	42
Lack of right input	16	24
High price of input	13	19
Perceived defects in quality	3	4
Lack of information	3	4
Hard panning	1	1
Risk involved	1	2
None	1	2
Tiredness	1	2
Total	67	100

Table 9: Constraints faced by farmers in using soil cover (crop residues)

Constraints	Frequency	%
Lack of labour	24	40
Lack of right input	13	22
High price of input	9	15
Lack of information	6	10
Risk involved	3	5
Perceived defects in quality	2	3
Lack of access to credit	1	2
None	1	2
Tiredness	1	2
Total	60	100

8 Output 2: The most appropriate legumes for integration into conservation agriculture systems screened

Legumes play an important role in smallholder farming systems. The project identified and screened legumes to be incorporated into CA systems. Various legume production practices (sole, rotation and intercropping) were evaluated and recommendations made on the appropriate and profitable agronomic practices for higher legume production. The screening of the best-bet grain legumes as cash crops to increase farmers' access to fertilizers, pesticides, herbicides, etc was of special importance.

8.1 Activities:

2.1 Synthesize information on existing knowledge, and state of the art technologies related to legume incorporation into CA systems

2.2 Undertake a participatory testing and evaluation of the legume productivity under CA systems

2.3 Screen the different legume crops in terms of suitability to the local climatic and socio-economic conditions

2.4 Evaluate the impact of the best-bet legume technologies as components of the CA systems

2.5 Link farmers to local, national and regional grain legume markets

8.2 Results

8.2.1 Evaluation of Technologies

Farmers at the benchmark sites participated in evaluation of the different treatments and chose the preferred options that they were willing to practice on their farms individually. Morphological features such as colour of the leaves, height/ thickness of maize stems, size of the ears and crop height, number and size of pods and colour of the leaves for soybeans were the criteria used to evaluate the crop performance.

Podding in Soybean

Farmers assessing the performance of the Maize/desmodium intercrop

Farmers evaluating the performance of maize fields under reduced/conventional tillage

8.2.2 Cover crop

One of the main principles underlying the practice of conservation agriculture is to provide sufficient soil surface cover to influence soil properties and smother weeds. In treatment 3 (T3) for all the mother and baby trials, desmodium was established under maize as a cover crop. In several of the trials, desmodium established well providing a good ground cover during the 2nd and 3rd seasons. It's anticipated that desmodium will provide sufficient soil cover especially over the dry season

A maize-desmodium intercrop showing good ground cover by desmodium

Under conventional systems, most farmers face difficulty in achieving enough biomass for mulching purposes. Crop residue has various and competing uses e.g. as animal feed, fuel, mulch etc. Producing enough biomass to cater for soil cover and the other competing uses is a challenge. Cover crops such as mucuna are not preferred by farmers because they don't give direct returns such as edible grains so alternatives such as grain legumes e.g. lablab, soybeans are preferred. These calls for farmers intensified and guided planning for a longer period involving rotation systems than the single season they have planned for previously. Timing of planting and selection of complementary crop mixes including appropriate crops with legume cover crops for nitrogen fixing qualities etc calls for new learning.

Cover crops will supply the amount of biomass necessary to increase soil organic matter and are a key component to avoid erosion. Another positive aspect of the use of cover crops is the reduction of the soil temperature during the day and as a consequence, evaporation is reduced and soil moisture is retained. Legume cover crops will supply nitrogen through biological fixation. In the first years of CA, the organic matter content also needs to be increased and the cover crops will supply this demand of biomass. In the first years of CA, the demand for nitrogen is high and therefore it is important to use legumes as the most rational source to supply this initial demand. Another important aspect is that the legumes are a protein source to feed the local people. It will not work where crop productivity is too low to achieve appreciable levels of ground cover.

As soybean dries most of the litter falls off increasing soil cover and organic matter

8.3 Farmer Field Days and Exchange Visits

Farmer field days were organized in the two catchment areas and both participating farmers and those from the surrounding communities attended. At least four farmer field days and 2 exchange visits were held at the benchmark sites to the TSBF long-term trial sites in Nyabenda.

Farmers assessing the performance of a soybean crop under CA

At least 200 farmers attended each of the field days while 50 farmers from each of the project sites participated in the exchange visits. The farmers had an opportunity to learn more on the various aspects of conservation agriculture. The demonstrations on the Mother-baby trials clearly showed how the basic principles of CA can be implemented by farmers of various socio-economic status albeit variously.

8.4 Farmer groups

Two farmer groups have been formed, registered and opened bank accounts gearing themselves for collective action. They will get funds on a credit for purchase of farm inputs. The farmers also participated in evaluation of the different treatments.

9 Output 3: Various conservation agriculture practices tested, adapted and demonstrated

Conservation agriculture like any other innovation has to be adapted to suite local conditions. Within each country two sites were selected taking into account level of agricultural potential, farming systems, market integration, land tenure, farm size and dynamics, rainfall regime, soil nutrient status, documented soil-related problems, previous and on-going soil-related intervention, organic resource availability and management, inorganic resource availability and management, market accessibility and infrastructure, and cash needs and gender. For the activities in each selected site, a multidisciplinary team was constituted comprising of biophysical and socioeconomic scientists and farmers groups and community-based organizations. These teams developed models linking work on CA, agricultural production and markets in the benchmark sites.

The various conservation agriculture techniques that are applicable to each of the project sites was tested at on-farm experimental plots. The project worked with farmers and other stakeholders to achieve this output. The farmers within existing soil fertility groups were the focal point for most of the activities. Selected technologies were tested on demonstration sites, preferably within school compounds. Both scientists and the farmer groups were trained on data collection from the treatments and record keeping. Analysis of results was done jointly by researchers and farmers to allow capacity building the of farmers for research and innovations to enable them undertake CA on their own.

9.1 Activities:

3.1 Three benchmark sites were Selected within high and low potential areas in each country
3.2 Make an inventory of soil fertility management technologies used in the benchmark sites and make an ex-ante economic profitability analysis.
3.3 Carry out baseline studies and identify successful case of fertilizer use at national level.
3.4 Undertake on-farm evaluation of most profitable fertilizer technologies
3.5 Determine socioeconomic factors leading to the adoption/ non adoption of the various fertilizer effectiveness improvement technologies
3.6 Determine the socio-economic and biophysical recommendation domains for the successful CA technologies
3.7 Strengthen farmers' knowledge base on innovative capacity (e.g., through participatory action research farmer field schools approach, field days, etc).

9.2 Tillage operation

One of the most significant challenges facing smallholder farmers practicing CA involves how to manage tillage operations in the absence of mechanized CA implements to achieve effective seeding, control weeds and avoid development of hardpans. Ox-drawn implements mainly rippers and sub-soilers have been provided to the target communities to facilitate tillage operations. The draught animal operators who operate on a commercial basis have access to these equipment and have been trained on how to use them effectively on designate CA fields to achieve the desired till. Fields with perennial weeds such as couch grass were initially sprayed with a herbicide to enhance the effectiveness of subsequent CA operations.

However, the number of draught animals that are available in the region is also limited, especially during the critical planting period. Hence, majority of the farmers prefer to prepare their land using the conventional hoe "jembe".

Ripping a field in Manyala, Butere District

As an initial step 8 artisans operating in marketing centres within the area have been trained how to fabricate hoes, prototypes of the Zambian "chaka" hoe that can be used by farmers to dig the planting holes or basins to a depth of at least 20cm. This will eliminate the need for ripping and sub-soiling, then the farmers can use the conventional hoe for weeding. For the cereal/cover crop plots the desmodium has provided more than 70% ground cover and has greatly minimized weed competition and surface run off.

9.3 Crop Yields

Yields Assessment

9.3.1 Maize Yield

For maize, the grain yield varied significantly between treatments and sites. Average maize grain yield was 1.2, 2.8, 3.0 and 2.8 t ha^{-1} for treatments 1, 2, 3 and 4 respectively (Table 2.3.1). Unfortunately, most of the common beans in treatments 1 & 4 under conventional tillage were destroyed by heavy rains that occurred at the start of the season resulting in minimal yields.

Table 10: Average Maize Grain Yield for the Different Treatments

Treat_No	Mean	Minimum	Maximum	Variance	s.d.
T1	**1.2**	0.2	2.2	0.2	0.5
T2	**2.8**	1.8	4.0	0.3	0.6
T3	**3.0**	2.0	4.0	0.5	0.7
T4	**2.8**	1.6	4.0	0.3	0.5

T1: Control – Conventional tillage (*maize/beans intercrop*); T2: Reduced Tillage- Cereal/Legume rotation
T3: Reduced Tillage- Cereal/cover crop (*maize/desmodium);*
T4: Conventional tillage (*maize/beans intercrop*)

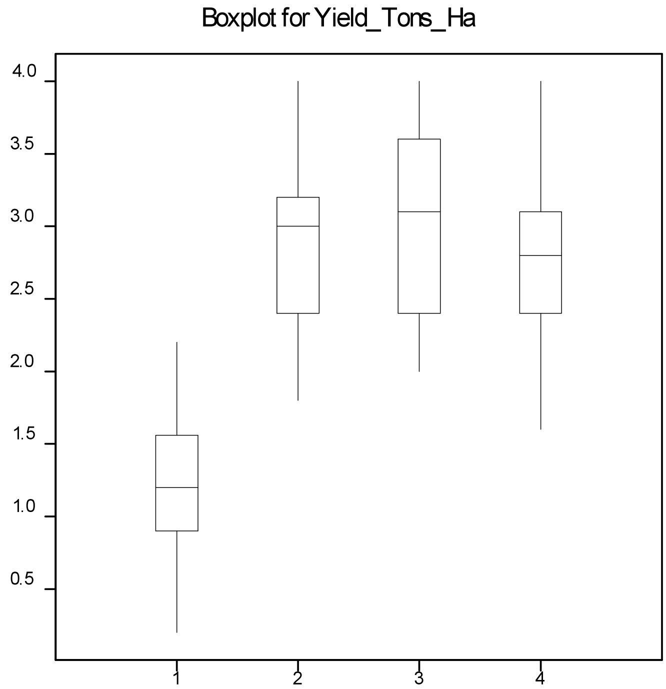

Figure 5:Box Plot showing the variation in Maize Grain for the different treatments

9.3.2 Bean Yield

For the intercrop system under conventional cropping system bean yield was 0.3 and 0.6 t/ha for treatments 1 and 4 respectively.

Table 11: Average Brean Grain Yield for the Conventional Treatment Plots

Treat_No	Mean	Minimum	Maximum	Variance	s.d.
T1	**0.3**	0.0	0.6	0.03	0.17
T4	**0.6**	0.0	1.0	0.06	0.25

T1: Control – Conventional tillage (*maize/beans intercrop*);
T4: Conventional tillage (*maize/beans intercrop*)

Output 4: Capacity of smallholder farmers in conservation agriculture practices developed and relevant agroenterprise development promoted

Building capacity of stakeholders in is essential for the adoption and sustainability of CA, especially in areas where there is limited knowledge on its practice. Conservation agriculture goes against many of the principles of conventional tillage practices such as the need to clear and plough land before planting crops. These are practices that farmers are used to undertaking every other season and there is need to change this mindset not only for the farmers, but also among extension personnel, government officials, researchers, and other persons involved in agricultural activities. The project facilitated farmer groups/ organizations to access knowledge and information and design a village-level system for further acquisition and distribution.

Training courses were organized for the various stakeholder groups to achieve the desired mind shift, as well as to provide the skills and information necessary to embark on conservation agriculture. For the project to be successful in terms of training, the various stakeholders were trained according to their roles and needs.

- **Farmers** were trained on practical skills and benefits of CA
- **Group organizers and extension agents** were trained on how to organize farmer field schools and use of other extension method to extend the principle and benefits of CA to farmers
- **Equipment manufacturers** (Jua kali artisans) were trained on how to make simple farm implements such as rippers, seeders etc to be used by smallholder farmers in conservation agriculture practices
- **Agro-dealers** were trained to ensure timely delivery of the right farm inputs and information to the farmers

Activities:

4.1. Identify stakeholder training needs in CA
4.2. Organize short term training courses on CA practices and ISFM technologies
4.3. Determine the efficiency of farm implement requirements by the smallholder farmers.
4.4. Train artisans from the Jua kali (small scale industry) sector on the innovation, development and production of appropriate conservation tillage implements that are applicable to the smallholder farmers.
4.5. Train agro-dealers to ensure timely delivery of the right farm inputs and information to the farmers

10 Output 5: Conservation agriculture practices scaled-up among smallholder farmers

The rate of adoption of technologies depends partially on how successful the dissemination exercise is conducted. Deliberate effort was made to sensitize farmers on practicing CA as an alternative to conventional tillage practices in achievement of sustainable crop production. The most promising CA technologies as identified by the smallholder farmers was disseminated to the smallholder farmers and other stakeholders in and out of the project area. This was done using appropriate communication and dissemination tools or farmer training methods such as farmer field schools (FFS), workshops and field days were used to train the farmers. Various dissemination materials (brochures, pamphlets, videos, manuals) were used.

Farmer Field schools (FFS) and demonstration trials, established on strategic sites were very important in capacity building and scaling-up. Audio-visual materials, extension brochures, policy briefs, newsletters, simplified farmer handbook and drama were developed and used for the promotion of best bet soil fertility restoration technologies. Farmer to farmer visits, field days and cross-site visits were organized. Scientific publications were produced for disseminating the results and the promotion of best-bet technologies to the scientific community. All these activities have ensured that more quality benefits are brought to more people over a wider geographical area more quickly, more equitably and more lastingly

10.1 Activities:

5.1. To disseminate research results to the farmers, extension agents, NGO's and policy makers
5.2. To assess the effectiveness of the tools used to accelerate adoption of CA
5.3. To use decision support tools (DSS) to identify "recommendation domains" that provide some economies of scale in the use of CA
5.4. To advocate for raising awareness of local community decision-makers to remove market constraints for small farmers
5.5. To develop a framework for action for the extrapolation of project results to other agro-environments
5.6. To promote policy dialogue at different levels to support the adoption CA and grain legume market options
5.7. Build capacity of communities and teams to establish and facilitate participatory monitoring and evaluation (PM&E) processes
5.8. Facilitate the establishment of a sustainable mechanism for access to and sharing of information by stakeholders within and across sites
5.9. Develop and promote strategic alliances with research and development organizations to disseminate best-bet technologies

11 Conclusion

There is a high awareness of CA and many of the farmers appreciate the various benefits these technologies but the level of implementation is not as high as expected. This is as a direct result of various constraints faced by farmers, key among them being lack of appropriate farm implements at affordable costs, associated farm inputs to enhance production and labour constraints. Weed management is also a challenge to most farmers and this also needs to be addressed effectively.

There is therefore, need to enhance access to reduced tillage equipment to most farmers, as this has only been done on a limited scale mainly for experimental purposes only. Large-scale adoption of CA practices requires a functioning input supply chain. Support of equipment sourcing, training, repair and service support at village level are challenges that public private sector partnerships needs to address. Most of the implements that are currently being used in the region are limited to the project sites and were mainly imported. Hence, the equipment are generally too expensive for most farmers to afford, as such discouraging adoption. Effort is being made, though variously to facilitate manufacture of some of these implements locally. In the Kilimo Trust sponsored project, effort has been made to train artisans locally so as they are able to fabricate some of the CA implements locally. In western Kenya, artisans have been trained to fabricate implements such as rippers, subsoilers and jab-planters in local workshops. More resources are needed to enhance the process and sustain it over time before it can reach a demand-driven level.

Similar support is needed to enable farmers have access to other agricultural inputs (seed, fertilizer, herbicides etc.). While farmers will eventually make major savings in inputs and especially labour, it is a challenge for smallholder farmers to begin to understand and use higher levels of agricultural inputs, especially for the transition years into CA. Appropriate weed management strategies also need to be put in place more so in the starting years for better weed control.

Therefore, there is a need to harness technologies that can greatly reduce labour demand and find ways of procuring credit to farmers. Strategic initiatives that will underpin the key factors that affect widespread adoption of CA technologies and innovations, and how these can be turned round to foster or facilitate downstream smallholder innovations are paramount for project success.