Pilot initiatives to introduce more sustainable farming practices are many in Africa, but documentation of them is scarce.

Yet signs indicate that understanding is growing among farmers, stakeholders, researchers, and policymakers that sustainable agriculture is based on a few simple principles. These principles can be adopted to local climates and soil qualities as well as to varied technological and socio-economic factors.

Conservation agriculture provides such a set of principles. It is one of the most promising ways of implementing sustainable agriculture while minimizing the environmental degradation that is all too common on the African continent.

It relies on three basic principles: 1) minimum soil disturbance or if possible, no tillage at all; 2) soil cover— permanent, if possible; and 3) crop rotation.

This book is one in a series of case studies on conservation agriculture with examples from Ghana, Zambia, Uganda, Kenya and Tanzania, published by the African Conservation Tillage Network (ACT) and the French Agricultural Research Centre for International Development (CIRAD).

ACT, a pan-African association, encourages smallholder farmers to adopt conservation agriculture practices. It involves private, public and non-government sectors: farmers, input suppliers and machinery manufacturers, researchers and extension workers—all dedicated to promoting conservation agriculture.

Financial and material support for the case studies came from the Food and Agriculture Organization of the United Nations (FAO), CIRAD, and the Regional Land Management Unit (RELMA) of the World Agroforestry Centre (ICRAF).

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Contents

Preface

Pilot initiatives to introduce more sustainable farming practices are many in Africa; thorough documentation of results and lessons learned is scarce. Yet signs indicate that understanding is growing among practising farmers, stakeholders, researchers, and to a certain degree, policymakers, that sustainable agriculture bases itself on simple core principles. These principles, making use of natural processes, can respond to local climatic conditions and soil qualities as well as technological and socio-economic factors and conditions. Conservation agriculture is one of the most concrete and promising ways of implementing sustainable agriculture in practice. It relies on three basic principles: 1) minimum soil disturbance or if possible, no-tillage seeding; 2) soil cover—if possible, permanent; and 3) useful crop rotations and associations.

Across Africa, interest is growing to adapt, adopt, and apply these principles to attain agricultural performance that improves productivity and protects the environment—it sustains environmental resilience.

The French Agricultural Research Centre for International Development (CIRAD), the Food and Agriculture Organization of the United Nations (FAO), the Regional Land Management Unit in the World Agroforestry Centre (RELMA) and the African Conservation Tillage Network (ACT) have jointly facilitated this case study series to verify and document the status and effect of pilot initiatives on conservation agriculture with focus on sub-Saharan Africa. Eight case studies from five countries—Ghana, Kenya (2), Tanzania (3), Uganda, Zambia—are published in this series. A joint synthesis publication with overall results, lessons learned and recommendations for Africa is forthcoming.

It is our intent this series will be a source of information on conservation agriculture in Africa. It throws light on controversial issues such as the challenges farmers face in keeping the soil covered, in gaining access to adequate no-tillage seeding equipment, in controlling weeds, and on the challenges projects and institutions face in implementing truly participatory approaches to technology development, even as it illustrates the benefits of systems based in conservation agriculture and the enthusiasm with which many stakeholders are taking it up.

Bernard Triomphe, CIRAD
Josef Kienzle, FAO
Martin Bwalya, ACT
Soren Damgaard-Larsen, RELMA

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Thanks to the technical editing and production team—Helen van Houten with Dali Mwagore, Keta Tom, Kellen Kebaara, Conrad Mudibo—who took on the task of assisting the case study teams and the series editors in going the 'last mile' towards publication.

Case study project background and method

Bernard Triomphe, Josef Kienzle, Martin Bwalya, Soren Damgaard-Larsen

This case study presents the status of conservation agriculture in Ghana. It is one in a series of eight case studies about conservation agriculture in Africa, which were developed within the framework of a collaboration between CIRAD (French Agricultural Research Centre for International Development), FAO (Food and Agriculture Organization of the United Nations), RELMA-in-ICRAF (Regional Land Management Unit of the World Agroforestry Centre) and ACT (African Conservation Tillage Network).

This introductory section outlines the overall background of the conservation agriculture case study project and the key methodological choices made. It also gives a brief overview of major results and observations across all case studies. This broad perspective allows the reader to appreciate both the commonalities among the eight case studies and the specifics of the two being presented here.

Conservation agriculture: a working definition

'Conservation agriculture' has been defined differently by different authors. Perhaps the most generic definition is the one provided by FAO:[1]

> *CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes.*

From this definition, we can infer that conservation agriculture is not an actual technology; rather, it refers to a wide array of specific technologies that are based on applying one or more of the three main conservation agriculture principles (IIRR and ACT 2005):

- reduce the intensity of soil tillage, or suppress it altogether
- cover the soil surface adequately—if possible completely and continuously throughout the year
- diversify crop rotations

Ideally, what we call 'conservation agriculture systems' comprise a specific set of components or individual practices that, combined in a coherent, locally adapted sequence, allow these three principles to be applied simultaneously (Erenstein 2003). When such a situation is achieved consistently, we speak of 'full conservation agriculture', as illustrated by the practices of many farmers in southern Brazil (do Prado Wildner 2004; Bolliger et al. 2006) and other Latin American countries (Scopel et al. 2004; KASSA 2006).

1 FAO conservation agriculture website: http://www.fao.org/ag/ca/index.html

Full conservation agriculture, however, is today rarely practised outside South America (Ekboir 2003; Derpsh 2005; Bollinger et al. 2006), and is indeed difficult to achieve right from the onset. Usually farmers who are willing, or obliged by circumstances, to reassess their farming practices and follow the path to more sustainable agriculture, embark on a long journey that takes them several years or even longer. This journey consists of consecutive phases, each characterized by use of specific practices that increasingly incorporate practice and mastery of the three principles. No journey appears to be linear, and no journey seems to comprise the exact same sequence of phases (fig. A), although some paths are more commonly followed than others.

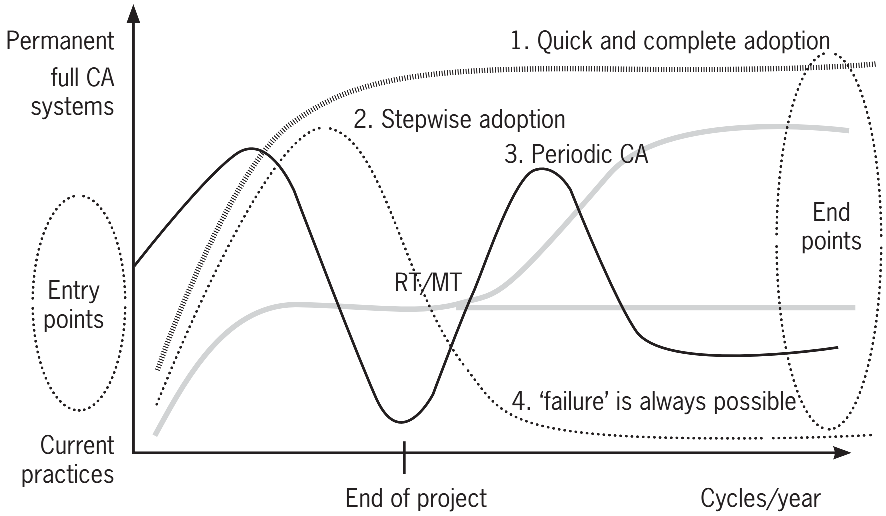

Figure A. Entry points and four hypothetical pathways towards adopting conservation agriculture:

1. Quick and complete adoption of conservation agriculture in its fullest form
2. Stepwise adoption of conservation agriculture practices, which may or may not lead to complete adoption over time (RT = reduced tillage, MT = minimum tillage)
3. Conservation agriculture practised during some cycles but not others
4. Use of conservation agriculture practices stops soon after the end of the project, perhaps because incentives are no longer available.

While the hope of many farmers and agronomists is that eventually most farmers in a given region will reach the full conservation agriculture phase, and better sooner than later, no phase in itself, no individual conservation agriculture system or set of practices can be considered intrinsically superior to the others (Triomphe et al. forthcoming).

Rather, they should be viewed as what can realistically be achieved at a given time and in a given farm context, depending on the environmental, socio-economic, institutional and political circumstances and constraints. Some factors and conditions clearly relate to the characteristics, preferences and experiences of individual farmers and farms—such as the capital available for investing in equipment and inputs, the choice of cover crops, the soil conditions prevailing at the time conservation agriculture is being introduced, the care with which a farmer applies inputs or controls weeds, or the ability to learn new practices and take risks (Erenstein 2003). Others, however, relate more to the local or regional environment of the farm: ease of access to equipment, inputs and relevant knowledge, links to markets, existence of policies favouring (or discouraging) the adoption of conservation agriculture practices, and so on.

Given this huge diversity of adoption pathways, we use the term 'conservation agriculture' in this booklet with a meaning as general and open as possible, trying to refrain from judging if some actual practices were 'real' or 'good' conservation agriculture, while others were 'partial' or 'poor'. Rather, we have made every effort to understand and explain what motivates farmers to try specific conservation agriculture practices, or what prevents them from trying the practices or from achieving success with them. At the heart of this assessment lies our desire to distinguish between conservation agriculture in theory (as promoters of conservation agriculture would like it to be implemented), and conservation agriculture in practice (as farmers are eventually able, or willing, to implement it).

Background

Why it was necessary to develop case studies

Rigorous documentation of successes, failures and challenges related to conservation agriculture adaptation and adoption is still rare, especially outside of South America. Also, most existing case studies have been written without relying on a unified systemic analytical framework, and hence are difficult to compare one with the other. They furthermore often demonstrate a strong bias towards emphasizing what is going well, overlooking process issues and problems encountered.

Under these conditions, the FAO working group on conservation agriculture and CIRAD decided to join forces in 2004 to contribute to a balanced documentation of conservation agriculture experiences and to better networking internationally. They were soon joined by RELMA-in-ICRAF and ACT, which had been actively involved in promoting conservation agriculture in eastern and southern Africa (Biamah et al. 2000; Steiner 2002; IIRR and ACT 2005) and which were also core partners in organizing the Third World Congress on Conservation Agriculture, which took place in October 2005.

Objectives

The overall objective of the conservation agriculture case study project was to strengthen collaboration among a number of key stakeholders who were preparing the Third World Congress on Conservation Agriculture, by improving understanding of past and current conservation agriculture experiences, and by improving networking among key stakeholders, with special emphasis on Africa.

Specific objectives for the case studies:

- Develop a framework for rigorously analysing ongoing conservation agriculture projects[2] and experiences and for characterizing in a holistic way

2 The word 'project' is used in this context with an inclusive meaning, as it can refer to

how conservation agriculture practices are adapted and adopted and their effect.

- Develop a number of contrasting conservation agriculture case studies by applying this framework in selected regions.

The aim was to provide the resulting outputs to conservation agriculture practitioners, scientists and decision makers, so that they could contribute to improving conservation agriculture project planning and implementation.

What does a case study entail?

Here, a case study is a short-term, mostly qualitative study that synthesizes experiences and results obtained by applying and using conservation agriculture principles and technologies in a specific region in past or ongoing efforts and projects. It is developed around a unified, locally adapted framework focusing on conservation agriculture techniques and processes, on key issues and lessons learned, as well as on shortcomings and successes.

Majors phases of the case study project

The case study project on conservation agriculture began in late 2004 (table A). Following agreement on an analytical framework in February 2005, most of the fieldwork was developed during March–September 2005 by small teams of project personnel based in the study site, with guidance from the project coordinators. Early results and preliminary products were presented at the Third World Congress on Conservation Agriculture, held in Nairobi in October 2005 (Boahen et al. 2005; Baudron et al. 2005).

In the first half of 2006, drafts of individual case studies were developed through an iterative review process. The review culminated in a workshop held in Moshi, Tanzania, in August 2006, during which case study leaders and conservation agriculture resource persons worked together to further improve the drafts and compare results among case studies. The final step in developing the case studies, during the last quarter of 2006, involved a new round of editing in interaction between a team of editors and case study leaders.

Key methodological choices

Case study framework

The framework was developed in several stages. It integrated a series of previously identified issues, such as those developed under the auspices of programmes such as the Direct Seeding, Mulching and Conservation Agriculture Global Partnership programme[3] of the Global Forum for Agricultural Research (GFAR), WOCAT[4] and Sustainet.[5]

individual ongoing projects in a region or a country, or to a succession of projects having taken place in one region or country over time, or to a number of projects operating simultaneously in one given region or country.

3 Website: http://agroecologie.cirad.fr/dmc/index

4 Website: http://www.wocat.org/

5 Sustainet website: http://www.sustainet.org

A major milestone for framework development was the workshop held in Nairobi in February 2005, which made possible direct interaction between the coordinators of the case study project and the future case study leaders.

Table A. Milestones of the case study project on conservation agriculture

Date	Product, activity, output
Late 2004	Preliminary case study selection, draft framework developed
February 2005	Start-up workshop with selected team leaders for the case studies; agreement on the framework
March–Sept 2005	Activities for developing the case studies in the various sites, including midterm reviews in Kenya, Tanzania and Ghana
October 2005	Preliminary results reported as posters, papers and oral presentation during Third World Congress on Conservation Agriculture, Nairobi, Kenya
March–July 2006	Review and revision of individual case study drafts
August 2006	Workshop on cross-analysing cases and discussing their publication
Oct–Dec 2006	Final editing of individual case study documents
Early 2007	Case studies published as books and booklets

Eventually what became the reference framework for this project, guiding case study development, was a list of questions and issues structured under six main headings (see ‘Reference framework for case studies on page xxiv for details):

- biophysical, socio-economic and institutional environment of conservation agriculture farming systems
- historical review of work related to conservation agriculture in the selected site, region or project
- specific technologies, packages or systems being promoted, and how they differ from existing practices and systems
- overview of adaptation and diffusion process towards conservation agriculture
- qualitative overview of impact and adoption, in its agronomic, economic and social dimensions
- key gaps and challenges in site-specific circumstances

Using this overall framework, each case study team selected and adapted the issues most relevant to their own conditions and circumstances. Similarly, they developed their own guidelines for interviews and workshops. Thus the actual application of the framework remained specific to each case study.

Selection of case studies

Since this project could develop only a handful of case studies at the time, it was important that criteria for selecting them be clear. They included:

- demonstrated strong local interest for participating in a case study and helping develop it, and particularly local commitment for allocating staff time and resources such as transportation and communication for related activities

- overall value the case study would add towards addressing key issues related to conservation agriculture, particularly in extracting original, worthwhile lessons on how its technologies performed, on ways they are diffused and adopted, and on links to sustainable agriculture and rural development[6]
- existence of at least a minimal body of local documentation on work related to conservation agriculture, from which a case study could be built
- complementarities with ongoing documentation efforts—preference often being given to situations for which no previous reports were available
- existence of a minimum trajectory of adaptation and diffusion, including evidence of some initial effect among farmers using conservation agriculture[7]

Based on a combination of these criteria, and following agreements reached among key stakeholders, 11 case studies were eventually selected (table B), out of which 8 were selected in Africa. More than half were directly linked to ongoing projects operating in eastern Africa.

How case studies were developed

The case studies were developed following an approach that presented a number of prominent features.

- It emphasized collaboration between insiders (local project staff) and a number of outsiders (case study coordinators and resource persons).
- It focused on a qualitative assessment of selected key issues and questions, based on participatory rural assessment techniques (interviews with key informants, collective workshops with selected stakeholders), which made it possible to collect testimonies.
- It relied on available evidence as found in project reports and documents.

Within these overall methodological choices, the specific steps and procedures followed to develop a case study included the following:

- Form a local case study team, typically comprising three to six members, usually practitioners involved in promoting local conservation agriculture.
- Develop a detailed work plan.
- Identify and collect local formal and grey literature about past or ongoing conservation agriculture activities in the region.
- Identify resource persons and institutions to serve as key informants.
- Hold interviews and workshops with key informants and stakeholders; observe conservation agriculture plots that farmers and farmer groups have implemented.
- Organize a mid-term review involving the local case study team, resource persons and project coordinators:

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6 The selection of cases was, however, not limited to 'success stories'; some of the sites experienced or still are experiencing difficulties. The important point was what useful lessons could be gained from looking at what had happened so far.

7 Since it usually takes decades before large-scale adoption occurs, few potential case study sites would have witnessed it. Hence projects were selected that were just beginning to adopt (and thus were still significantly dependent on the project), provided that the technologies were already being tested at commercial scale under farmers' conditions.

- Review progress, difficulties, and preliminary findings.
- Agree on priority activities for completing the case study and on adjustments needed in the original work plan, framework or methods.
- Identify concrete products to be presented during the Third World Congress on conservation agriculture (Nairobi, October 2005)
- Make a number of field visits to discuss with farmers and farmer groups and observe conservation agriculture experiments and demonstrations.

- Write up the case study draft.
- Prepare and present preliminary outputs for the Third World Congress on conservation agriculture (posters, oral presentations, papers).
- Develop the case study document in interaction with external reviewers.

The results obtained within the context of each case study outline an emerging but as yet incomplete picture about conservation agriculture in a given site. The case studies are qualitative in nature and relied principally on field observation. The case study teams had only some three to five months in which to compile their information. Their access to quantitative data was often limited. At times team members found it quite difficult to separate their role of critically assessing how conservation agriculture was functioning from their normal role as promoters of conservation agriculture.

The evidence the teams uncovered, however, is a major step forward. The findings are broadly consistent with the experiences and perceptions of most stakeholders and resource persons, and as such, they provide a legitimate, unrivalled view of present successes, challenges and the way forward. The studies are furthermore quite useful in pointing out to which specific areas and issues future projects should direct their efforts.

This book focuses on two specific case studies. A number of results and lessons, however, can be drawn from a cross-analysis of all eight case studies selected. Such an analysis offers a unique opportunity to look at key technical and process issues and will be the focus of a separate publication.

The cross-analysis will summarize the information available to assess conservation agriculture practices implemented by farmers and their effects on crop productivity and profitability, and on labour use. It will discuss adoption trends. It will examine the approaches used to develop and promote conservation agriculture practices and systems, including the roles stakeholders, farmers' associations and the farmers themselves play in the process. It will analyse the extent to which adequate policy support is in place. In it, the following topics receive special attention. Preliminary comments follow.

First-hand observations

Tillage intensity

All types of tillage intensities are found across case studies: from minimum tillage to ripping to actual no-tillage. Most case studies highlight a number of difficulties farmers face when abandoning conventional tillage. It seems many do not go directly to no-tillage, and rely instead on reduced tillage as an intermediate step, if only because of restricted access to no-till seeders. This applies to case studies in Arumeru, Karatu, Laikipia and Zambia.

Table B. Key characteristics of case studies selected in Africa

Country, region	*Climate / type of farmers*	*Experience with CA*	*Adoption status*	*Supportive project*	*Team leader*
Kenya					
Laikipia	Semi-arid highlands / small- and large-scale, manual and animal traction	> 10 yrs (large), 2–3 years (smallholders)	Growing adoption (large), incipient (smallholders)	CA-SARD Kenya	Tom Apina, Paul Wamai, CA-SARD
Siaya	Humid lowland / small, vulnerable households, manual agriculture	3–5 years	Incipient	CA-SARD Kenya	Philip Mwangi, Kennedy Otieno, CA-SARD
Tanzania					
Karatu	Semi-arid to sub-humid, highland / manual agriculture	Late 1990s / early 2000	Incipient	CA-SARD Tanzania	Dominick Ringo, RECODA
Arumeru	Semi-arid to sub-humid, manual agriculture, highly degraded soils	Late 1990s / early 2000	Incipient	CA-SARD Tanzania	Catherine Maguzu, RECODA
Mbeya	Semi-arid / smallholders, manual and animal traction		Incipient	FAO-TCP	Saidi Mkomwa, ARI Uyole, TCP
Ghana					
Brong Ahafo, Ashanti	Rainforest transition / smallholders, purely manual agriculture	> 10–15 years	Significant but stagnant	FAO-RAFA / RELMA	Philip Boahen, consultant
Uganda					
Pallisa, Mbarara, Mbale	Humid to sub-humid / smallholders	3–5 years	Incipient	FAO-TCP	Paul Nyende, consultant
Zambia					
Southern Province	Semi-arid / smallholders, manual and animal traction	> 10 years	Large-scale, increasing adoption	CIRAD-WWF, ASP	F. Baudron, CIRAD-WWF, H. Mwanza, ASP

ASP – Agricultural Support Project (Sida funded), Zambia; CA-SARD – Conservation Agriculture for Sustainable Agriculture and Rural Development (FAO, sponsored by Germany), CIRAD – French Agricultural Research Centre for International Development; FAO – Food and Agriculture Organization of the United Nations; FAO-RAFA – FAO Regional Office for Africa; RECODA – Research, Community and Organizational Development Associates; RELMA – Regional Land Management Unit of the World Agroforestry Centre; SARI – Selian Agricultural Research Institute, Tanzania; TCP – Technical Cooperation Project (FAO sponsored); WWF – World Wide Fund for Nature

Soil cover

Providing adequate soil cover is a cornerstone of conservation agriculture. Yet most farmers face great difficulties in achieving it. Farmers tend to collect residue or allow livestock herds to graze freely on crop residue. This may be an individual decision, or it may be the result of agreements and traditions regulating the relationships between farmers and pastoralists, such as with the Maasai in northern Tanzania. Producing enough biomass to cater for both adequate soil cover and livestock demands is a challenge. Replacing a food legume used traditionally in intercropping (such as beans) by a cover crop (such as canavalia or mucuna) might not be attractive to a farmer whose primary objective is achieving food security. This may explain the success that *Dolichos lablab* is having with Kenyan and Tanzanian farmers, as it is a multiple-purpose cover crop, able to provide food (both grain and leaves are edible), income, forage and soil cover.

Weed control

Weed control remains a challenge, especially when farming is done manually. As most farmers do not manage to keep their soils adequately covered, reducing tillage tends to increase aggressive weed growth. Controlling weeds adequately, which is critical to avoid crop failure, requires hoeing numerous times[8] or using herbicides such as glyphosate. For many farm families, neither option is feasible. Labour resources are scarce or expensive, or access to herbicides and sprayers is restricted. More efforts are definitely needed to identify suitable cover crops and to achieve soil cover if herbicide dependency is deemed undesirable.

Equipment and inputs

Reduced tillage implements such as rippers and no-till seeders have been made available to farmers on an experimental basis. Often implements are imported from Brazil. Farmers are also being helped to get specific inputs, such as herbicides and cover crop seeds. Many farmers have restricted access to both implements and inputs; thus they are likely to delay planting, which adversely affects yield and income.

Family labour is increasingly scarce. This situation should ultimately lead to technologies such as reduced tillage systems, direct seeding technologies, herbicides, weed wipes or sprayers that save labour, although many farmers may not find them accessible or affordable.

Large-scale adoption of conservation agriculture practices requires a functioning input supply chain. This means both private and public sectors must play a more proactive role in developing local capacity for manufacturing and making available appropriate implements and in devising innovative implement-sharing schemes (hire services, Laikipia) and adequate rural finance systems. Empowered farmers groups are perceived as being the right entry point for making inputs and services available.

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8 For example, in southern Zambia conservation agriculture promoters recommend weeding four to six times.

Overemphasis on field-scale, technical issues?

Many projects and teams tend to focus on technical issues such as tillage, cover crops, weed control and implements at the field scale. This focus often implies less attention is given to non-technical issues, for example rural finance, marketing and value chain development, organizational or policy issues.

Farmer groups

The role of government institutions and publicly funded projects is essential. Case studies in northern Tanzania and Kenya emphasize participatory approaches, in particular farmer field schools. Early indications are that these field schools are a cost-effective way of participatory training. Groups of 10–30 farmers engage in collective and individual experimentation and learn conservation agriculture principles and practices. Beyond the issue of groups, projects and institutions can potentially develop more participatory and responsive approaches, with farmers more clearly in control.

Indigenous knowledge and innovative technology

Indigenous knowledge compatible with the principles of conservation agriculture is widespread across case study sites. Such is the case for the 'proka' slash-and-mulch system in Ghana, and for the farmers who are knowledgeable about the benefits of cereal–legume intercrops.

Ongoing projects tend to undervalue indigenous knowledge. One reason may be that conservation agriculture champions are keen to transfer external knowledge and innovative technology packages as a means of replicating the success stories that evolved in southern Brazil over a period of decades. Another reason is the tendency to perceive more the negatives of local traditions and farmer practices, such as grazing rules, without trying to understand the reasons for them. Tapping into indigenous knowledge and farmer innovation combined with imported innovative technology could well prove important in the long run.

♦ ♦ ♦ ♦ ♦

This booklet now focuses on the situation of conservation agriculture in Laikipia and Siaya districts in Kenya . It illustrates precisely some of the successes, and some of the challenges, that farmers and conservation agriculture projects alike face in their efforts to understand and implement conservation agriculture.

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Conservation agriculture in Kenya

Pascal Kaumbutho and Josef Kienzle

The government of Kenya is currently operating under the guidance of the Economic Recovery Strategy (ERS) for Wealth and Employment Creation (2003–2007). ERS has identified agriculture as an important tool and vehicle for realizing its objective. This is because agriculture is the backbone of the national economy, contributing directly 26% of GDP and 60% of export earnings. Agriculture is the main rural development tool, as 80% of the population remains rural with livelihoods anchored in agricultural performance.

The Kenya government's Strategy for Revitalizing Agriculture (SRA), 2004–2014, an ERS offshoot, notes that 51% of the Kenya population is food insecure, able to obtain only limited supplies of food and the food is of low nutritional value.

Two-thirds of the country is semi-arid to arid. The large and rapidly increasing human population exerts pressure on the fragile, semi-arid and arid ecosystem. This is at the heart of the desertification now taking place. Land degradation has become a serious problem in the medium- to high-potential land, especially where cultivation has extended to steep slopes without adequate soil conservation. Those living in arid and semi-arid lands, and especially women and children, are particularly vulnerable.

At a national conference on revitalizing the agricultural sector for economic growth, 'Kilimo Bora kwa Ustawi', held 20–24 February 2005, senior government officials, development partners, NGOs and private businesses confirmed the need to transform the agricultural sector, calling for fundamental policy changes, for institutional, legal and regulatory reforms, and for switching to modern farming practices. These reforms are essential for Kenya to shift from subsistence to market production and to ensure that agriculture will again become the main engine of economic growth while eliminating hunger and poverty.

The strategy recognizes that past plans and development programmes have failed to make a real impact in the fight against poverty. It gives the reason for this as partial or no implementation of such plans. SRA is not an agricultural policy in itself. It is a broad framework guiding policy and institutional reforms that provides six strategic areas of intervention:

- streamlining the agricultural policy framework
- creating an enabling environment for private sector investment
- improving delivery of support services
- promoting marketing, agroprocessing and trade
- placing agricultural development issues in the mainstream of other sectors
- strengthening institutional implementation framework

Despite the importance of agriculture, its full potential has not been realized. Decreasing size of farms, failure to use appropriate technology adequately, unreliable rainfall, poor marketing infrastructure, limited access to credit, high cost of farm supplies and machinery, poor market information and early warning systems, and lack of a land-use policy have resulted in low productivity. The decline in major commodities has been attributed to unfavourable weather, low commodity prices, poor crop husbandry and poor infrastructure.

Conservation agriculture activities and interventions as implemented touch on all the SRA areas. 'Conservation agriculture' is not an entirely new concept; some farmers have long practised aspects of it, although they have not so named it. The term summarizes a farming concept that embraces the simultaneous application of three basic principles:

- reduced or minimal soil disturbance through reduced or no-tillage practices
- permanent soil cover, with either dead mulch or cover crops
- useful crop rotations or associations that are in line with local preferences and circumstances

The project whose case studies are presented here was implemented under the name Conservation Agriculture for Sustainable Agriculture and Rural Development (CA-SARD). Funded by the German Trust Fund through the Food and Agriculture Organization of the United Nations (FAO) and the governments of Kenya and Tanzania, it was put into operation in three districts in Tanzania and five in Kenya—Bungoma, Laikipia, Mbeere, Nakuru and Siaya.

Due to limited resources, the case studies cover only Laikipia and Siaya Districts, selected because of their greatly contrasting topography and socio-economic conditions.

Laikipia is semi-arid, averaging 650 mm of rainfall annually. Located on the leeward western slopes of Mt Kenya, both its culture and its topography are diverse. Farmers keep livestock and grow subsistence and commercial crops including maize, beans, potato, wheat and horticultural crops like cabbage, tomato and snow peas. A few farmers grow wheat commercially on farms ranging from 2000 to 6000 acres. Subsistence farmers also grow wheat even uneconomically on plots of land as small as a quarter of an acre. Except on the few large-scale farms, farmers practise conventional farming to grow their food. But with regular ploughing and other conventional practices, they experience recurrent crop failure in this semi-arid farming zone.

Some of the obstacles to overcome in Laikipia include lack of access to inputs or to markets in a relatively remote district with poor infrastructure. The district has had several rural development projects and programme initiatives, but progress is yet to be made in empowering farmers, developing central support structures or protecting the environment.

Siaya District is characterized by large, underutilized stretches of fertile, high-potential agricultural land. The high rainfall, averaging 1400 mm annually, is largely wasted in a zone where traditional farming practice is the norm. Several development interventions in conservation agriculture, by both government and non-government organizations, have brought in a wide range of technologies but the approach has been uncoordinated and piecemeal.

Except for the recently established Dominion Company Estate, Siaya has only smallholder farmers. The district has one of the country's highest labour shortages, brought about by rural-to-urban migration and the high prevalence of HIV and AIDS. Also prevalent is tripanosomosis, which kills the draught animals local people depend on for farmwork and rural transport. Many traditional practices tend to hinder fast agricultural and general economic growth. Grazing livestock on crop residue, abiding by the tradition that dictates elders must plant before youth, and following similar practices of traditional etiquette affect agricultural performance overall.

The project

CA-SARD was a two-year project whose official term was June 2004 to July 2006.[1] The project was part of a scaling up and refocusing process for conservation agriculture, continuing from the pioneering conservation tillage farmer pilot trials that RELMA sponsored in1998–2002. Previous conservation agriculture work had been sponsored by GTZ through the African Conservation Tillage (ACT) Network, and FAO through a Technical Cooperation Project (TCP/KEN/2904, 2002–2004). The CA-SARD project advanced conservation agriculture interventions and made enormous progress, specifically by adopting farmer field school (FFS) methods, training support staff and farmers, bringing in advanced conservation agriculture equipment, advancing artisan training, and forging links with the private sector.

The CA-SARD project started fieldwork in October 2004, in the short rains season of 2004/05. By the close of the project, farmers had successfully experimented with conservation agriculture practices for one to four seasons.

To date the number of farmer field schools has increased from an initial 26 formal to some 60 formal and informal farmer groups, all engaged in a range of conservation agriculture practices. Some 3200 farmers are practising on about 23,000 acres, in and around project localities. This includes Laikipia, where large-scale farmers are reported to have placed some 20,000 acres and medium-scale farmers another 400 acres under conservation agriculture, with a degree of collaboration among them. Laikipia has large-, medium- and small-scale farmers, but in other districts most farmers are small scale, and some are newly practising conservation agriculture on plots scarcely larger than a quarter acre. Estimates have indicated that about 22,000 farmers in the vicinity of the project localities are aware of conservation agriculture, although not all are practising it. These farmers have learned of it by talking with other farmers or by visiting field days or a neighbour's farm. Some have asked practising farmer groups for training. Some have asked to hire the conservation agriculture equipment services the project provides to practising farmer groups.

The case studies

A major output of the project has been the case studies published here. They were undertaken as a way to generate factual information to which policymakers and

1 A second project phase, CA-SARD II, was initiated in March 2007. Building on lessons learned and recommendations made from the first project phase, it will run for three years, to March 2010.

supporters of agricultural development in the country can refer. They aim to capture experiences and relay information in a factual, quantitative and comprehensive manner.

They will hopefully help convince other rural development efforts that results can be gained more rapidly by combining the efforts of conservation agriculture and the FFS extension method. This combination so far clearly indicates that it fast-tracks in the sustained fight against poverty and food insecurity. The case studies help demonstrate as real the specific gains that conservation agriculture can make towards broad-based agricultural growth and development, as anticipated and spelled out in the SRA.

The broad perspective and nature of conservation agriculture linked with the FFS approach can potentially be further exploited in scaling up towards mainstream support in developing the country's agriculture. Hopefully the following advances and links help make clear the niche conservation agriculture has in national and regional development:

- Conservation agriculture and farmer field schools are a winning combination for linking empowered farmers to markets.
- Conservation agriculture enhances and renews motivation towards conserving soil and water.
- Leguminous cover crops as advocated take a big step in the journey towards natural resuscitation of soil fertility and biodiversity.
- Conservation agriculture is a labour-saving technology, promoting no-tillage and zero-weeding; its improved production methods reduce labour.
- Sustained production through conservation agriculture improves nutrition for vulnerable communities, including those infected or affected by HIV and AIDS.
- Conservation agriculture linked with agroforestry practice improves livelihoods and causes real development.
- Farmer-led hire services of innovative farming equipment are introduced and cooperation between large- and small-scale farmers is encouraged.
- Conservation agriculture and FFS networks advance input and product value chains, further developing agro-enterprise.
- Conservation agriculture encourages industrial development of agricultural engineering and artisanry.
- Conservation agriculture can be the link that connects private sector enterprises and even government ministries that strive to preserve the environment and water quality and to improve health.

Conservation agriculture, to advance, must deal with several challenges and shortcomings:

- Developing conservation agriculture with FFS methods requires formally developing structures and teams to facilitate farmers.
- The group approach for farmer empowerment and scaling-up programmes may hold back some who are able to move faster than group speed.
- Stakeholder support in institutions, the private sector and other enterprise development partners may not be readily forthcoming in the short term, yet

they are necessary for growth with market focus.

- An inflexible and long-term framework of government-led development plans and programmes should not obscure the benefits to farmers of conservation agriculture.

Reference framework for case studies

Based on the activities developed in the early stages of the project, the following questions appeared critical for structuring the framework around which all case studies would be based. They are grouped under three overarching headings:

- **Specific technical aspects related to conservation agriculture systems**
  - What are the key obstacles, challenges and way forward for controlling weeds in conservation agriculture?
  - Under what conditions does conservation agriculture lead to saving farmers labour?
  - What are the key obstacles, challenges and way forward related to crop–livestock interaction while using and adopting conservation agriculture systems?
  - What are the key obstacles, challenges and way forward for conservation agriculture in low-rainfall (semi-arid) areas?
- **Conservation agriculture learning and adoption processes**
  - What does it take to 'learn' conservation agriculture, both individually and collectively (activities, processes, etc.)?
  - What influence does the mindset of farmers, technicians and researchers have on adapting and adopting conservation agriculture practices?
  - What are the relative roles of technology transfer and local adaptation in gaining large-scale adoption of conservation agriculture systems?
  - What are the entry points and pathways that lead to large-scale adoption of conservation agriculture? Are some more effective than others?
  - Have large-scale farmers a comparative advantage in adopting conservation agriculture? What advantages and why? Under what conditions can conservation agriculture work for smallholders and resource-poor households?
  - What are the key lessons learned in scaling up adoption? Do's and don'ts, and why.
- **Generic description of the conservation agriculture project**
  - Biophysical, socio-economic and institutional environment of conservation agriculture work.
  - Trajectory of related work in the selected region, site, project.
  - Overview of the conservation agriculture adaptation and diffusion process.
  - Conservation agriculture impact.
  - Present gaps and challenges in conservation agriculture work.

Laikipia District

Tom Apina, Paul Wamai, Phillip K. Mwangi

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Abbreviations

ACT	Africa Conservation Tillage Network
CA	conservation agriculture
CA-SARD	Conservation Agriculture for Sustainable Agriculture and Rural Development
CGA	Cereal Growers Association
CIRAD	Centre de Corporation International en Researcher Agronomique pour le Développement
COMESA	Common Market for East and Southern Africa
EABL	East African Breweries Ltd
FAO	Food and Agriculture Organization of United Nations
FFS	farmer field school
GHARP	Great Horn of Africa Rainwater Programme
GoK	government of Kenya
HIV/AIDS	human immunodeficiency virus/acquired immunodeficiency syndrome
ICRAF	World Agroforestry Centre
ILRI	International Livestock Research Institute
KARI	Kenya Agricultural Research Institute
KENDAT	Kenya Network for Draught Animal Technology
KCTI	Kenya Conservation Tillage Initiative
KRA	Kenya Rainwater Association
LRNP	Legume Research Network Project
MDG	Millennium Development Goal
MoA	Ministry of Agriculture
NCPB	National Cereals & Produce Board
NGO	non-governmental organization
RELMA	Regional Land Management Unit
SLM	sustainable land management
WFP	World Food Programme of the United Nations

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Executive summary

Laikipia District is located in the arid region of Rift Valley Province in Kenya. Half of the people in the district suffer from food deficiency arising from rampant drought. Agriculture is the main economic activity of the district with livestock production and ranching taking up 75% of the total land being used. Agricultural production is limited to the wetter western part. There are various categories of farmers in the district, including large-scale barley and wheat farmers, horticultural flower farmers along the streams, and small-scale farmers with integrated crop production practices.

This study was made to document the history and extent of adoption and adaptation of conservation agriculture and to establish in quantifiable and qualitative terms its impact on food security for vulnerable households, hence its contribution to Millennium Development Goal 1 and to the Kenya government's economic recovery strategy for creating wealth and employment.

The study was carried out in 2005 by a team of three researchers who interviewed key informants and conducted a literature review on past conservation agricultural research and projects related to the district. The study found that majority of conservation agriculture adopters were large-scale farmers who had the goal of reducing production costs to remain in business. Despite efforts by several projects to promote conservation agriculture among small-scale farmers, adoption among them was still limited to a few established farmer field school groups, with insignificant automatic replication of the practice. The reduced labour attribute of conservation agriculture—reduced or no tillage and weeding —was a motivating factor among small-scale farmers. The farmer field school approach had a significant impact among the groups established by the Conservation Agriculture for Sustainable Agriculture and Rural Development (CA-SARD) project. The challenges small-scale farmers faced in adopting conservation agriculture were numerous: inadequate or lack of initial capital for farm inputs, unavailability of farm inputs; difficulties in managing weeds and cover crops; insufficient soil cover; and the need to change mindset on tillage operations.

Farmers practising conservation agriculture progressively increased their crop yield from adoption time, attaining optimum production when accumulated crop residue provided 100% cover, ensuring maximum water infiltration and the best harvest. Soil fertility and weed control also increased considerably. The effect of conservation agriculture on households infected or affected by HIV and AIDS reflected in reduced labour and increased household nutrition and food supply was identified as a potential motivator.

1 Introduction

The arid and semi-arid regions of the country, in which Laikipia District falls, are disproportionately affected by these challenges. Policymakers have done little to address the plight of farmers in these regions. Small-scale farmers are the most affected owing to their socio-economic vulnerability, inability to adopt modern farming techniques, and limited access to information on agricultural development. However, the district has higher agricultural productivity than neighbouring districts, attributed to large-scale wheat and barley farms and emerging flower companies that rely on irrigation water from the Ewaso Ngiro River and smaller contributories flowing from Mt Kenya and the Aberdares range.

Farming in the arid and semi-arid lands in the north and north-eastern parts of Kenya has declined over the years owing to changing and unpredictable rainfall patterns and increasing poverty levels, and the fact that most of the households cannot afford required farm inputs.

The farming system in Laikipia is largely conventional, involving ploughing, harrowing, planting, first weeding and sometimes second weeding. Harvested crop residue is collected and stored for livestock because pasture is in short supply. Monocropping is a common practice among small-scale farmers, most of whom own less than 2 ha of land.

Agricultural sector players in the district are slowly introducing conservation agriculture in the area. While conservation agriculture is not new for large-scale farmers, some of whom have practised it for the last three decades, small-scale farmers are struggling to change their mindset from intensive to zero tillage. The goal of conservation agriculture is to maintain and improve crop yields and land resilience against drought and other hazards while at the same time protecting and stimulating the biological function of the soil. Conservation agriculture is closely related to conservation tillage. According to Unger et al. (1988) conservation tillage embraces crop production systems involving management of surface residue. No tillage, minimum tillage, reduced tillage and mulch tillage are terms synonymous with conservation tillage (Willis and Ameniya 1973; Lal 1973, 1974, 1976; Phillips et al. 1980; Greenland 1981; Unger et al. 1988, Antapa and Angen 1990; Opara-Nadi 1990; Ahn and Hintze 1990).

Study objective

The main aim of this study was to establish the extent of adoption and adaptation of conservation agriculture in Laikipia District, reviewing past and present conservation agriculture activities in the area and their overall contribution to alleviating poverty by increasing food security for vulnerable households.

This report is organized into nine sections: background information on the district; 2) materials and methods used in the study and criteria used to select the sites; 3) conservation agriculture activities in the area; 4) comparison of conservation agriculture as recommended by experts with farmers' practice; 5) extent of adaptation and adoption of conservation agriculture, with specific case stories;

6) impact of conservation agriculture in the area; 7) gaps and challenges facing promotion and adoption of conservation agriculture in the district; 8) discussion of the various findings of the study; and 9) concluding remarks and way forward for promoting conservation agriculture in the region.

2 Contextual information

Background

Biophysical conditions

Laikipia District covers 972,000 ha extending from the north-eastern foot of the Aberdares to the western foot of Mt Kenya and lying about 200 km north of Nairobi. The equator crosses the southern parts of Laikipia near Nyahururu and Nanyuki towns, and the district lies between 36° and 37°E longitude. Laikipia borders Samburu and Isiolo to the north, Nakuru and Baringo to the west, Meru to the east and Nyeri and Nyandarua to the south (fig. 1). There are seven divisions, 25 locations and 50 sublocations. The influence of the mountain land mass produces a steep ecological gradient on the plateau, giving rise to several altitude-related agroecological zones ranging from subhumid (agroclimatic zone IV) to semi-arid (agroclimatic zones V and VI) zones (fig. 2). The district, in the rain shadow of the Mt Kenya ranges, suffers a generally unreliable, inadequate and unevenly distributed rainfall. It is therefore characterized by a predominantly semi-arid climate (Jaetzold and Schmidt 1983) with a rainfall pattern varying from unimodal on the western side to a tropical bimodal pattern on the eastern side (Gichuki et al. 1998). Annual rainfall ranges from about 900 mm near Mt Kenya to about 500 mm in the extreme west (fig. 3).

Figure 1. Position of Laikipia District in Kenya

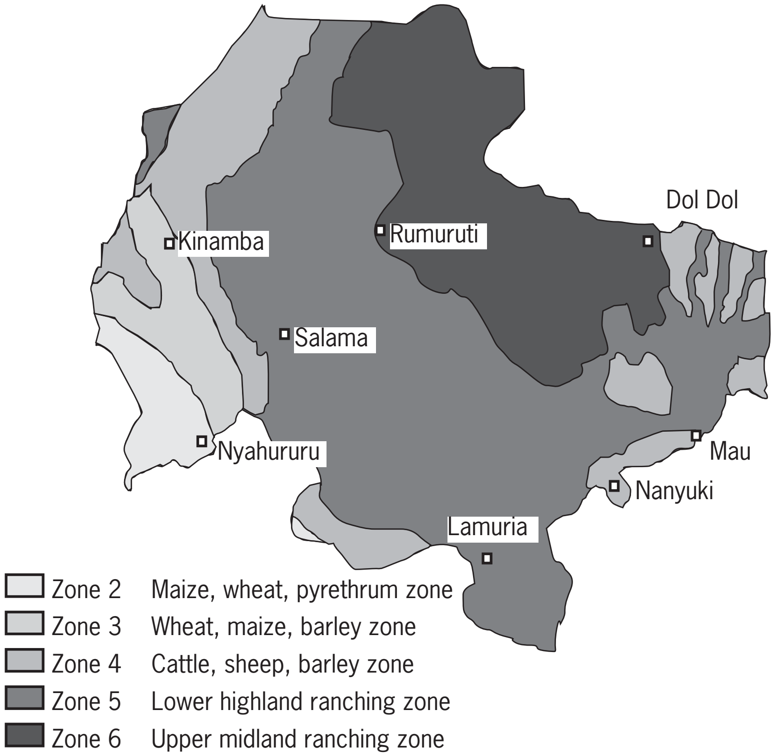


Figure 2. Agroecological zones characteristic of Laikipia District.

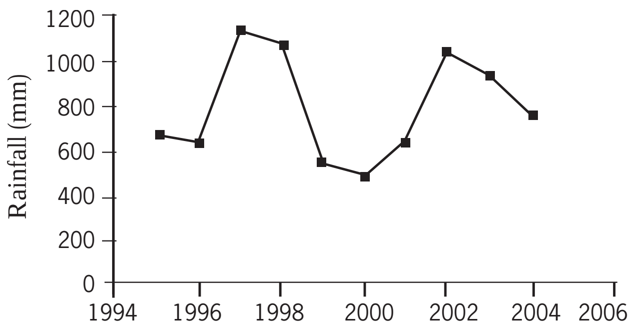


Figure 3. Average annual rainfall in Laikipia District.

The mean annual temperature ranges between 21 °C and 30 °C, with 6 to 8 hours of sunshine daily. The western and southern parts of the district are cooler. June is the coolest month and February the hottest. The highlands higher than 2600 m comprise mountain foot slopes, hills and scarps with shallow gravel soils, while the lowland mountain slopes have deeper clay loam soils on volcanic rocks. The lower plateaus with elevations below 1800 m have sandy clay soils. The highlands of the

Laikipia Plateau in the west have friable, very deep clay soils with excellent physical properties. Pockets of imperfectly drained, cracking clay soils (chromic-pellic Vertisols) are also found in some parts of the district (Kihara and Ng'ethe 1999).

Socio-economic conditions

Laikipia has a population of about 410,000 with an average of 4 persons per household (GoK 2000–2005). Households mainly comprise dependants, who include children orphaned by AIDS-related deaths of their parents and the aged. Table 1 provides the latest population statistics for the district.

Table 1. Population of Laikipia, by division

Division	Population in 2000	Population in 2005
Central	82,240	97,989
Lamuria	40,880	48,675
Mukogondo	13,983	16,680
Ngarua	69,565	82,993
Nyahururu	39,706	47,369
Ol Moran	11,812	14,091
Rumuruti	83,770	99,337
Total population	341,956	407,734

Source: DIDC, Laikipia population projections 2000–2005

Agriculture is the main source of livelihood for most households in the district, with only a small portion of the population in employment. The district regularly suffers annual food deficits (fig. 4), and almost half of the population benefits from government or World Food Programme (WFP) food aid. Adoption of sustainable agricultural practices has been identified in the government strategy paper on revitalizing agriculture as the lasting solution to food insecurity in the arid and semi-arid lands (GoK 2004).

Originally Laikipia was inhabited by the Maasai but now the Kikuyu and the Meru people are the majority. Other minor groups include the Samburu, Somali and Pokot. The Maasai practised traditional pastoralism and land was communally owned. Pastoral activities exist in the northern parts of the district, which were previously designated 'native reserves' during the colonial period. Although the greater part of this land is still communally owned, communal ranches have declined and a new system of private ranch ownership emerged, especially in the early 1990s (table 2).

Most parts of the district are undergoing significant changes in land use, from commercial ranching and an undisturbed ecosystem to demarcated small units under peasantry (Kiteme et al. 1998). This is associated with the inflow of people from the neighbouring and more densely populated districts in Central and Eastern provinces (Ngigi 2003). Immigrants account for about 70% of the adult population in the district (Bachmann 1995). Most immigrants seek to make a living out of subsistence cropping and small-scale livestock production. For instance, the Kikuyu and Meru in the district mainly depend on arable crops for their livelihood although some keep some sheep, cattle, goats and poultry.

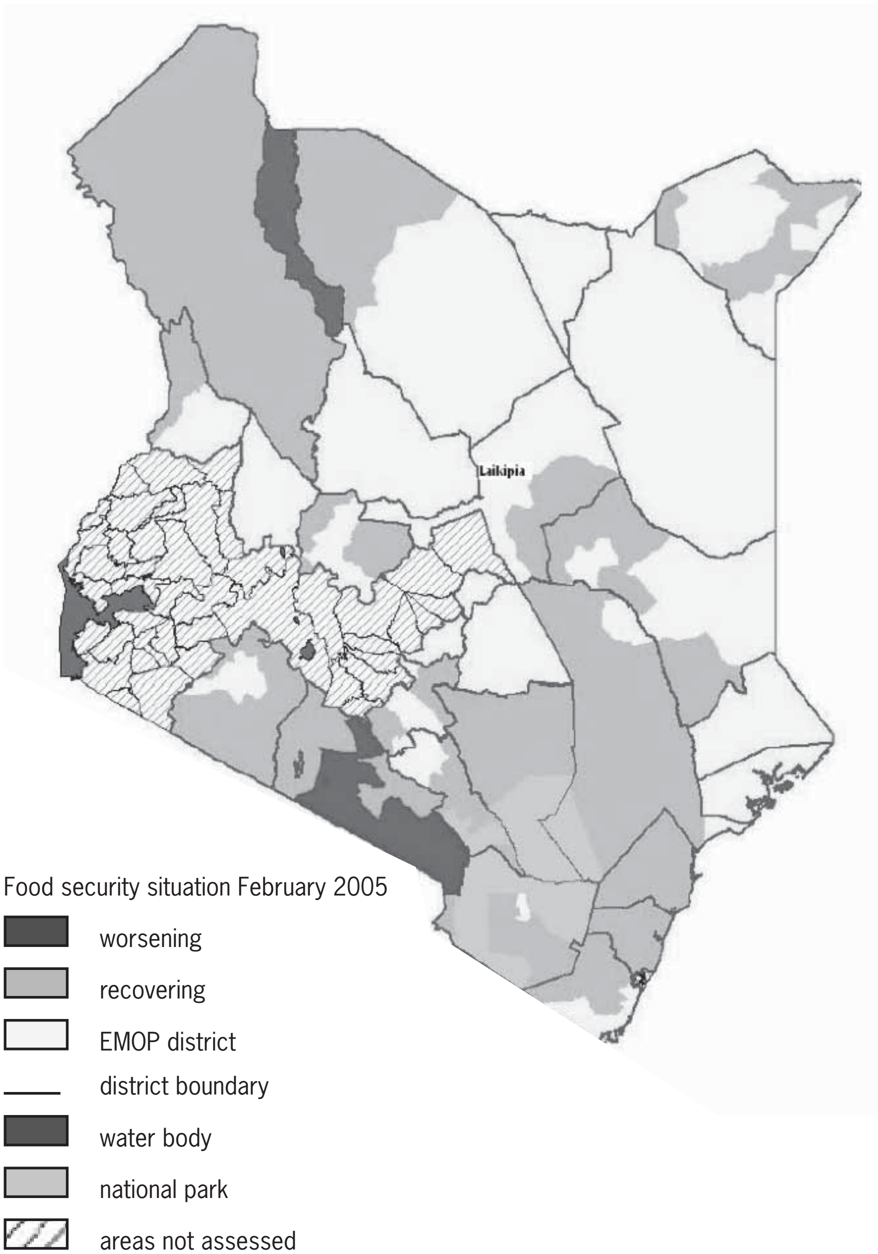


Figure 4. Food security status in Laikipia District. These data are from a study undertaken in February 2005 by the Njaa Marufuku Kenya programme.

Table 2. Land use in Laikipia, by division

Farming system	Dominant divisions	Description
Ranching	Central, Lamuria, Ol Moran, Rumuruti	Concentrated in Central and Rumuruti divisions. Farm sizes are 4100–41,000 ha. Beef cattle, sheep and goats are kept. Camels and wildlife are increasing in importance
Large-scale mixed farming	Central, Rumuruti	Most farms specialize in floriculture (> 41–2050 ha)
Medium-scale mixed farming	Central, Lamuria, Ngarua, Nyahururu, Rumuruti	Crops include wheat, barley and horticulture and some grasses. Livestock kept include dairy cattle, pigs, poultry and dairy goats (>8.2–41 ha)
Small-scale irrigated farming	Central, Lamuria Rumuruti	Horticultural crops like tomatoes, onions, vegetables and fruits (0.41–8.2 ha) are grown
Small-scale mixed farms	Central, Lamuria, Ngarua, Nyahururu, Ol Moran, Rumuruti	Crops like maize, beans, sorghum and millet are grown for subsistence purposes. Crop failure is frequent (0.41–2 ha)
Pastoralism	Central, Mukogodo, Ol Moran, Rumuruti	Concentrated in Mukogodo Division; mainly undertaken by Maasai pastoralists in group ranches. Livestock include cattle, sheep, goats, donkeys and camels. Most group ranches are heavily degraded.

Source: District Agricultural Office, Laikipia (2005)

The main crops grown include maize (*Zea mays*)—estimated to take about 51% of the planted area—beans (*Phaseolus vulgaris*), potato (*Solanum tuberosum*) and horticultural crops like kale, cabbage, tomato, onion and spinach. Wheat, barley and horticultural crops have great potential and the opportunity to grow them has been successfully seized by large-scale farmers. Cash crops like coffee, pyrethrum, barley, pineapples and castor oil have been successfully tried and are produced in small quantities in Ngarua, Nyahururu and Rumuruti Divisions. Millet (*Pennisetum typhoides*), sorghum (guinea corn) and sunflower are new crops being tried in the district but are yet to yield satisfactorily. Communities in this area seldom eat millet or sorghum, and introducing these drought-escaping crops successfully would be a worthwhile endeavour. Most small-scale farmers intercrop maize with beans, wheat and sweet potato. Maize is grown as both a cash crop and a staple food while wheat and barley are commercial crops. The yield of these crops is poor owing to moisture stress and soil infertility.

Large-scale farms grow mainly wheat and barley as cash crops and vegetables for export. Production of crops has generally been low because rainfall is unreliable and inadequate, soil fertility is low, and farmers are not able to adopt modern farming techniques. This has made food production difficult and adoption of inherited production systems and technologies by immigrants from higher potential districts unsustainable (Wiesmann 1998; Kunzi et al. 1998). Figure 5 shows the yield trend of wheat and maize in Laikipia District during the past 14 years. The drastic decline of these staple foods for most communities in the district is definitely a contributing factor to food shortage in the region. Similar trends have been noted in other equally important crops.

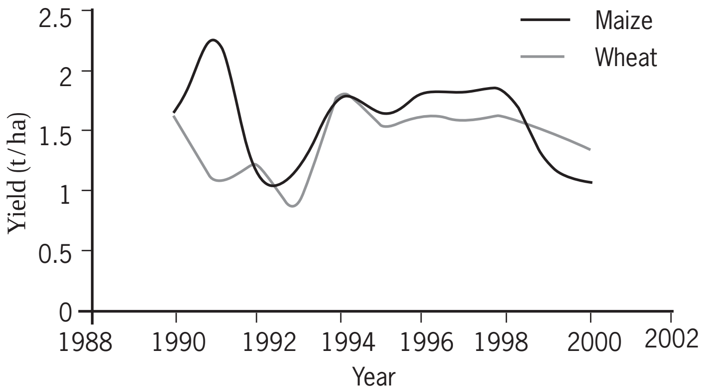


Figure 5. Trend in maize and wheat production in Laikipia District (Laikipia District DAO Annual Report 2003).

Currently 75% of the land area is under livestock production and game with large-scale ranching occupying more than half the land and concentrated mainly in the drier plateau that is home to large amounts of native fauna.

Agricultural activities are mainly restricted to wetter western parts of the district and a few fertile areas in the east where farms are subdivided into 2–20-ha holdings. Only 15% of the land is under crop production. On average land ownership per household is 2 ha. However, land ownership and tenancy are highly skewed with just a few farmers owning ranches and large-scale farms ranging from a few hundred to a few thousand hectares (see section 6). Competition between cropping and other land-use systems is increasing and the scale of land degradation in the district is high. Figure 6 depicts the main land-use systems in the district.

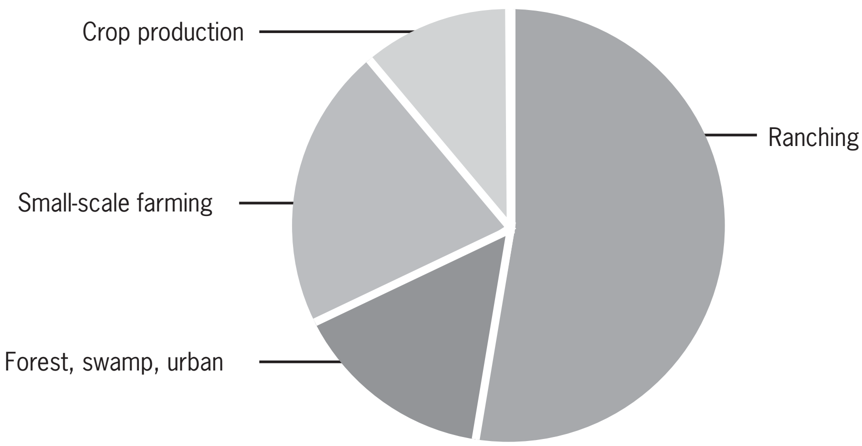


Figure 6. Land use in Laikipia District.

The farming operations on small farms rely largely on human labour and trained animals for draught power. Large-scale farmers own tractors and other mechanical farming implements, which they infrequently hire out. Some medium-scale farmers own tractors and other farming implements but hire specific equipment at certain times of the year from contractors inside and outside the district. In many cases small-scale farmers also hire agricultural machinery, especially combine harvesters. . Obtaining adequate labour for agricultural operations is a serious problem because of urban migration of young and energetic adults who previously flooded major centres in the district in search of jobs. HIV and AIDS, malaria and other diseases and the associated high mortality rate have also taken a toll on labour. Table 3 summarizes data on farm equipment in the district.

Table 3. Agricultural machinery in Laikipia District

Farm power source	Total available	Ownership		Common implements involved
		Own	Hired	
Tractors	150	100	50	direct seeder subsoiler heavy and light tine harrows chisel plough GPS sprayer mouldboard plough
Draught animals (trained oxen or donkeys)	200	170	30	Magoye ripper subsoiler animal-drawn direct seeder animal-drawn sprayer Bukura Mark II plough ordinary Victory plough
Hand (human power)	30,000	28,000	2000	hand hoe fork jembe jab planter machete planting stick

Source: Indicative estimation from interviews with key informants

The market for agricultural produce in the district is untapped because physical infrastructure is dilapidated as a result of poor or no maintenance. Apart from the major highways, the roads used by farmers to transport produce to the market are in poor condition and sometimes during the rains are completely impassable to public vehicles. This means that smallholder farmers have to walk long distances to buy farm inputs or to sell surplus produce. However, large- and medium-scale farmers in the district have almost no problems with marketing agricultural produce since they have established market outlets. Some of the challenges farmers face in trying to gain access to markets in major commercial centres are summarized in table 4.

The state of rural roads has improved with maintenance efforts financed by the Constituency Development Fund. All the major towns in the district are well served with postal and telecommunication facilities, but there are only five post offices

Table 4. Market variables for some crops in Laikipia District

Crop	Main buyers	Comparison in price	Challenges farmers face
Maize	Business people from major urban centres (intermediaries)	Average buying price from the farmer at farm level at harvest is USD 0.15 per 1 kg. The selling price to millers and supermarkets after value addition is USD 0.45 per 1 kg	Intermediaries pay low prices to farmers since they obtain the produce at the farm gate or nearby centres and pay the cost of getting the produce to the urban centres despite the dilapidated roads. High poverty levels in rural areas leave farmers no option but to sell to the intermediaries, as this saves them from walking long distances to urban markets. Small-scale farmers in rural areas do not have storage facilities or patience to upgrade the facilities to store produce until prices get better, and intermediaries capitalize on this and their ability to add value
	National Cereals and Produce Board (NCPB)	Average buying price at the NCPB depot in major urban centres within the district is USD 0.18 per 1 kg	NCPB expects farmers to deliver produce to its depots. Payment for produce is delayed. These two challenges encourage farmers to sell produce to intermediaries at much lower prices
Wheat	Millers	Average farm gate price is USD 0.24 per 1 kg	Large- and medium-scale farmers dominate wheat production, and since quantities are large, millers either collect the wheat or farmers deliver it to the millers using hired transport
			Since small-scale wheat farmers find it difficult to access the market available to millers, intermediaries buy wheat from them for about USD 0.20 per kg and sell to the millers and other outlets in large quantities
Barley	Kenya Malting	Price is negotiated between selected large-scale farmers and Kenya Malting, a subsidiary of East African Breweries	Barley growing is restricted to certified farmers for quality-control purposes

Source: Based on indicative estimate figures from interviews with key informants in 2006

in the district. All telephone exchanges serving fixed-line clients have subscriber trunk dialling services except those in Doldol and Lamuria centres. Accessibility to Internet services is limited to the major urban centres, including Nanyuki, Naro Moru and Nyahururu. A mobile telephone network covers almost half of the district but concentrates on the western side where population density is high.

The district is served by two power distribution grids. The Central Rift grid serves Nyahururu, Ngarua and Rumuruti and the Mt Kenya grid the eastern part of the district. Judging by the number of electricity records only 4500 consumers are legally connected with electricity. Thus there is need to intensify the Rural Electrification Programme to cover more in rural areas.

The district is served by railway lines, with two principal stations, at Nanyuki and Nyahururu. Maintenance of railway lines and stations is adequately undertaken by the Kenya Railways Corporation. Train traffic, however, is very low and farmers with perishable agricultural produce may not rely on it. The major airstrips are in Nanyuki, Nyahururu and Rumuruti towns and are owned and maintained by the Kenya Airports Authority. These are commonly used by tourists visiting the district. A number of private airstrips serve the wildlife sanctuaries and the large private ranches.

3 Materials and methods

Case study framework

The framework for the study was developed at a workshop in Nairobi, 28 January–4 February 2005, involving teams from several countries in Africa, and it was to be used for similar studies across the continent. It consisted of a number of key variables and methods for collecting data (appendix 1).

Selection of the case study area

Past and present conservation agriculture activities in the arid and semi-arid region led to the selection of Laikipia District as the study area. Being a vast district, the team could not assess farming practices in all divisions in the time and the resources allocated for the study. The case study exhaustively covered Lamuria and Central Divisions (fig. 7), which were the most advanced in adoption of at least some aspects of conservation agriculture, probably because of the presence of large-scale wheat and barley farmers that were keen to adopt tillage techniques that reduce production costs.

Case study team

The study was launched in 2005 with a team of three persons who were well versed in conservation agriculture and understood the background on agricultural systems and biophysical features of the district. The team leader was responsible for organizing and synthesizing information obtained from the field. The team was to present its findings as draft reports for independent review by a team of professionals drawn from CIRAD, FAO, ACT, RELMA/ICRAF and the FAO/Ministry of Agriculture project Conservation Agriculture for Sustainable Agriculture and Rural Development (CA-SARD).

Methodology

The team made several visits to the case study farms and interviewed key informants (appendix 2) identified according to the specific areas of interest as stipulated in the case study framework. The team also held several participatory rural appraisals and focus group discussions with members of farmer field schools and self-help groups to obtain information. At a meeting with district stakeholders participants shared their understanding of conservation agriculture.

The group was supported from time to time by national and international experts drawn from key organizations participating in the project. A literature review was conducted at the district information resource centre and at several libraries as the team deemed fit. The team worked closely with the district's Ministry of Agriculture (MoA) frontline extension staff, who have long-term experience and understanding of agricultural systems of the district.

Data collection and analysis

Most of the information on yield and biophysical characteristics was extracted from records kept by a number of large-scale farmers in the study areas. It was easy to get data from large-scale farmers, but data on small-scale farmers were estimations generated through farmer interviews. The estimation was based on the average figures among those provided by the farmers after numerous, tactful probings.

4 History of conservation agriculture in Laikipia

Large-scale farmers in Laikipia have practised conservation tillage for over three decades, but their small-scale counterparts were learning about it for the first time through various donor-funded projects.

To develop farming techniques suitable for small-scale farmers in the region, farm experimental research focused on seed variety screening and conservation tillage. These technologies were introduced to farmers by organizations such as the Kenya Agricultural Research Institute (KARI), the Regional Land Management Unit based at the World Agroforestry Centre (RELMA in ICRAF), FAO, the Kenya Network for Draught Animal Technology (KENDAT), the International Livestock Research Institute (ILRI) and the Kenya Rainwater Harvesting Association (KRA). KENDAT, an NGO based in Nairobi, worked from 1997 to 1998 with various groups in the Central Division who were interested in adopting draught-animal technology and conservation tillage. The project provided farmers, on a cost-sharing basis, with subsoilers and rippers as a way of promoting conservation tillage. They also held several training events for farmers on the technology and on-farm data collection techniques. The NGO also has equipment retail shops in Nanyuki town.

Beginning 2000 and ending in 2003, the Semi-Arid Rural Development Programme (SARDEP) promoted sustainable development, water and soil conservation and livestock production among small-scale farmers in the region. The project approach was to identify various groups with common interest. They facilitated and promoted an aspect of rural development suggested by each group. For example, the Dume Self-Help Group in Timau was assisted to grow Napier grass for livestock and for sale, while others interested in draught-animal power were provided with lump stand ploughs on a lease agreement.

Since 2000 KARI, through the Legume Research Network Project (LRNP), has been screening and promoting adoption of legume cover crops in Matanya around the Sweetwaters area of Lamuria Division with support from Rockefeller Foundation. The main objectives were to scientifically identify suitable green legume cover crops for the region and to promote their adoption by smallholder farmers to improve soil fertility and food security. KRA in collaboration with the Great Horn of Africa Rainwater Harvesting Programme (GHARP) and KENDAT promoted conservation tillage among small-scale farmers in Central and Lamuria Divisions from 2004 to 2005, as an in situ water conservation method.

The most recent intervention is the CA-SARD project, which started in 2004. The first phase focused on promoting conservation agriculture through the farmer field school (see section 6). By 2006 the project had established two groups in Lamuria and was moving to establish others in other divisions. Unlike other projects, CA-SARD has engaged various stakeholders such as suppliers of farm inputs, equipment, livestock and machines, and policymakers. The project has also fostered interaction between large and small-scale farmers to share practical experiences about conservation agriculture.

The study found that large-scale wheat and barley farmers adopted some aspects of conservation agriculture as a response to the rising cost of production and liberalization of the wheat market in the country. Conservation agriculture, which emphasizes the practices of minimum soil disturbance, permanent soil cover, and crop rotation or association, is not different from conservation tillage except in terminology. The fact that conservation agriculture is a package that involves application of the three practices, however, makes it unique and applicable to both small- and large-scale farmers in most parts of the country, especially in arid and semi-arid regions. This means that a farmer could start using one of the practices and progressively adopt the others until they achieve zero land tillage, plant directly under mulch, and rotate and associate crops based on their nutritional value and other valuable characteristics.

Over 90% of the farming in Kenya is based on conventional practices such as soil inversion, where crop residue is burned or fed to livestock, and a low level of fertilizer applied. This has resulted in decline in soil fertility, leading to such serious food shortage in the district that most of the population relies on relief food provided by the government and other donor agencies.

The study found that various categories of farmers in the district had some understanding of conservation agriculture principles. Medium- and large-scale farmers, who have used conservation agriculture in their wheat and barley farms for almost three decades, regard conservation agriculture as a farming practice lying between zero tillage and minimum tillage but with the additional benefit of incorporating crop rotation and fallow systems. These farmers have invested in agricultural machinery that only minimally disturbs the soil, and they share crop residue between mulch and livestock. But even among the large- and medium-scale farmers there were no uniform procedures in conservation tillage.

Small-scale farmers on the other hand have only minimally adopted conservation agriculture concepts despite being the target of concerted efforts to promote conservation agriculture by various initiatives. The study found that information on these pilot projects is usually limited to few groups and enterprising farmers. Automatic scaling up of conservation agriculture, which is usually expected to pick up immediately a practice is tested and validated by the farmers, did not occur because the farmers were not attracted to it and the dissemination strategies were inadequate. As small-scale farmers in the district often rely on very small pieces of land, they hesitate to risk adopting a technology they are unsure of. So far less than 100 small-scale farmers have been influenced by the CA-SARD project to adopt conservation agriculture. This is because the project has only two farmer field schools through which conservation agriculture is promoted.

Results from such a project cannot be a conclusive indication of the status of conservation agriculture among small-scale farmers. Limited tillage research and manufacturer neglect of making small-scale tools and equipment were found as significant constraints to the adoption of conservation agriculture. Despite efforts by KENDAT and other organizations to promote use of draught animals and conservation tillage equipment, no noticeable impact has been seen beyond the life of the projects owing to farmer inability to acquire conservation agriculture tools without financial assistance from sponsoring bodies.

5 Conservation agriculture technologies

Recommended practices

Conservation agriculture involves growing food and fibre while protecting the environment and all its resources. It is based on the integrated management of soil, water and agricultural resources. The goal is to maintain and improve crop yields and the soil's resilience in the face of drought and other hazards, while at the same time protecting and stimulating the biological function of the soil. Two essential features of conservation agriculture are no tillage and maintenance of a cover (live or dead vegetal material) on the soil surface. Crops are seeded or planted through this cover with special equipment. Although an essential feature of conservation agriculture, no-tillage by itself does not qualify as conservation agriculture. Ploughing for even one crop within the rotation and not maintaining a permanent soil cover is not conservation agriculture. With conservation agriculture the soil cover inhibits germination of many weed seeds, minimizing weed competition with the crop. In the first few years herbicide may still be needed, making location-specific knowledge of weeds and herbicide application important. Conservation agriculture also involves planning crop sequences over several seasons to minimize the build-up of pests or diseases and to optimize plant nutrient use through synergy between crop types and by alternating shallow-rooting with deep-rooting crops. Continuous use of the cropland is allowed. While this is the classical description of conservation agriculture as recommended by experts, farmers in the study area have their own practices that they call conservation agriculture (see section 6). Whether these should be considered as conservation agriculture or simply a step in the right direction is a matter of debate and discussion.

In general conservation agriculture requires a dramatic change in mentality. It states:

- Soil is a habitat for roots and soil organisms. Any damage to it endangers soil fertility and leads to land degradation.
- A permanent soil cover is the only way to protect, feed and regenerate the soil as a habitat.
- Tillage does not create soil structure but distorts soil life.

- Practices that are not compatible with conservation agriculture and must be abandoned, including
  - ploughing, harrowing or any kind of tillage, except reduced tillage in very specific situations
  - burning of plant residue, incorporation of organic matter or plant residue into the soil; these practices disrupt soil life and structure, remove the soil cover, and destroy humus by enhancing organic matter mineralization
  - uncontrolled grazing, which may completely destroy soil cover and induce soil compaction
  - uncontrolled use of chemicals (fertilizers and pesticides), which would endanger soil life

Conservation agriculture as practised by farmers

Crop rotation

Small-scale farmers in the district from time immemorial cultivated maize, beans, irish potato, wheat and horticultural crops such as *sukuma wiki* (kale), cabbage and tomato in rotation without any specific schedule or plan. The choice of crop to rotate is based on the size of land a farmer owns or can hire, resources to purchase required farm inputs and economic returns expected from the sale of such a crop. Very few farmers relate crop rotation to control of pest and diseases or soil fertility improvement.

Large-scale farmers, on the other hand, have crop rotational plans for wheat, barley, canola and fallow. They also have different ways of rotating crops. The large-scale nature of their field operations limits options for crop diversification. For instance, similar equipment is used in all field operations for the three crops.

Intercropping

Traditionally the farming communities in the study area intercrop maize and beans to diversify cropping options for greater yield and increased household income. Few farmers attach soil fertility improvement to this practice. Since beans mature much earlier than maize, they are uprooted and taken to an open place to dry before shelling. The huge heap of bean crop residue is then set on fire.

Introduction of *Dolichos lablab* as an alternative intercrop to beans to provide crop cover has gained popularity among some farmers through the farmer field schools established by CA-SARD and the activities of LNRP, both of which have been working in the region with small-scale farmers. Lablab popularity is attributed to the fact that its seeds are a common delicacy for Kikuyu and Meru communities.

Large-scale farmers have limited options for intercropping crops because of management implications, which could be costly.

Conservation tillage

Large-scale farmers have invested heavily in minimum tillage equipment. Even though there is little uniformity among farmers on how much they should restrict their tillage operations, use of the disk plough is a thing of the past for large-scale farmers in the area save for its use to break the resistant weed cycle. Following the low rainfall and its unpredictability, farmers have to rely on in situ harvesting of water, using tine harrows at specific times. Mulch planting is found among large-scale farmers mainly from after-harvest residue of wheat, barley and canola crops. While most large-scale farmers control their livestock numbers, grazing is restricted to some sections of the farm. In some cases sheep are grazed in crop fields for short periods to control weeds and also to improve soil fertility through their droppings. These farmers use herbicides for weed control.

Small-scale farmers are still glued to conventional farming and they use the Victory plough and the *jembe*.[1] They weed and plant using jembes or machetes. Farmers working with CA-SARD farmer field schools have access to conservation agriculture equipment and knowledge and are experimenting with conservation agriculture principles on a section of their plots. They use jab planters, or animal- or tractor-drawn direct planters. Animal-drawn subsoilers are used in fields with hardpan, while animal-drawn Magoye rippers are used for in situ harvesting of water. Some farmers at the early stages of adopting conservation agriculture use animal-drawn and pedestrian pull sprayers for applying glyphosate herbicide for weed control before planting.

6 Adoption and diffusion

Farmers in the district adopting conservation agriculture are now practising direct planting, which causes minimal soil disturbance. Figure 7 shows areas of the district where farmers are found who are adopting one or more elements of conservation agriculture.

Conservation agriculture adoption in the district is dominated by large- and medium-scale farmers, mainly to reduce production costs and increase profitability of their farms. Most small-scale farmers are slow in responding to market dynamics that require them to adjust their production processes to remain competitive. Small-scale farming in the district is characterized by poor or no record keeping, poor farming practices, and poor awareness of the returns of the enterprise. Convincing small-scale farmers not to plough or weed their farms is not easy. Even after years of interventions promoting conservation agriculture in the district some small-scale farmers remain reluctant to adopt it. The following cases give a clear picture of the status of conservation agriculture adoption in the Laikipia.

Lengetia Farm

This large farm in Lamuria Division is owned and managed by Mr and Mrs Laurie Sessions. It borders large wild game and livestock ranches. The Sessions own 278.8 ha of land and rent some 1722 ha. The farm falls within zone 5 (lower highland ranching zone) where rainfall is not reliable and ranges between 750 and 800 mm (fig. 3). The soil on the farm is red and black volcanic soils. Wheat and barley are the main crops, and canola and sunflower are rotational crops (fig. 7). Initially Mr Sessions used conventional

1 A hand digging tool similar to but bigger than a hand hoe.

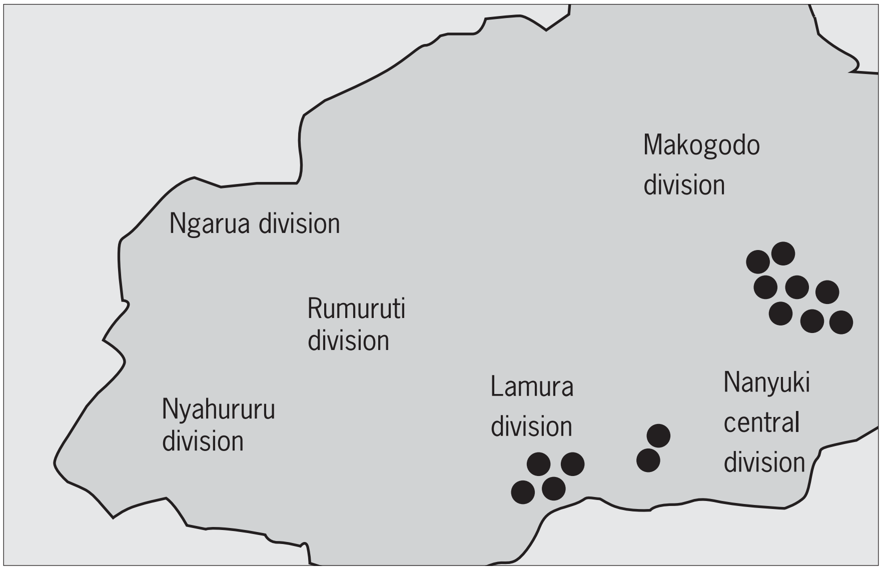


Figure 7. Map of Laikipia District showing areas where farmers adopted conservation agriculture (indicated by black dots)

tillage to produce wheat and barley on 410 ha of land. He faced a myriad problems, including declining soil fertility, high fertilizer requirements and high production costs associated with high oil prices, increased soil erosion, emergence of plough pans and the decline in wheat prices following trade liberalization in the Common Market for East and Southern African (COMESA) countries. These problems translated into production costs so high that his produce was no longer competitive.

In 2000 after seeing an Australian no-till planter used on a friend's farm and obtaining information on the technology, he decided to acquire his own no-till planter. In 2002 an Australian pneumatic direct seeder was assembled on his farm by the manufacturer's mechanics who travelled purposely to ensure that the machine was operating and the user was well versed with its operation manual (see colour section). He embarked on growing wheat and barley using zero-tillage, increasing his cropped area from 410 to 615 ha by 2003, and 1927 ha in 2004, which excluded 172.2 ha rented in Timau in Central Division. To date he is perhaps one of the few zero-till adopters in the district able to fully exploit the advantages of this particular practice.

The benefits of zero tillage did not come immediately after he acquired the planter but in the second season, after significant build-up of soil cover from crop residue. Because he understood the new farming technique, he restored soil biomass by accumulating and spreading the crop residue evenly on the crop fields after each harvest and did not allow his livestock to graze freely on the cropped fields, which they had done previously. Instead he isolated a portion of his land for grazing and also baled fodder for the livestock. He used a herbicide as soon as weeds emerged in the harvested fields to reduce the weed seed bank. He believes that from the time he started conservation agriculture he has reduced the weed seed bank by about 30%.

Even without staff cuts following adoption of conservation agriculture, the Sessions have reduced their production costs by about 55%, in part due to considerable reductions in tractor power requirements and farm operations and the concomitant reductions in manpower and fuel consumption. Anecdotally he summed it all up by saying, 'Because of conservation agriculture, my blood pressure has gone down, and one cannot cost that.'

Zero tillage has increased crop yields and, because of enormous mulch developed due to an accumulation of crop residue, moisture retention is greatly improved. Mr Sessions does not worry much about the erratic rainfall patterns, thanks to the in situ water-harvesting property of zero-tillage. At first neighbouring wheat farmers thought that he was irrigating his land since his crops were always green and healthy while theirs often failed when rainfall was poor.

Farm operations

An average of 1845 ha of land was under zero-tillage at the time of the study. The major crops grown were wheat and barley, but he was introducing canola as a rotational crop between wheat and barley (fig. 7). The decision to introduce canola was associated with the resistance to glyphosate and other herbicides of several grass weeds such as *Cynadon dactylon* and also to counter the emergence of volunteer growth of either barley or wheat.

The crop residue was left on the soil surface after the crop was harvested and that particular field was not planted during the following season to allow for regeneration of the soil and for water to be stored in the soil. During the fallow, weeds were minimized by spraying glyphosate and for the more resistant weeds, other types of herbicides. This ensured that the weed seed bank was considerably reduced. The practice of leaving a field fallow for one or more seasons could change if he continued using canola as a rotation crop. The economic importance of canola could also be a factor, especially if he ventured into producing biofuel.

Mr Sessions practises a seasonal rotation (fig. 7). He is also trying out crops such as sorghum and sunflower to diversify the rotation.

The pneumatic direct seeder causes minimal soil disturbance. It is designed to allow 12-inch (30.5 cm) interrow spacing, which is wider than the 8 inches (20.3) in conventional planting for both wheat and barley. The wider spacing is highly recommended by researchers and extension agents for this area since it provides a crop with a larger area to obtain nutrients and moisture. Soil compaction from machinery moving on the crop field was reduced by ensuring that wheels of the tractor and other equipment used a defined path during all field operations (colour section). Both the sprayers and planters are compatible and can follow same track. Mr Sessions was yet to buy a compatible combine harvester.

To prevent hardpan from developing with zero tillage, Mr Sessions decided to subsoil each crop field every 4–5 years as a preventive measure. He also ploughed when couch grass developed resistance to herbicide. As his red volcanic soils are associated with soil compaction, he took care to ensure that most tractor operations are done while the land was dry.

Crops grown

Wheat and barley are the principal crops grown under zero tillage. Mr Sessions has a contract with the Kenya Malting Company to produce barley, so this crop had a ready and reliable market. He sells wheat to local millers. Oil was extracted from canola using a manual ram press manufactured locally by the Appropriate Technology (APPROTEC) group, and it was sold to domestic consumers in the district. This was a minor activity. Blending canola oil with diesel to make biofuel for farm operations was viewed as a viable undertaking. A nearby large-scale farmer was at an advanced stage of developing a biofuel extraction and blending plant and Mr Sessions was following its progress with considerable interest.

Sorghum, a drought-resistant crop, is doing well under zero tillage (colour section). This success could influence local small-scale farmers to grow the crop under conservation agriculture to reduce dependence on relief food. The obstacle in promoting this crop was that ugali[2] from sorghum flour was not a familiar dish for the communities in the district, unlike in western Kenya.

Land quality changes associated with conservation agriculture

Mr Sessions believed that soil quality had improved since he began using zero tillage. He attributed this to the decomposition of crop residue. Soil moisture had been retained all through years and soil fertility had improved with the increase in soil organic matter (colour section). He believed that the use of controlled traffic paths for farm machinery had reduced soil compaction considerably and that the improved soil structure had increased the presence of microorganisms in the soil. He summed it all by saying, 'When I smell this soil, I feel that it is alive and healthy'. There was a big difference between the state of his soil and that of the neighbouring farmer, who did not practise zero tillage.

Challenges in practising conservation agriculture

According to Mr Sessions, crops were attacked by insects and diseases more often with zero tillage than before since the crop residue harboured insects and diseases. This meant that he had to spray more often than before, increasing his spraying costs by 50%, but he said that conservation agriculture was still more profitable than conventional farming. Weeds such as couch grass (*Cynadon dactylon*) and amaranthus tended to become resistant to herbicides over time (colour section). In such cases he had to plough the fields, wait for weeds to emerge and then spray to control them completely. This practice, however, destroys the gains made in soil fertility and moisture retention. Increases in soil moisture availability led to water grass emerging as a weed that depletes soil moisture (colour section).

Gross marginal analysis of conservation agriculture

Mr Sessions said that with conservation agriculture he had reduced the need for tractor power by 74%, eliminating operations such ploughing and harrowing. And since tractor operations were undertaken when the soil surface was dry, he

2 A mixture of flour and water cooked to form a semi-solid dough.

needed less traction. Labour requirements were reduced by about 10%. This made it possible for him to maintain a lean, reasonably specialized staff. With the wide interrow spacing, seed requirements were reduced by about 40%, leading to a considerable saving. Since he adopted conservation agriculture, his barley and wheat yields increased to between 1.5 and 3.3 t per ha per season, compared with about 0.9 t per ha obtained with conventional practice.

Reasons for practising conservation agriculture

Apart from the direct benefits associated with reduced farming costs, reduced annual precipitation was probably one of the most important factors that turned Mr Sessions to conservation agriculture. He believed that the crop residue accumulating over time provided permanent soil cover, which harvested in situ most of the rainfall received and prevented moisture from evaporating. Increasing cost of production with the upsurge in oil prices and declining wheat prices associated with importation of cheap wheat are other important factors that led him to adopt conservation agriculture principles.

Change in cropping area

With the success of zero tillage, Mr Sessions has been gradually increasing his cropped area, which had reached 1845 ha by the time of the study in 2005. Initially he had rented pieces of land in Timau and Narok, where he planted both wheat and barley under zero tillage, but he dropped these fields when operation costs escalated and he found it was not possible to supervise crops, which would have been necessary to get maximum benefits from conservation agriculture. Even though conservation agriculture required time before a farmer saw the benefits, he did not hesitate to start it on the 1845 ha since the tenure of that land was stable and he could continue enjoying the benefits of conservation agriculture in the future.

Shocks in farming business

Declining wheat prices associated with the coming into force of the COMESA trade agreement were a major challenge to the Sessions. However, the steep reduction in production costs through conservation agriculture has convinced him to continue wheat production. Barley had a ready market and together with canola could sustain the farm. Other shocks included crop pests and diseases. Weeds, particularly those resistant to herbicides (such as amaranthus, couch grass) and those associated with moisture from crop residue (such as water grass), also were a great challenge to the farm.

Input suppliers

The farmer bulked his own wheat seed and exchanged seed with farmers from Timau approximately every three years to improve seed variety. He said that certified wheat seed from major companies such as Kenya Seed was quite expensive. Barley seed was provided by Kenya Malting Company. The main fertilizer supplier was Yara Company; chemicals were obtained from a range of companies such as Lachlan, Bayer East Africa, Agricare, Hygrotech, Amiran and Twiga Chemicals. Mr Sessions checked weed resistance to herbicides by alternating chemicals from various companies every season. He imported zero-tillage equipment such as sprayers and no-till planters mainly from an Australian company whose machinery and after-sale service were reliable. He said that this equipment was robust compared with local varieties. He procured a few direct seeders and sprayers from Ndume, a local company based in Rift Valley Province.

Mr Sessions had three direct pneumatic seeders, two from Australia, one of which had 150-horsepower capacity and was capable of sowing 39–41 ha per day; the other with 130-horsepower capacity was capable of sowing 31–33 ha per day. The one planter purchased locally from Ndume had a horsepower of 85 and could cover 19–21 ha per day. His Australian sprayer, which was 18 m wide and required a 70-horsepower tractor, could cover 103 ha a day. He also had a sprayer purchased locally from Hardi, which was 12 m wide and covered 41 ha per day. In total he had 15 tractors, ranging in capacity from 35 to 150 horsepower.

Availability of credit and other incentives

Being a large-scale farmer, Mr Sessions had good bargaining power and a credit rating that enabled him to obtain various agricultural inputs on credit. He said that he spends up to KES 25 million (USD 334,000) on chemicals every season. He was a member of the Cereal Growers Association (CGA), a national umbrella organization representing the interests of all cereal farmers in the country.

Cooperation with small-scale farmers

What made Mr Sessions different from other large-scale farmers in Laikipia was his open desire to influence small-scale farmers to adopt conservation agriculture, which he believed was the only viable option available for crop farmers in that region. He not only talked about conservation agriculture with small-scale farmers but was also willing and ready to facilitate any process that would increase adoption of its concepts. He said that every harvest several families spend a whole day picking up leftover wheat in his crop fields. He did not stop them but said he felt awkward about it and that it was one reason he was working closely with members of two farmer field schools and the CA-SARD Project to promote conservation agriculture among small-scale farmers. He allowed conservation agriculture members to use his Brazilian no-till tractor planter provided by the CA-SARD project to plant (colour section). Mr Sessions had also worked closely with the management of the CA-SARD Project to promote conservation agriculture within and outside the district. He agreed to host a field visit by participants of the Third World Congress on Conservation Agriculture at the request of the chairperson of the congress organizing committee. He had hosted several CA-SARD delegations of scientists and experts on his farm. He said that all the interactions with CA-SARD and other projects had strengthened his resolve to proceed with conservation agriculture and become its ambassador in the region.

Because of the success of the farmer field schools established by the CA-SARD project, Mr Sessions had influenced the Ol Pajeta Conservancy to establish up to 100 farmer field schools among the neighbouring small-scale farmers. The conservancy has already employed a full-time extension officer with the responsibility of starting farmer field schools, aiming for a target of 100 groups. The conservancy did not provide grants to the groups but offered advice on conservation agriculture and gave out farm inputs for the trial plots. With this venture, the conservancy, which included Mr Sessions and the management of Ol Pajeta and Solio Ranches, lobbied chemical companies to donate herbicides, fertilizers and insecticides to be used in the established schools. They were also looking for closer collaboration with other projects promoting conservation agriculture. Their desire was for conservation agriculture to form the backbone of the established field school. Mr Sessions had hosted several field days where small-scale farmers had had the opportunity to interact with large-scale farmers and to be exposed to the benefits of conservation agriculture. He established conservation agriculture trial plots for maize, lablab and sunflower and organized field days for small-scale farmers.

Wangu Investments

Wangu Investments, located in the foothills of the Mt Kenya range, occupies a total area of 1225 ha. The company is involved in both livestock and crop production. The firm is owned by some 10,000 shareholders and is run by a hired manager. The fields are divided into plots of 12–30 ha spread. The cropping fields are on the leeward side of the mountain so are in a rain shadow. Crops are grown along well-designed contours to minimize impact of soil erosion and optimize water infiltration (colour section). The area has two growing seasons a year: February–July and August–February.

Wangu Investments began adopting elements of conservation agriculture in 1987 to counter the increasing cost of production and the changing and declining precipitation. Adoption increased gradually over the years. The main crops grown were wheat and barley. Wheat was produced for local millers and barley for Kenya Malting Company. About 10,000 sheep are kept for wool and mutton, and 800 dairy and beef cattle.

Conservation agriculture practice at Wangu Investments

At Wangu Investments conservation agriculture was referred to as conservation tillage. To them it comprised two very important concepts: minimum tillage and zero tillage. The difference lay in land preparation and equipment used both in preparing the land and planting (colour section). They also had an elaborate fallow system where fields were left idle 7–8 months to regenerate. The practice involved a rotation to ensure that there were crops in the field every season.

Minimum tillage involved very minimal soil disturbance that mostly was geared towards in situ water harvesting. The colour section shows land being prepared for planting during the following season

Minimum tillage as practised at Wangu Investments involves:

- The combine harvester used to harvest barley and wheat has a secondary attachment at the rear that chops and spreads the crop residue on the field to provide even cover on the surface.

- Once the field is harvested and the crop residue spread evenly, some livestock, mainly sheep, are left to graze for some time. The sheep feed on the emerging weeds, and manure from their droppings is spread evenly on the entire field, improving soil fertility. They graze in a field for a month before moving to another field.
- The field is then cultivated using a heavy tine harrow (colour section) whose purpose is to increase water filtering into the soil in preparation for the next season. This process also helps in breaking any hardpan that may have been created by the grazing sheep and in mixing the manure and crop residue with soil for speedy decomposition, improving the soil fertility and structure with minimal soil disturbance.
- After some time and close to the start of the cropping season the field is sprayed with herbicides once or twice at different times.
- In the seventh to eighth month the field is cultivated again with a light tine harrow before planting with a pneumatic direct seeder.
- After germination of the crop emerging weed (not very common) is controlled by selective application of herbicides.

According to the farmers, zero tillage involved the same process as minimum tillage except for the planters and the interrow spacing involved. The planter used in zero tillage had a coulter in front of the seed and fertilizer outlet (colour section) while the minimum-till planter had small tine harrows positioned in front of the fertilizer and seed outlets (colour section) above. Interrow spacing was 15 inches for the zero till planter and 12 inches for minimum tillage.

Motivation for adopting conservation tillage

Wangu Investments has progressively increased the land under conservation tillage since adopting the practice in response to increases in yield and as a technological response to declining rainfall levels over the years. The firm uses conservation tillage in fields in lower altitudes where rainfall is limited but conventional tillage for higher altitudes. The management nevertheless concurred that the declining rainfall, even for the fields at high altitudes, could lead to adoption of conservation tillage in all their crop fields.

Gross marginal analysis

Table 5 illustrates the benefits reaped from conservation tillage. The farmers interviewed said that they had realized substantial reductions in tractor power requirements, labour and fuel consumption.

With these substantial reductions in the cost of production, the firm is confident of being in the wheat business even with the COMESA trade agreement coming into force.

Weeds, especially broom grass, emerged when there was no ploughing, so the farmers ploughed the fields where weeds were prevalent or burned the growth to retard their growth and germination. This is usually done every five years in such fields. The option of ploughing was preferred owing to the high cost of the herbicides that would eliminate the grass.

Table 5. Yield comparison of conservation agriculture and conventional farming

Farming practice	Crop	Yield (t/ha)	Production cost (USD per ha)	Profit range (USD per ha)
Conservation tillage	wheat	4–4.83	528–624	432–528
	barley	4.4–5.5	528–624	528–696
Conventional tillage	wheat	4–4.4	792	158.4–264
	barley	4–4.4	792	158.4–264

Source: Indicative estimates from Wangu Investments crops officer (it is assumed that wheat and barley are sold at the same price)

Negative effects of conservation tillage

Weeds, especially broom grass, emerged when there was no ploughing, so the famers ploughed the fields where weeds were prevalent or burned the growth to retard their growth and germination. This is usually done every five years in such fields. The option of ploughing was preferred owing to the high cost of the herbicides that would eliminate the grass.

Major input suppliers

Wangu Investments procured most conservation tillage equipment from Ndume, which is preferred because most of their equipment is tailor-made for specific applications. Availability of spare parts and after-sale service are some of the factors that endeared Wangu Investment to the supplier. Wheat seed is prepared on the farm since certified seed from major seed companies is expensive. Barley seed is provided by the Kenya Malting Company on credit. The study could not obtain information on the actual cost of this seed. Fertilizer and farm chemicals are obtained from a range of companies, including Bayer EA, Lachlan, Twiga Chemicals and Syngenta.

Kisima Farm

Mr Martin Byer of Kisima Farm has practised zero tillage in his wheat and barley fields for the last 30 years. Up to 2400 ha of land was put under zero tillage every season. Canola and peas are grown in rotation with the two main crops of wheat and barley. Wheat is sold to local millers, barley to the Kenya Malting Company, and rapeseed oil from canola to oil companies. Plans were at an advanced stage for venturing into biofuel production.

Conservation agriculture practice

On this farm conservation agriculture is synonymous with zero tillage, with herbicides used to kill the weeds, crops planted using direct seeders imported from Canada, and after harvesting, crop residue left to accumulate and provide permanent soil cover to conserve moisture and increase soil fertility. Initially crop fields were left fallow after harvesting to facilitate regeneration of soil nutrients, but this has been scaled down substantially with the introduction of canola and peas as rotational crops.

Motivation to adopt conservation agriculture

The amount of rainfall every season was not adequate for most crops grown on the farm. Zero tillage ensures that the little rain that fell was properly harvested and conserved in the soil to reduce evaporation. This was achieved by the permanent soil cover provided by accumulated crop residue left in the fields.

Declining prices of wheat and the eventual coming into force of the COMESA trade agreement on agricultural products require that agricultural firms put in place measures to reduce production costs. Zero tillage drastically lowered the cost of tractor use, labour and fuel. Since the farm adopted zero tillage soil analysis records have showed considerable improvements in soil fertility and structure.

Zero tillage has reduced soil erosion despite the sloping topography of the crop fields. With zero tillage the farmer harvests on average 4 t/ha of wheat or barley, but yields can surpass this. As the land owner, the farmer is in a position to enjoy the long-term benefits of conservation agriculture, which as he understands are not immediate and require proper initial capital investment.

Problems with practising conservation agriculture

Weeds, especially couch grass, were a big problem in some fields. When pronounced, the field was ploughed to eliminate them. This practice negated the benefit of minimum soil disturbance, but it was the best option since it took several years before ploughing was needed again. The farmer associated the emergence and resistance of couch grass with zero tillage.

Interaction between large- and small-scale farmers

Kisima Farm borders many small-scale farmers who grow wheat, maize, irish potato and numerous horticultural crops. These farmers purchased wheat as ordinary consumers from Kisima Farm only to later use it as seed on their farms, as certified seed was expensive and the farmers believed that Kisima had a good, clean wheat variety. The small-scale farmers attended field days organized by the Cereal Growers Association (CGA) at Kisima, where they saw zero tillage in use and its benefit of improving yield (colour section). Both large- and small-scale farmers were CGA members so they interacted and shared ideas at different CGA functions. However, unlike the large-scale farmers who have greater bargaining power with stakeholders, intermediaries exploited the smallholders, who had no access to credit and lacked the capacity to acquire current information on improved modern farming practices. The farmer said that small-scale farmers, especially those growing wheat, were aware of zero tillage but were limited in adopting it by lack of access to capital.

Sources of farm inputs

Mr Byer obtained fertilizer from Yara Company in Nairobi, and chemicals from a range of companies such as Bayer East Africa, Lachlan Kenya and Twiga Chemicals. Most of the zero-till implements were imported from either Canada or England, while tractors were procured locally from SAME tractors.

Views on the future of conservation agriculture

Mr Byer believed that using biofuel would drastically lower his cost of production and make his farm competitive, especially in the world wheat market. Growing canola under zero tillage and rotating it with other main crops presented an opportunity to enhance adoption of conservation agriculture not only among large-scale but also small-scale farmers, who would be attracted to the economic potential of rotating canola and wheat under conservation agriculture. The farmer was already exploring the possibility of installing an oil extracting plant to use rapeseed from the farm instead of selling it to oil companies. Adoption of biofuel could also be this farm's contribution to the global effort to reduce greenhouse gasses from the atmosphere, a recommendation of the Kyoto protocol of which Kenya is a signatory.

Dume Soil Conservation Self-Help Group

The Dume Soil Conservation Self-Help Group was a formal group comprising mainly small-scale farmers who owned 0.2–0.82 ha of land. Formed in 1997 with a membership of 42, the group has the following objectives:

- scaling up use of draught-animal power in promoting conservation agriculture practices
- promoting sustainable agricultural practices aimed at improving the living standards of members
- enhancing self-reliance among its members
- addressing food insecurity through adoption of modern farming practices

The group was exceptional in the sense that it consisted of immigrants from the greater Meru District, a high-potential area. They first continued with farming practices they had used in their old district but had to adjust to the poorer environment by adopting farming practices that could enable them produce food for subsistence and for sale. This group had worked with various projects from 1998 to the time of the study to promote adoption and adaptation of farming technologies that would make them food secure. KENDAT worked with the group between 1997 and 1998, especially with farmers interested in using draught animals. The project provided farmers with subsoilers and rippers on a cost-sharing basis to promote conservation tillage. They also conducted training sessions in using draught animals in and collecting data.

Between 1998 and 2001 RELMA funded conservation tillage experiments initiated by KENDAT. Ten farmers were selected from this group and provided with seed, fertilizers and herbicides. Each farmer was required to rent a 0.41 ha piece of land for demonstration. RELMA/ICRAF provided technical support to ensure that the demonstration plots and learning process were properly coordinated. The farmers received the yield obtained from such plots.

The CA-SARD project did not directly support the group's activities but closely worked with them to transform them from conservation tillage to conservation agriculture farmers. The project offered some members of the group technical support and training on equipment and animal hiring. The group was involved in several activities, including a 'merry go round'[3] and field days to promote adoption of conservation agriculture and draught-animal use among small-scale farmers.

Crops grown by farmers in this group include french beans (grown under irrigation and mainly for commercial purposes), maize, irish potato, beans and wheat. Irish potato and wheat were among the most common crops. Some 30% of group members grew their crops using some element of conservation agriculture, and the rest showed willingness to practise it but were limited by lack of resources. The group also had a limited amount of conservation agriculture equipment, which contributed to their lack of adoption. They had one each of an animal-drawn direct planter, a subsoiler, a jab planter and a ripper. They said that soil fertility had declined with monocropping and lack of strategies to counter increasing soil degradation. This region, like the rest of the district, is on the leeward side of Mt Kenya and receives little precipitation. The emergence of horticultural farms in the region affected these small-scale farmers by polluting water sources and by unusual crop pests and diseases emerging that attacked their crops. They claimed that such pests and diseases affected their wheat more frequently than before, since they migrated from large-scale wheat farms, which were regularly sprayed with pesticides.

Conservation agriculture practice by the Dume Self-Help Group

The Dume Self-Help Group was aware of some elements of conservation agriculture, partly owing to their proximity to large-scale wheat farmers who practised minimum or zero tillage, and partly as a result of the work of organizations such as KENDAT and RELMA in promoting conservation agriculture, using draught animals and no-tillage equipment such as the Magoye ripper and subsoilers. Through the CA-SARD project, a man who had acquired a Brazilian animal-drawn planter hired it out affordably to plant wheat, beans and maize for group members and others (colour section). Farmers' access to this equipment was probably one of the most important entry points for conservation agriculture, owing to its convenience, efficiency in applying both seed and fertilizer, affordability, and the fact that most members of this group had trained in using draught animals. The demand for this equipment was overwhelming, according to a focus group discussion organized by the study team, and most farmers were even ready to purchase another unit immediately at a cost of USD 300. Although the group considered conservation agriculture a good practice, without equipment few small-scale farmers would adopt animal-drawn planters. They expressed willingness to acquire the equipment either through purchase or by leasing. Their understanding of conservation agriculture was well stated in these phrases: 'Don't remove crop residue from the field and just plant without ploughing,' 'Conservation agriculture helps eliminate the hardpan, since when you leave residue in the field, the moisture conserved helps soften the hardpan.'

The group also worked closely with the Ministry of Agriculture (MoA) extension officers who guided them on the suitability of seeds, fertilizer and chemicals. However, at a focus group discussion session it was noted that the MoA extension staff were

3 A common-interest group arrangement that helps members in turns, socio-economically and materially.

not always available to solve farmers' numerous agronomic problems, so farmers needed to empower themselves with necessary knowledge in crop production. They aimed to achieve this through collaboration with interested projects.

Small-scale farmers in this area owned very small areas of land. Some of them resorted to renting land at KES 2000 (USD 26) per hectare per year. Landlords gave such farmers stringent conditions, which in most cases were unfavourable to conservation agriculture, since the tenancy of such hired lands was too short to ignite significant economic returns. Therefore, small-scale farmers were quite sceptical about practising conservation agriculture on rented land.

Cropping systems among the small-scale farmers hindered adoption of conservation agriculture. For instance, farmers planted irish potato, which did quite well in this region. However, harvesting the potatoes involved maximum soil disturbance, affecting conservation of moisture and soil fertility.

It was common for farmers to feed livestock on crop residue since pastureland for grazing is limited (colour section). With the negative impact of grazing livestock on the crop fields, some small-scale farmers adopted a 3:7 ratio for crop residue left in the field and fed to livestock. They aimed to gradually increase the volume of residue left in the field to eventually provide a permanent soil cover.

Thome Farmer Field School

The Thome[4] Farmer Field School was started in 2004 by Paul Wamai after he trained in farmer field school methodology and conservation agriculture technology. The group started with 30 members (18 male and 12 female) but by the time of the study there were 26 (16 male and 10 female) active members, the rest having dropped out by natural attrition or loss of interest. The group received a grant of USD 500 from FAO through the CA-SARD project to acquire a trial plot from one of their members, procure seeds and learning materials, and pay a facilitator for transport and lunch every time they visited. This grant was expected to last two seasons, after which they were expected to have acquired adequate skills through participatory technical demonstrations.

Reason for group formation

The group is in Lamuria Division, which is in agroecological zone 5 characterized by inadequate and unreliable rainfall and high rates of evapotranspiration. The area is greatly degraded from overstocking, and several gullies have been formed. Crop failure was high in this region but surprisingly the residents had not given up cropping, and every season they planted maize, wheat, beans and other crops (colour section). They practised monocropping and limited crop rotation. Synthetic fertilizers were used infrequently and where applied were in amounts inadequate to make significant effect on crop yield. Feeding livestock on crop residue or grazing them on fields already harvested was a practice engraved in the culture of the community, so they considered being advised to do otherwise quite strange. After all, in prevailing dry conditions this would be expected of small-scale farmers who

4 The Kikuyu name for entrance.

integrate crop and livestock production on less than 2 ha of land. Farming here was conventional (involving ploughing) and weeding was undertaken once or twice using a hand hoe. No tillage was perceived as strange. Against this background, CA-SARD sought to address the problems of continued land degradation and declining soil fertility by introducing conservation agriculture techniques via the farmer field school approach. The project engaged farmers in testing and validating the three conservation agriculture principles through their full participation in the established participatory technology demonstrations.

Why farmer field schools are used to promote conservation agriculture in the area

The farmer field school approach is described as a 'school without walls' and a platform for improving the decisionmaking capacity of farming communities and stimulating local innovation for sustainable agriculture. It is a forum where farmers make regular field observations, relate their observations to the ecosystem, and apply their previous experience and any new information to make a crop management decisions with the guidance of a facilitator.

As an extension approach, it is a dynamic, hands-on, innovative and participatory discovery learning process built upon the principles of adult education. Every learner is a potential trainer and the facilitators must be technically strong. Farmer field schools enable farmers to discover and learn about their own agroecology and integrated farming and pest management. On the basis of this knowledge they become independent and confident decisionmakers, and experts in their own fields after successful completion of the farmer field school curriculum.

The farmer field school approach complements existing research and extension activities through shortening the time it takes to get research from the research station to adoption on farmers' fields by:

- involving farmers in experimentation
- enhancing the capacity of extension staff to serve as technically skilled and group-sensitive facilitators of farmers' experimental learning
- increasing the expertise of farmers to make logical decisions on what works best for them, based on their own observations of experimental plots in their farmer field school
- establishing coherent farmer groups that facilitate the work of extension and research workers, providing the demand for a demand-driven system (colour section)

Extent of conservation agriculture adoption by group members

Out of 26 group members, 15 were practising conservation agriculture on their individual farms, and the number was expected to rise, particularly as yield improvements on farms of the early adopters were likely to influence the others. The most common practice that was adopted (by 80% of those adopting conservation agriculture) was use of cover crops to improve soil fertility, provide soil cover and smother weeds, and the locals used *Dolichos lablab* for food. Planting was mainly by tractor-drawn direct planter, jab planter and machete for those adopters who had no access to modern conservation agriculture tools provided to the group by the CA-SARD project. About 50% of the adopting farmers had developed a mechanism for sharing crop residue between livestock and mulch. Grazing on the harvested crop fields had also reduced by the same level among the same group of farmers. Interest in conservation agriculture technology had increased among those who were not members of the farmer field school but who had seen increased crop yields on their neighbours who had adopted conservation agriculture even in dry seasons when there was complete crop failure on farms using conventional farming practices.

Challenges faced by agriculture farmer field school group members

Not only was the area characterized by harsh climatic conditions unfavourable for agricultural production, it also lacked basic infrastructure such as roads and markets, which made it very difficult for farmers to acquire inputs and sell their produce. To get certified seeds and fertilizer, for instance, a farmer would have to walk long distances to the nearest town. The situation was even worse during the rainy season when prices for the inputs were inflated if they were stocked at the local shopping centres so that when a farmer decided to purchase from the stores, it would be difficult to break even with the yield levels they had been obtaining. For farmers to obtain significant yield using conservation agriculture, they had to plant certified seeds together with the correct quantity of fertilizer and use the right equipment at the right time. Farmers in this area definitely had a difficult task in adopting conservation agriculture, and the fact that the practice did not produce results immediately despite the heavy capital investment meant that the practice would be adopted only by farmers with a solid economic base that would enable them to wait for 1–2 years before the natural dynamics of conservation agriculture took effect.

Equipment promoted by the CA-SARD project was not available in the market, and the few items provided for the group were not enough to serve all the members, especially due to the fact that they all required the equipment at the same time at the beginning of the season. The group had only three jab planters and one tractor-drawn planter. With this amount of equipment, one didn't expect much in terms of automatic replication of the practice, since the tools were not even sufficient to serve the group members alone. Use of herbicides was a problem for farmers in this area due to its high cost, beyond the reach of many farmers, and lack of suitable equipment for applying it. They used a knapsack sprayer in their trial plot but one did not expect an individual to spray a whole hectare with a knapsack sprayer and hope for uniform distribution of chemical since it was tedious and had a high margin of application error.

Small-scale farmer who adopted conservation agriculture

Mrs Esther Muthoni is a small-scale farmer from Lamuria Division. Her household of six people includes her husband, two daughters and two grandchildren. Their parcel of land measures 4.1 ha, most of which she had put under crops and the rest left as grazing field for livestock. She kept local poultry in enclosed cages to control the spread of diseases and to preserve them from being preyed on. She used the poultry droppings as manure on her farm. Due to water scarcity in the area, she had intensified roof water harvesting, which she said was adequate for her domestic water requirements during the entire dry season. She confessed that crop failure was common in the area and she could remember getting a bumper harvest only during the El Niño rains. She had no option other than farming to support her entire household.

Mrs Muthoni began adopting conservation agriculture in February 2005 after joining the Thome Farmer Field School, where she learned its principles. She is a registered member and the treasurer of the group. She said that in the initial stages, her husband was not comfortable with her attending regular meetings with other farmers and even going on trips during farmer-to-farmer exchange visits. She would, however, update him on what they learned in the schools and her experience in the various exchange visits and field days where she and others represented the farmer field school members. This made her husband proud and quite supportive of her initiatives.

Mrs Muthoni and the rest of her household adopted conservation agriculture principles on part of their cropping field. Her two daughters, who had completed high school but were jobless, were not left behind. She said that the practice had created a job for them. Before she heard about conservation agriculture, she used to practise conventional farming where she would plough the land, plant using a machete or jembe and weed either once or twice depending on the intensity of the emerging weeds. She allowed livestock to graze in the crop field after harvest, clearing the entire crop residue and leaving the land bare and exposed. After joining the farmer field school and learning about conservation agriculture, she began by intercropping *Dolichos lablab* with maize under direct planting, using fertilizer through pot-holing, since she did not receive a jab planter from the group in time. She noticed a big improvement in maize yield and for the first time she harvested 40 kg of lablab from 0.41 ha. Lablab seed is a favourite delicacy for her family members. She felt quite encouraged with these results. Even though the maize did not perform as well as she expected, she was confident she was making the right decision to ditch conventional farming for conservation agriculture.

Crop residue was left in the field for the first time after her first conservation agriculture season, and the crops for the second cropping season, with maize at the silking stage at the time the study was undertaken, were doing much better than those of her neighbours, who she said were quite eager to try conservation agriculture on their farms. At the time of the study she was one of the most aggressive adopters of conservation agriculture on a small scale in the division. She said: ‘I work much less in the farm with conservation agriculture than before, yet the yields are good and my family rarely goes hungry.’ She had increased her conservation agriculture plot to 1.23 ha by the time the study team visited her.

It was inspiring that even though she did not own any conservation agriculture equipment, her desire to transform all her farming techniques to conform with conservation agriculture had made her innovative. For instance, because she could not get a jab planter or a no-till tractor planter in time for planting, she decided to plant by pitting using a machete and a hand hoe in the entire 1.23 ha plot and to plant maize and lablab without excessively disturbing the soil. She said at the time she was doing that her neighbours thought that she was crazy, but by the time of the study, she confirmed that the very people who thought that she was mad were asking her for advice on how to start adopting conservation agriculture on their farms.

She was very generous with information and willingly taught her interested neighbours conservation agriculture principles and adoption techniques. Realizing that the Thome Farmer Field School had played a major role in transforming her farming practices, she recommended that her neighbours also join it if they really wanted to exploit conservation agriculture opportunities. She jovially said she hoped that after graduating herself she would eventually become a facilitator and start her own school.

Mrs Muthoni says that the agroecological system analysis she learned in the school, where various factors affecting crops were analysed to find the reasons for failure or success in any activity they undertook, had made her creative and more conscious of farming practices. She learned about various group dynamic techniques, which had enhanced her level of interaction within her family, neighbours and field school colleagues. She said that her relationship with her husband improved as there was enough food in the house and she had more time for the family because she did not need to weed or plough the plot as she did before. In addition, she no longer needed to ask her husband for money as often since she got sufficient income from the sale of *D. lablab*, which fetches USD 1.40 per kg. Her health had also improved since she eats well and has more time to tidy herself. Also her husband started spending more time at home with her.

Through the farmer field school she visited other conservation agriculture farmers in various districts, so she was widely exposed as to how other farmers practise conservation agriculture. She said that such events provided her with an opportunity to share her experience and learn from farmers in other parts of the country. Representing the school, she also had the opportunity to train in farming as a business at Baraka Agricultural College in Nakuru. On her return, she taught her farmer field school colleagues. As a result of the training she started bee-keeping on her farm. Other field school farmers also started bee-keeping and other enterprises based on their training in Baraka College.

Challenges faced in practising conservation agriculture

Some of the challenges Mrs Muthoni has to contend with practising conservation agriculture included:

- unreliable and localized rainfall
- weed management problems
- lack of conservation agriculture equipment
- wild animal invasion of crop fields, especially elephants
- frosts, which were extremely destructive to the crops
- pest and diseases, especially those affecting cover crops

Mrs Muthoni conceded that she continued some practices that were important to her but negated the principles of conservation agriculture, such as cultivating irish potato, which greatly disturbs the soil during harvesting. Irish potato did very well on her farm and formed a key source of income for the household.

She concluded, 'Conservation agriculture has opened my eyes. I see how my life is changing for the better—and it has increased my appetite for *njahi* [*Dolichos lablab*].'

7 Adoption and impact

As indicated in chapter 4 on the history of conservation agriculture, one of the most recent projects to promote conservation agriculture in the district is CA-SARD, which facilitated the establishment of two farmer field school in Lamuria Division. The farmer field school formed units for disseminating conservation agriculture technology among small-scale farmers in the surrounding communities. The project has provided farmer field school members with jab planters, animal-drawn planters and tractor drawn planters, which farmers use for direct seeding at their convenience. Jab planters in particular have been widely accepted owing to their efficiency in applying seeds and fertilizer. The jab planter is also portable and easy to operate. Women in particular are eager to use this easy-to-operate equipment on their farms. With the jab planter one person performs the work that was initially done by three. The labour saved as a result can be used for other economically viable activities such as selling horticultural products and domestic goods at the local shopping centres. Preliminary indicative findings of the study show that agricultural labour is reduced by 30–40% with conservation agriculture. Youth who initially shied away from farming due to its laborious nature are slowly returning to assist their parents, since conservation agriculture requires limited labour despite its enormous returns.

The tractor-drawn planter available for farmer field school members is also being used by other farmers through an elaborate agreement with a tractor hirer who is also a large-scale farmer. Farmers have the choice of using a tractor-mounted direct planter, a jab planter or an animal-drawn direct planter, depending on their land area. The animal-drawn planter is popular only in some areas around Timau, where there are small-scale draught animal and equipment hirers. The farmer field school established by the CA-SARD project had not started using animal-drawn planters for lack of trained draught animals. Table 6 provides an economic analysis of using conservation tillage equipment introduced by RELMA and KENDAT for small-scale farmers in the Timau area.

Maize and lablab are the most common crops promoted through conservation agriculture in the district, but large-scale farmers concentrate on growing wheat and barley under conservation agriculture.

Animal- and human-drawn sprayers were some of the simplest herbicide applicating equipment the CA-SARD project provided to the small-scale farmers through the farmer field school. With the help of a facilitator, members of these groups have trained in applying herbicides using the equipment, safety precautions, and how to calibrate the equipment to attain the required application rates.

Conservation agriculture does not discourage farmers from keeping livestock; it only emphasizes sustainable coexistence that ensures that both livestock and soil remain healthy. Farmers have to strike a balance to reap maximum benefits in both enterprises by allocating a reasonable portion of crop residue for mulch and fodder and avoiding grazing on crop fields. Some large- and medium-scale farmers in the district have managed to strike this balance; however, most small-scale farmers continue feeding all crop residue to their livestock, leaving the crop fields bare and

Table 6. Benefits comparing conservation agriculture tillage operations with conventional farming

Treatments	Net plot size (ha)	Germination rate (%)	Stover weight at harvest (kg/ha)	Grain weight (kg/ha)	Gross margin (KES/ha)
Conventional	0.01	90	3500	700	8343
Ripping	0.01	80	2000	500	3343
Ridging	0.01	80	2000	500	3343
Pick-axing	0.01	85	2800	600	5843

Source: KCTI report 2003

susceptible to environmental degradation. Small-scale conservation agriculture adopters in the district find it difficult to leave crop residue in the fields as they must also protect them from thieves or unauthorized grazing. Some have even managed to strike a balance on how much to bale for fodder and how much to leave as mulch, but this group still numbers few, since many farmers are not aware of conservation agriculture.

Conservation agriculture is probably one of the few viable farming practices if the number of persons relying on government relief food is to decrease. One should not be blind to the fact that small-scale farming in climatic conditions such as those in Laikipia is not easy and requires determination. It is impossible to accurately estimate the extent of adoption of conservation agriculture in the district as it is a new practice that is yet to enter the agricultural extension system at both the district and national levels. Adoption among farmer field school members in the district is impressive, and this could be attributed to the immediate success with lablab, which has continued to perform well in the individual and farmer field school plots. Conservation agriculture adopters have also been able to harvest some maize even with little rainfall while their neighbours succumb to complete crop failure. The success realized by these small-scale adopters has increased adoption among their neighbours who are not members of the schools. A study carried out in the district by the GHARP/KRA project after the 2001 long rains produced the results shown in table 7.

Large-scale conservation agriculture adopters in the district are crop specific. For instance, a field will have either wheat or barley; in some cases such fields are left fallow after harvesting, or a rotational crop such as canola or sorghum is grown. Small-scale farmers, on the other hand, have no specific cropping trend. For instance, one plants maize in one season and follows it immediately with wheat. Except for farmer field school members, hardly any small-scale farmer in the district adopts all the conservation agriculture principles promoted by the CA-SARD project.

Small-scale farmers are also yet to determine which crop between maize and wheat gives higher returns and in particular the difference each makes when grown under conservation agriculture.

Table 7. Yield comparison between conservation agriculture and CT for major crops in Laikipia

Crop type	Crop yield (t/ha)		Yield increase (t/ha)	Percentage increase
	Conservation tillage	Conventional tillage		
Maize (with bean intercrop)	3.3–4.5	1.3––2.2	2.0–2.2	100–150
Wheat	3.3–3.6	1.3–1.8	1.8–2.0	100–150
Potato	12.8	6.4–9.6	3.2–6.4	50–200
Bean (with maize intercrop)	0.6–0.9	0.2–0.4	0.3–0.5	102–155

Source: KRA/GHARP publication (2003): Rainwater harvesting for improved food security

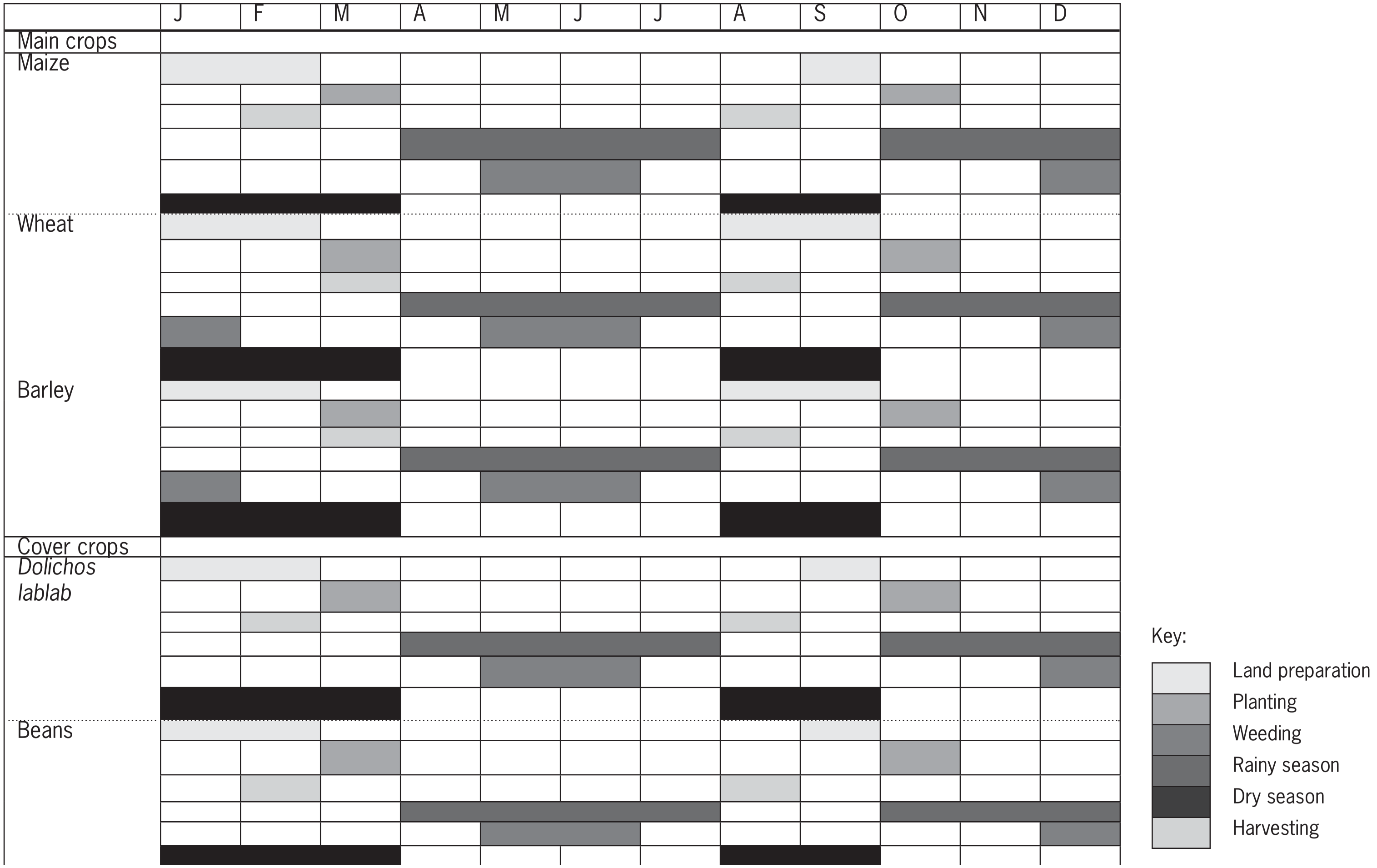
Farmers in Timau grow large volumes of irish potato. This practice is incompatible with conservation agriculture. Farmers in such enterprises have to strike a viable economic and environmental balance to obtain maximum returns from crop production. Table 8 shows the seasonal pattern of major crops grown in the district.

Farmer field days and farmer-to-farmer exchange visits are some of the activities that have exposed conservation agriculture adopters to more exciting practices and experiences. The CA-SARD project has established a link between the small- and large-scale conservation agriculture farmers with the aim of enhancing interaction that would promote conservation agriculture concepts across the entire district. Mr Sessions of Lengetia Farm is an example of a large-scale farmer who is keen to promote conservation agriculture among small-scale farmers, since he believes that it is the only solution for food insecurity in the region.

During farmer field days in the district both large- and small-scale farmers have worked together to ensure their success. All stakeholders in agriculture usually take part on such occasions. Small-scale farmers specifically exploit the opportunity by asking questions on issues they do not understand well; they also showcase their innovations (colour section). The project has also helped farmers visit conservation agriculture farmers in other parts of the country. This presents an opportunity for farmers to share the challenges and the successes of conservation agriculture. Most farmers believe in the potential of conservation agriculture only after seeing it in practice, when they are likely to adopt the practice.

Gender and group dynamics are key pillars that must be addressed for farmer groups to be strong and cohesive. The CA-SARD project has facilitated the training of farmer field school members on gender and group dynamics so that the groups remain cohesive and conscious of how they share positions of responsibilities among members. Such training has enhanced acceptance of gender roles and conservation agriculture promotion since family conflicts have been reduced.

Table 8. Annual seasonal calendar for common crops grown in Laikipia



Based on interviews held and information from participatory rural appraisal and focus group discussion meetings and literature review study

This district is severely affected by HIV and AIDS and death rates are high. The major concern is that young and energetic people, who are needed to work onthe farms, are the worst affected. Conservation agriculture could not have come at a better time, since household labour availability is diminishing. Conservation agriculture is the only farming concept that reduces labour requirements and the amount of energy required. Indeed, even the sick can still plant using jab planters.

The nutritional value for the affected households from increased yields in conservation agriculture plots has the potential of prolonging the lives of people living with HIV and this way helps reduce the numbers of orphans.

8 Gaps and challenges

The study identified several challenges that need to be addressed before conservation agriculture could generate the desired impact in the district, especially among vulnerable farming households.

Gaps in work in the district

Most conservation agriculture work and other related projects such as those on conservation tillage was concentrated at similar sites. In some cases the same groups were used to promote certain technologies. Although this approach could be good for continuity and progression, only a few small-scale farmers benefit. The challenge, therefore, is for new initiatives to venture into new groups that truly need modern farming practices that have the potential of improving their livelihood.

Small-scale farmers residing far from towns or market centres would be willing to adopt conservation agriculture but they do not have access to inputs owing to poor infrastructure; thus they are hindered from trying out the practice. When farm inputs suppliers and manufacturers stay away from small-scale farmers in rural areas, the latter feel that such products are not meant for them, and so they continue with conventional farming. Unavailability of equipment, especially for conservation agriculture, has a negative effect on promotion efforts. Simple equipment such as rippers and subsoilers, which could be fabricated locally by trained artisans, is still not within the reach of many farmers.

With the increasing demand for quality agricultural products, farmers are starting to add value to their produce and to develop marketing strategies to compete effectively with others. Some enterprising small-scale farmers in the district are pursuing this course, but a large number still sell their raw produce, fetching low prices.

General adoption challenges in the district

The biggest challenge lies with small-scale farmers who aren't able to get the farm inputs needed for conservation agriculture. For instance, a sprayer is needed to control weeds without disturbing the soil. The area of land farmed determines the capacity of the sprayer to be used. The larger the amount of land being farmed, the greater the likelihood a farmer will be motivated to invest in equipment to ensure the quality and quantity of the spray. Small-scale farmers do not have options since they can barely afford even a knapsack sprayer. A farmer who cannot afford the equipment for direct seeding may resort to pot-holing. One can imagine how long it would take a poor farmer to make holes in a 1-ha plot. The price of seed, fertilizer and chemicals is so high that farmers hesitate to invest their scarce resources in acquiring them, the yield being because of uncertainty of rainfall.

The unreliability and inadequacy of rainfall and its changing patterns make the adoption of conservation agriculture by small-scale farmers difficult. They use little mulch or not at all. Most smallholder farms in the district are bare.

Rural agricultural extension in the district is spearheaded by the Ministry of Agriculture. NGOs, community-based organizations and various projects supplement these efforts. Most small-scale farmers in rural parts of the district do not have access to any information on modern agricultural practices, since the extension providers tend to concentrate at one place where they are sure the effect of what they are promoting has a high chance of success. These are the sites also where they take visitors who get a good (though false) impression of the project. The situation relegates many poor farming households to perpetual poverty with no alternative but to queue for relief food at the local chief's camp.

Livestock are an integral part of the farming communities in the district and some communities even attach more value to livestock than to crop production. It is common to allow livestock to graze in harvested crop fields. Since pasture is limited, farmers adopting conservation agriculture have to decide whether to abandon this practice or to slash the crop residue and store it for fodder (colour section). They have to strike a balance based on economic evaluation of the choices.

Owing to the small plot sizes in the district, coupled with the fact that these plots also accommodate the homesteads, enterprising farmers usually rent parcels of land from other farmers. Only very infertile parcels of land are available for rent. Adopting conservation agriculture on such pieces of land would definitely improve their quality. The problem is that since hire terms are informal and based on a verbal agreement, the landowner is likely to repossess the piece of land after the conservation agriculture farmer has struggled to improve its quality.

Access to credit among small-scale farmers is difficult since lending institutions consider farming at their level risky. But large-scale farmers in the district get credit from banks and even input suppliers. It therefore takes great sacrifice and determination for small-scale farmers to successfully adopt conservation agriculture on more than 0.82 ha without external financial input.

Managing weeds with minimal soil disturbance is probably one of the biggest agronomic challenges that conservation agriculture adopters in the district have to contend with. While large-scale farmers have chemicals and equipment to deal the weed menace, small-scale farmers lack the capacity to control weeds using modern techniques of herbicide application. They have no choice but to practice conventional weeding or shallow weeding and weed uprooting. The extent to which shallow weeding exposes the soil is beyond the scope of this study. The use of cover crops such as *Dolichos lablab* to smoother weeds is not 100% successful and varies from one agroecological zone to another. For instance, it works well where vegetative growth of the cover crop is good. However, with *D. lablab* promoted in Laikipia, the development of pods is better than that of its vegetative growth.

Crop pests and diseases have been on the increase in the recent past in the district. While large-scale farmers have the capacity to contain any invasion or attack, their small-scale counterparts lack the resources or even the knowledge to counter even minor attacks. One group interviewed by the study team associated the rising cases of pests and diseases on their farms to the neighbouring horticultural farms that use chemicals driving the pest towards their farms. The truth of this is still to be determined. A large-scale farmer also confirmed to the study team that the crop residue left on the farm as mulch forces him to use more chemicals to control pests and diseases than before when the residue was burned. Again, whether this is true or false is a subject for further investigation. Millipede attack, for instance, is a big challenge for small-scale farmers, since the pest consumes the seeds before they germinate and they affect root development. Farmers have developed techniques to counter this involving planting seeds smeared with a mixture of bran and pesticide. The team could not establish the effectiveness of this practice.

General challenges

Laikipia is a vast arid district; therefore promoting a technology such as conservation agriculture in the entire district requires concerted efforts from all stakeholders operating in the district. This collaboration in agricultural development has been lacking, leading to duplicating efforts and creating confusion among farmers, who receive conflicting messages. For instance, if one group is using conservation tillage and the other conservation agriculture in the same region, it is senseless that they do not work together and complement each other. The extension staff from the seed, fertilizer and chemical companies and suppliers do not interact with conservation agriculture promoters except during farmer field days, after which every group goes its own way.

Frontline extension staff of the Ministry of Agriculture have not sufficiently been involved in promoting conservation agriculture, since they have not been trained in it. These people interact with farmers more than do the staff of any project, NGO or community-based organization, and they remain with the farmers when the rest leave. The frontline extension officers in the district still lack suitable means of transport and motivation to enable them to reach many of the farmers and promote conservation agriculture.

Conservation agriculture requires substantial initial investment, which should be recouped after the natural dynamics have balanced out. But this takes time. Smallholder farmers cannot afford to risk adopting a farming practice that requires them to invest much without a guaranteed positive outcome. This makes promoting conservation agriculture difficult, since the farmers expect more than the technical support offers for free. For instance CA-SARD project farmers feel that the project should continue supporting them with grants until they start getting substantial profit from their farms using the new practice. They do not consider adequate the one-time grant to run the participatory demonstrations and the school for two seasons. After that, the farmers are expected to have acquired knowledge to adopt conservation agriculture in their individual plots. Eliminating the dependence on handouts is difficult since the farmers also interact with other projects where they receive farm inputs for both the group activities and their individual plots. To instil a sense of ownership in any technology they should be encouraged to make a personal contribution and not to expect everything handed out. This is the challenge conservation agriculture promoters have to face any time they meet small-scale farmers in groups or individually.

Small-scale farmers are bound by tradition to subdivide land for family members. For instance, a father shares his piece of land among his sons and the sons will do the same when the time comes. In many cases the economic thresholds of such pieces of land have been surpassed and promoting conservation agriculture on such plots makes little economic sense.

The private sector is not involved in promoting conservation agriculture, so it is difficult to link farmers with service providers. For instance, the CA-SARD project is promoting conservation agriculture with equipment from Brazil, but farmers cannot afford to buy such imported equipment directly. The local seed companies are not aware of new equipment such as jab planters so that they could grade the seeds suitable for them. Since farmers cannot afford MP seeds, which are sold in large quantities, they use HP seeds with this equipment, blocking the seed plates.

9 Discussion

Two distinct categories of farmers adopt conservation agriculture in Laikipia. One group is yearning for a technology or a practice for subsistence production while the other group sees the potential to reduce the cost of production, increasing their profit. This category continually looks for recent developments in conservation agriculture. The first group represents small-scale farmers, and the second group large-scale farmers. Are the said adopter farmers really practising conservation agriculture? *FAO Soil Bulletin* no. 78 says, 'The use of no-tillage by itself does not qualify for conservation agriculture. As long as a farmer ploughs for at least one crop within the rotation or does not maintain a permanent soil cover, he does not practice conservation.' While large-scale farmers are close to fulfilling this requirement since they generate high volumes of crop residue from wheat and barley, smallholder farmers who grow maize and often have low yield are far from it. The transformation of small-scale farming to business-oriented farming is not possible among many farmers in the district since their immediate need is food for subsistence before they can consider selling the surplus. The story of the small-scale farmer in Lamuria Division is evidence enough that with conservation agriculture smallholder farmers can generate surplus food for sale, earning income that could improve the livelihood of the household.

Disseminating information promoting uptake of conservation agriculture in the district has not gathered the momentum needed to create the mass awareness that will switch farmers from conventional farming.

Farmers learn from one another more easily than from scientists, researchers and extension agents. Therefore, promoting conservation agriculture through farmer field schools has strengthened peer learning among farmers to the extent that some farmers have found themselves practising conservation agriculture because they want their plots to do better than the rest. Farmer-to-farmer exchange visits and field days have enabled farmers to interact and share experiences. Two farmer field schools in such a vast district are too few to generate impact.

The supply of agricultural labour has gone down considerably with the movement of young and energetic persons to urban centres for greener pastures. The situation has further worsened with the high rate of deaths related to AIDS within the district. Most households are now headed by the elderly, who are unable to do a lot of farm field work. The labour-saving aspect of conservation agriculture is a good entry point for such smallholding farmers. The biggest challenge is changing the farmer's mentality to stop tilling the land.

Equipment use is usually the backbone of any new technology such that without it the practice will not diffuse much among the target group. Availability of conservation agriculture equipment for small-scale farmers in the district is extremely low and or non-existent in the local markets. The short-term solution would be to encourage machine and equipment hirers to understand conservation agriculture requirements and to provide the services to farmers at a cost. The long-term solution would be for local manufacturers to supply the equipment to the markets once sufficient demand is created.

Pests and diseases continue to hit small-scale farmers hard since they cannot afford to rotate crops or use certified seed. Farmer field schools follow the integrated pest management curriculum and it is noteworthy that promoting conservation agriculture has been integrated into this curriculum. Farmers should be encouraged to find alternative means of handling pests and diseases because the cost of the recommended chemicals continues to rise.

Introducing the farmer field school in rural agricultural extension has injected fresh impetus into a field that was slowly losing recognition by its target group owing to its poor performance. It is important to involve farmers in analysing the results of the findings from samples researchers collect from their plots. Many times researchers and scientists take soil and crop samples for analysis but share the reports produced only among themselves, creating a loss of trust by farmers for researchers in general.

10 Conclusions

Will small-scale farmers in Laikipia District adopt conservation agriculture in the future? Success lies in involving both small- and large-scale farmers in formulating strategies and policies for enhancing its principles. All stakeholders need to develop a common platform for promoting sustainable best practices without duplicating efforts, which confuses farmers.

Success in Laikipia District is evident on large farms, and the positive thing about this is that small-scale farmers are starting to realize that conservation agriculture has potential and they are slowly adopting it. Problems with resistant weeds should be researched further to ensure that production is maximized. This will reduce the annual wheat deficit the country now contends with. More efforts are needed to create awareness, especially by establishing conservation agriculture farmer field schools in various regions in the district. The number of such groups so far established by projects promoting conservation agriculture is a good indicator but these are too few for impact. Interaction between small- and large-scale farmers, as seen in the cases studies, should be encouraged to foster sharing of experience on the challenges and benefits of conservation agriculture.

Training of government agricultural extension workers on conservation agriculture should be encouraged to speed up establishment of new farmer field schools. Farmers who have graduated from a field school help facilitate new groups after undergoing training on field school methodologies and conservation agriculture.

Conservation agriculture farmers need to diversify their crops to suit market demand. Targeting high-valued varieties would enable them to fetch better prices. Emphasis has been put on maize and *Dolichos lablab*, giving little attention to other crops that smallholders grow such as kale, cabbage, irish potato and pyrethrum. Conservation agriculture promoters therefore need to let the farmers evaluate and validate the technology using a variety of crops, including traditional types. Cover crops should be diversified to ensure that the varieties selected are suitable for the farmer's agroecological zone.

The recommendation made by KARI through LRNP, which was screening a legume cover group in Matanya area of Lamuria Division, should be considered. *Dolichos lablab*, which is being promoted, could be suitable for the area but there may be other crops that would be better. Efforts by one large-scale farmer (Lengetia farm) to establish trials of several crops using conservation agriculture is a good gesture that should be supported, because recommending a particular crop from such experiments would be more practical and viable for local farmers than bringing a crop from outside and asking farmers to grow it using a new farming practice that they are not familiar with. Many times farmers are involved in participatory on-farm research with scientists and extension agents. They volunteer a lot of information, and samples are even taken from their farms. What happens after that? Scientists write good reports and make recommendations that they share only among themselves, excluding the farmer whose plight they need to address. Promoters of conservation agriculture and other technologies need to make some effort to apply the findings of various consultants to solving farmers' problems, since this is the only way farmers will feel part of the team.

Equipment is an important aspect in technology adaptation and adoption. When a tool is introduced to a farmer along with a technology and it fails, the farmer will blame the technology and not the tool. When a tool is introduced without information on where it can be purchased the farmer will view the technology as research in progress that cannot address his or her immediate need. Inaccessibility, unavailability and the high cost of equipment for conservation agriculture are the biggest hindrances to promoting and adopting the practice among smallholder farmers in the district.

Adoption level in the district is tilted towards large-scale farmers, who can afford to have the equipment tailor-made to their specifications. Promotion of conservation agriculture should therefore involve lobbying equipment manufacturers and importers to manufacture equipment that is affordable and suitable for smallholder farmers, as they do for large-scale farmers. According to FAO (2003), 'Humans and draught animals will continue to be the main source of power for the foreseeable future'. Manufacturers need to take this into account in developing equipment such as the jab planter and animal-drawn direct seeders. Are the manufacturers compelled to do this? The answer is 'no'. These companies are businesses that will produce the equipment only when the demand makes economic sense. Tractor and equipment hirers also need to be involved in promoting conservation agriculture. It would create a good opportunity for expanding their equipment hire business to the smallholder farmers.

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Appendix 1 Laikipia District case study framework

Issues: biophysical, socio-economic and institutional environment

- What are the main features of the agroecological zones under which your case study area falls (climate, vegetation, soil, topography, etc.)?
- What are the key relevant geographical patterns in the region (economic activities, urban centres, basic infrastructure, markets and communication)?
- What are the most relevant socioeconomic and sociocultural characteristics of families and communities, (including HI and AIDS and livelihood-related aspects)?
- What are the main characteristics of the farming systems and cropping systems in the area (crops, rotations, calendar, techniques, source of power, crop–livestock interactions, etc.)?
- What are the main formal and non-formal as well as indigenous or traditional institutions in the region, and how do they affect agriculture?
- To what extent are various community groups, including marginalized groups, represented in the institutions and in decisionmaking?
- What are the legitimacy, credibility and trust of the institutions and how are they widely accepted in the area?

Description of conservation agriculture technologies

This section analyses two types of conservation agriculture technologies: those being promoted or prescribed and those currently under development (through on-station or on-farm experimentation). They need to be compared with current farmer practices and defined specifically for each type of rotation and main crop.

- Which tillage operations are being prescribed under conservation agriculture, if any? How frequent are they?
- What implements are being prescribed under conservation agriculture systems? (specify the source of power).
- What are the prescribed sources of soil cover (slashed vs imported, crop residue, cover crops)? Indicate any competing uses for the biomass used for providing soil cover as well as uses given to cover crop seed (such as market, food or feed).
- How are the farmers notified that the cover be managed (mechanically, chemically, biologically, etc.)?
- What rotation patterns are prescribed under conservation agriculture? For which main crops have conservation agriculture technologies been made available? For which crops are these still missing?
- Are there specific conservation agriculture technologies that are being promoted for specific types of farmers? Explain.
- When are farmers expected to start reaping the first benefits from applying conservation agriculture technologies?
- Have specific entry points and pathways been used for introducing conservation agriculture technologies?

- To what extent do the conservation agriculture technologies being promoted incorporate indigenous knowledge?
- Are there any conservation agriculture technologies that have been abandoned altogether by institutions or projects after being introduced? If yes, for what reasons?

History of work related to conservation agriculture in the selected area

- Which stakeholders (institutions or projects) have been involved in conservation agriculture work? When? And on what aspects have they worked?
- What has been the specific role played over time by the following stakeholders: the private sector, farmers' associations, NGOs and faith-based institutions?
- For each stakeholder, who have been the target groups for conservation agriculture work in the region? What has been the initial motivation (driving force) for introducing conservation agriculture work? Where did the initial conservation agriculture knowledge come from?
- For each stakeholder, which conservation agriculture-related activities have been carried out over time?

Overview of conservation agriculture adaptation and diffusion process

- What have been the main approaches and methods used in adapting, disseminating and scaling up conservation agriculture practices used by the various stakeholders involved in related work? For example, farmer experimentation, training, field days, demonstrations.
- Who has conducted the various adaptation and dissemination tasks and activities? What has been the specific role played by farmers in this process?
- Have the approaches used to disseminate conservation agriculture been adapted (tailored) specifically for different types of farmers (larger or smaller farms, vulnerable heads of households, men or women)? If yes, how?
- Which entry points have been used for introducing conservation agriculture techniques? On what basis have these entry points been identified?
- Have projects or institutions been providing incentives for conservation agriculture adoption? Which ones? At which conditions? For how long? With what result?
- To what extent have the following groups (elders, traditional leaders, the younger generation, large-scale farmers) reacted or responded to conservation agriculture and how did they influence the adoption of conservation agriculture practices by others?
- Have the communities developed or reformulated certain bylaws to favour conservation agriculture?

- Have they received support from institutions or projects for doing so?
- How have institutions or projects involved in conservation agriculture work kept track of changes induced by its adoption?

Conservation agriculture impact and adoption

Agronomic and environmental aspects at the field level

- Have the farmers who adopted conservation agriculture practices observed an effect on any of the following attributes: crop yield, yield stability, planting calendar, weeding calendar?
- What changes did they observe on soil fertility or erosion?
- Has adoption of conservation agriculture led to changes in water quality and availability at the community and watershed level?
- Have the adopted conservation agriculture practices had an impact on biodiversity?
- How have monetary inputs and outputs changed as a result of adopting conservation agriculture?
- How safe have the adopted conservation agriculture technologies been to humans and to the environment, compared with traditional practices?
- Have farmers who adopted conservation agriculture practices modified them compared with what was prescribed? What did they modify? Why? How did they proceed to do it?

Socio-economic and process aspects

- Has the adoption of conservation agriculture practices changed the workload and division or sharing for labour between men and women (also seasonality)? How?
- How do those who adopted conservation agriculture practices (men and women) benefit economically in the process?
- Have the adopted conservation agriculture practices helped families to cope better with adverse situations?
- Has introducing and adopting conservation agriculture changed relationships among farmers within their community or among neighbouring farmers? What has caused the changes, if any?
- How do the landless daily-wage labourers and other marginalized groups benefit from conservation agriculture practices?
- How has conservation agriculture affected female-headed households?
- How did the access to distribution and control of key resources change for smallholder and marginal farmers (men and women) as a result of conservation agriculture adoption?
- Have certain entry points and pathways for conservation agriculture adoption proven more conducive to large-scale adoption than others? Explain.
- Have land tenure systems played a role in adopting conservation agriculture?
- Have certain government policies influenced conservation agriculture

adoption (positively or negatively)? Which ones and how?

- How did farmers who adopted the practices modify them? How did they bridge the missing support?
- Have some of the conservation agriculture technologies 'spontaneously' been adopted by some farmers? Which ones? Why have they met success?

Present gaps and challenges in conservation agriculture work in the region or project

- What were the enabling and hindering factors in achieving economic and financial viability? What are the main challenges?
- What are the main reasons for the observed impacts or lack of them (internal and external factors)? What are the main challenges?
- What are the enabling and hindering factors in achieving social and cultural acceptance? What are the main challenges and the way forward?
- What are the enabling and hindering factors (internal and external) for the most relevant of the institution's scaling-up activities?

Key issues

Weed control in conservation agriculture

- How have weed control methods changed as the result of introducing conservation agriculture?
- What has been the effect of introducing conservation agriculture on weed pressure? Are there weeds that have proved more difficult to control under conservation agriculture? Which ones? And why?
- Have conservation agriculture techniques been an effective weed control mechanism compared with other techniques?
- Has good weed control been possible under conservation agriculture without use of herbicides? Will this be an option in the future?
- Gender and weed control issues

Conservation agriculture and inputs (implements, cover crop seeds, herbicides, training, technical advice, etc.)

- Have the inputs necessary for adopting conservation agriculture been accessible to farmers in the region? Under which conditions? At what prices? For which power sources?
- Have farmers been able to undertake the investments necessary to equip themselves with conservation agriculture implements?

Conservation agriculture versus labour issues

- What has been the effect of conservation agriculture practices on labour intensity, distribution and arrangements (family labour: women, children, etc)?
- How has applying conservation agriculture practices affected the cropping calendar flexibility?

- What has been the effect of using conservation agriculture implements on labour requirements?

Biomass management

- Is the availability of biomass enough to keep the soil covered at critical stages?
- Have farmers been able to keep the soil cover in the context of bush fires, termites, roaming herds, sweeping winds?
- How has the biomass been managed between soil cover and livestock needs?
- Are any practices, beliefs, rules or recommendations in conflict with the objective of maintaining the soil covered?

Suitability of conservation agriculture under different biophysical conditions

- Are there soil types and conditions or topographies in which conservation agriculture practices have not been adapted or not been successful? If yes, which?
- Are there crops for which no conservation agriculture technologies have been developed?

Appendix 2

Persons and groups met during the study

Name	Organization/ company	Position/ responsibility	Location
	Wangu Investments	crops manager/ officer	Central
Angaine	Medium-scale farmer	farm manager	Central
Martin Dyer	Kisima farm	farm manager	Timau
Wilson Kamau	Bayer East Africa	sales representative	Laikipia District
Angus Ker	Lachlan Kenya	sales and marketing manager	Laikipia District
Timothy Kinuthia	Monsanto	sales representative	Mt Kenya region
J. Mureithi	Legume Research Network	coordinator	Nairobi
Muriuki	Small-scale farmer	draught animal and equipment hirer	Central
Ndirangu	Ministry of Agriculture	extension officer	Laikipia District
Lowrie Sessions	Lengetia farm	chief executive officer	Lamuria
Wachira	Ministry of Agriculture	district agricultural officer	Laikipia District
Wachira		DIRC officer	Laikipia District
Paul Wamai	CA-SARD project	farmer field school facilitator	Lamuria
John Wanjau	FarmChem Kenya Ltd	sales representative	Laikipia District

Farmer groups met during the study

Name of the group	Location	Attendance
Birisha Farmer Field School	Lamuria	46
Dume Soil Conservation Self-Help Group	Central	20
Nyela Farmer Field School	Lamuria/Nyeri (located at the border of Nyeri and Laikipia)	11
Thome Farmer Field School	Lamuria	26

Siaya District

Philip K. Mwangi, Kennedy O. Okelo, Tom Apina

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Abbreviations

CA	conservation agriculture
CDF	Constituency Development Fund
CIRAD	Centre de Corporation International en Researcher Agronomique pour le Développement
FAO	Food and Agriculture Organization of the United Nations
GDP	gross domestic product
ICIPE	International Centre for Insect Physiology and Ecology
ICRAF	International Centre for Research in Agroforestry
KARI	Kenya Agricultural Research Institute
KES	Kenya shilling, in this booklet, valued at 72 to USD 1
MDG	Millennium Development Goals
NGO	non-governmental organization
Sida	Swedish International Development Cooperation Agency
SLM	sustainable land management
USD	US dollar

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Executive summary

Conservation agriculture, frequently cited as a solution to food insecurity in arid and semi-arid regions, is based on three core principles: minimum soil disturbance, permanent soil cover, and crop rotations and associations. Its suitability in sub-Saharan Africa has yet to be examined from technical, economic and social perspectives. The interest in fostering conservation agriculture in Siaya District stems from its potential to address problems straining small-scale farmers in the region:

- *Food security*. Conservation agriculture can potentially contribute to household food security by using rainwater more efficiently and increasing soil fertility by introducing nitrogen-fixing cover crops, such as lablab and mucuna.
- *Demand of household labour*. HIV, AIDS and other diseases such as malaria, and rural migration to towns are reducing available labour in the households and increasing the labour burden on women and children. Conservation agriculture could reduce the labour required for preparing land, weeding and harvesting.
- *Household income*. Conservation agriculture could possibly reduce the cost to hire farm power services and buy fertilizer, while generating additional revenue by producing cash crops and providing time to engage in other businesses.

The study highlights Siaya District's characteristics and farming family activities, mainly crop production, livestock production and fishing. Draught animals are the main agricultural power source; it is cheaper than tractor power. District infrastructure is not well developed. The district has a network of earth and murram roads, which are inaccessible during rainy seasons, hindering transportation. Telecommunication and piped water are also inadequate and available only in urban centres. Most of the district dos not have electricity.

Over the years, rainfall has changed and in most of the country it is not adequate to support crops. There is a need to conserve the rainfall within the soil. Conservation agriculture has a solution for this. The conservation agriculture technology is geared towards replenishing soils, conserving water and assuring farmers their soils will produce for them and future generations. Convincing farmers to stop ploughing is a big challenge. Some farmers will plough even when they have no weed problem. They remove crop residue either to have a clean seedbed or to feed their livestock. Farmers are always challenged to cover their soil. *Dolichos lablab* is a legume cover crop farmers have adopted. Weeds are still a threat to crop production because they compete with crops and reduce crop yields.

Conservation agriculture in Siaya had seen several uncoordinated interventions in wide-ranging but piece-meal approaches. Farmers looked to new farming practices to compensate for the scourge of HIV/AIDS and other ills, like tripanosomiasis, which killed draught animals. Many organizations and institutions have been involved in conservation agriculture: the Food and Agriculture Organization of the United Nations (FAO), the World Agroforestry Centre (ICRAF), the Kenya Agricultural Research Institute (KARI), the Technical Cooperation Programme, Farming in Tsetse Controlled Areas (FITCA), the International Centre for Insect Physiology and Ecology (ICIPE) and the Consortium for Scaling-Up Options for Farm Productivity. FAO had two projects, the Technical Cooperation Programme and Conservation Agriculture and Sustainable Agriculture and Rural Development, which promoted the three principles of conservation agriculture. ICRAF promoted improved fallows in agroforestry. FITCA promoted draught animals in farming and collaborated with the Kenya Network for Draught Animal Technology (KENDAT) and Triple W Engineering on draught animal technology. Farming in Tsetse controlled Areas introduced legume cover crops such as mucuna and canavallia. They collaborated with Monsanto and Bayer East Africa to promote weed control using herbicides. ICIPE and KARI were involved in controlling striga weed and stem borer and improving soil fertility using push-pull technology. The Consortium for Scaling-Up Options for Farm Productivity was an umbrella body mandated to scale up conservation agriculture in the district in the 1990s.

Conservation agriculture is a set of principles that can be adapted to suit the local conditions. Farmer understanding of conservation agriculture are described. Methods promoting conservation agriculture in the district include farmer field schools, demonstrations, farmer extension, field days and exchange visits.

Siaya has challenges of traditional behaviour and practice that often hinder agricultural growth. Grazing on crop residue and planting schedules where the elder must plant first affects agricultural performance. Though conservation agriculture was equipment limited, some farmers, especially farmer field school members, adopted conservation agriculture and no longer ploughed their land but planted directly by using hand hoes and direct planters such as jab planters and animal-drawn mulch planters. A hire system using an animal-drawn mulch planter was developed. There was high demand for direct-planting equipment even from non-field school members. Direct planting converted farmers to conservation agriculture. Farmers who adopted cover cropping with lablab benefited with improved soil fertility and reduced weed population in one season.

Conservation agriculture had some successes. Failures came from missing links between farmers and service providers. Trained conservation agriculture personnel were few and could not help all the district farmers. Suggestions to promote conservation agriculture were made to spread conservation agriculture and reach all farmers.

1 Introduction

The Kenyan economy is dominated by smallholder, low-revenue agriculture and small-scale livestock management. Tourism is also an important income source because it brings in foreign currency. Poverty is prevalent in the rural population; most depend on natural resources for their livelihoods.

Siaya has large tracts of idle, fertile and high0potential land. About 120,000 farm families, 80% of the district population, engage in crop and livestock production and are important in developing the district. The district's poverty stands at 58%. (Siaya District Development Plan 2002–2008).

Conservation agriculture was introduced in Siaya in several uncoordinated interventions using wide-ranging, but piece-meal technology. High rainfall goes underused where traditional farming practice is the norm. Growth in agriculture and improved rural income reduces overall poverty. Agriculture provides raw materials to manufacturing and indirectly stimulates growth in non-farm income and employment (SRA 2004–2014).

Conservation agriculture is probably the only way to go if food security in Siaya District is to be addressed in totality. The district is rated as one of the poorest in the country. Its contribution to the national poverty stands at 1.85% (Siaya Development Plan 2002-2008).

This study gives a brief background of Siaya District and its cultural and economic trends and how they affect livelihood. It looks at conservation agriculture in the district, the work done, the entry points, the adoption, the adaptation and its future.

2 Characteristics of Siaya District

Physical

Siaya is one of the districts in the central part of Nyanza Province of Kenya (fig. 1).

Siaya District is bordered by Busia District to the north-west, Vihiga and Butere-Mumias to the north, Bondo District on the south and Kisumu District to the east. The district area is about 1520 km^2 between latitude 0º 26º to 0º 18º north and longitude 33° 58º east and 34º 33º west. The equator passes through the southern part of the district at the border with Bondo District.

Administrative boundaries. Siaya is divided into seven administrative divisions: Boro, Karemo, Ugunja, Ukwala, Uranga, Wagai and Yala. These divisions are divided into 30 locations and 128 sublocations. See table 1.

Features and topography

The district has several natural features, including Lake Victoria in the south-west and Lake Kanyaboli (Ox Bow Lake) in the south central. Several permanent rivers that form part of the Lake Victoria catchment flow through it. These include the

Figure 1. Map of Siaya District, Kenya.

Table 1. Area and administrative units

Divisions	Area (km²)	Location	Sublocation
Boro	180.1	3	12
Karemo	235.1	4	17
Ugunja	198.8	5	21
Ukwala	319.5	6	28
Uranga	183.4	3	13
Wagai	193.3	5	18
Yala	209.8	4	19
Total	1520.0	30	128

Source: District commissioner office, Siaya 2001

Nzoia and Yala, which originate from the Cherangani Hills in Rift Valley Province and drain into Lake Victoria. Several tributaries join these two major rivers, including the Wuoroya, Sese, Fuludhi and Wadhbar.

The south-western part of the district, with Lake Kanyaboli, is fairly flat and associated with flooding. The central and eastern parts are mostly undulating and hilly. The district rises from 1140 m above sea level in the eastern part to 1400 m in the west.

Climate

The district experiences bimodal rainfall. Its topography and climate have great influence on the amount and distribution of rainfall, which ranges between 900 and 2000 mm annually (fig. 2). Rainfall, especially in the eastern part, is bimodal. The western part, stretching towards Bondo District, is drier from August to March, while the entire district is dry from December to March. The eastern part has high rainfall throughout the year. The eastern part and neighbouring regions receive 1400 mm average annual rainfall, while the other parts of the district receive 1100 mm (fig. 3). The long rains fall between March and June, with the peak in April and May. The short rains occur between August and November and are usually accompanied by hailstorms. Usually 60% of the rainfall in both seasons is available at planting time.

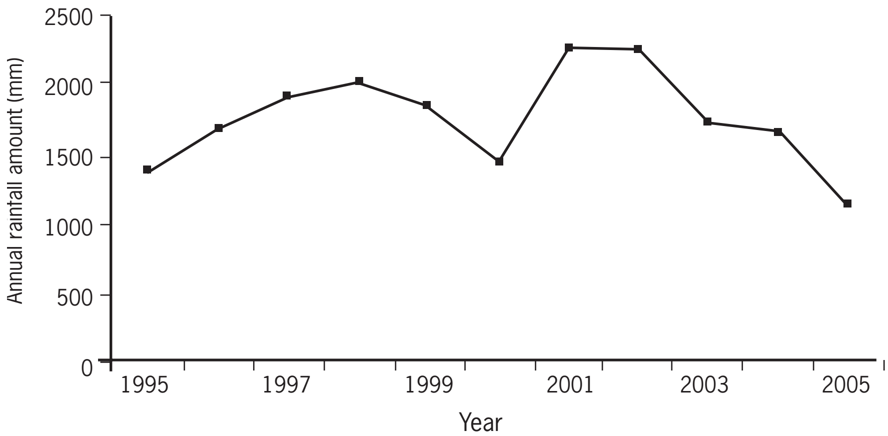

Figure 2. Annual rainfall 1995–2005 (Ministry of Water Resource Development, Siaya 2006)

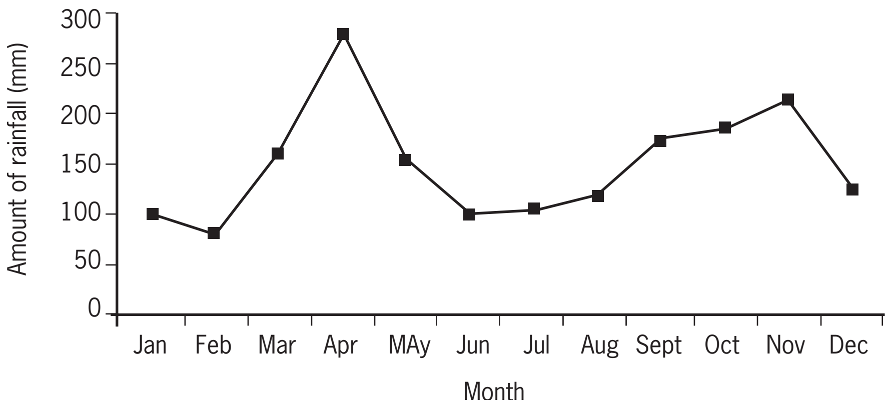

Figure 3. Average monthly rainfall 1995–2005 (Ministry of Water Resource Development, Siaya 2006).

Temperatures within the district vary with altitude. The mean annual temperature is 21.75 ºC. The humidity is relatively high, with mean evaporation rate ranging between 1800 mm and 2000 mm annually, somewhat higher than the rainfall received in most district areas. The district is hotter in March and September during the equinoxes, when the sun is on the equator.

Siaya contains four agroecological zones. Table 2 presents these zones in the district and the most prominent farming systems used in them.

Table 2. Main agroecological zones for Siaya District

Climate zone	Altitude (m)	Annual rainfall (mm)	Regions within the district
UM1	1500–1800	1800–2000	Ulumbi and Marenyo (Yala Division)
LM1	1300–1500	1800–2000	East, Central and North Gem, Ugunja, Boro and Ukwala Divisions
LM2	1200–1350	900–1500	South Gem, Boro, North Ukwala, Uranga Division
LM3	1140–1250	800–1400	Boro, Lower Ukwala, Uranga

UM – upper midland, LM – lower midland

Lake Victoria, on the south-western side of the district, greatly affects the physical features and climate in Siaya. At night, humidity is high because of the land breeze. The temperature around the lake region is about 22.5ºC throughout the year, influencing vegetation growth. The rate of evapotranspiration is high in the regions around the lake, limiting soil water available for plants. Lake Victoria and Lake Kanyaboli and their catchments provide habitat for many plant and animal species. The lakes are a good resource for fishing income.

Soil type and fertility

Soil fertility in the district ranges from moderate to low. Fertilizer is essential on most soils for any meaningful yield. The main soil type is Ferrasols. Most areas have underlying plinthite 'murram' with poor moisture retention. The north-western parts have sandy Ferrasols with underlying heavy murram.

A wide range of food and cash crops, including vegetables, are grown in the district. Cotton, coffee, sugar cane and tobacco are the main cash crops. Horticultural vegetables are partly grown under irrigation, while bananas are rainfed and considered a security subsistence crop and a cash crop. Root crops such as cassava and sweet potato are widely grown as security crops.

Livestock in the district is mainly local breeds. However, a growing number of initiatives support upgrading the local zebu cattle and commercial poultry production. Dairy breeds are also being introduced into the district.

People and settlements

The people

The district is predominantly occupied by the Luo community, with traces of the Manyala community, a subtribe of the Abaluhya. Traditionally, the men were pastoralists and fishermen, while crop production was marginal and mainly left to women. However, this has greatly changed; crop production has become the main economic activity for most households.

Settlement patterns

Settlement patterns in the district follow the agroecological zones, with high-potential areas having the highest population density. Most of the population are rural poor with limited access to basic needs. Siaya has 493,326 people: 227,044 males and 266,282 females. The most densely populated division is Yala with 410 persons/km^2 and the least densely populated is Uranga Division with 233 persons/km^2 (table 3). The population is expected to rise to 520,697 people by 2008 (Siaya District Development Plan 2002–2008).

Table 3. Estimated population distribution by division and density

Division	Area (km^2)	Density (no./ km^2)
Boro	180.1	270
Karemo	235.1	336
Ugunja	198.8	398
Ukwala	319.5	318
Uranga	183.4	233
Wagai	193.3	289
Yala	209.8	410
Total area/ average density	1520.0	325

Source: District statistics office, Siaya 2001

Poverty in Siaya

Poverty has been increasing over the years, from 41% in 1984 to 58% in 2001 (Siaya District Development Plan 2002–2008). The high incidence of HIV and AIDS has resulted in many children being orphaned and many families spending a lot of their cash and time caring for sick relatives. HIV prevalence has steadily increased and now stands at 38.4%. This has resulted in a high mortality rate, especially among the labour force, and contributed to a low, 0.9%, annual population growth (Siaya District Development Plan 2002–2008).

Poverty is worse in the Boro, Lower Ukwala, Uranga and Karemo Divisions, which have low rainfall and poor soils. This means that more than half of the district's population is poor. It is less in divisions with fertile soil and good climate, such as Yala, Ukwala and Ugunja. The causes of increased poverty are diverse: poor soils leading to low yields, reliance on traditional agriculture methods, unpredictable rainfall, high death rate from HIV and AIDS, collapse of the main district cash crops, lack of industry, and deleterious cultural beliefs and practices.

Socio-economic characteristics of families and the community

Crop production has, for most households, overtaken fishing and livestock farming as the key economic activity. The present land-tenure system limits livestock movement and grazing space. Fishing income around the lake has shrunk because of increased water pollution, overfishing and poor fishing techniques, leading to the fish depletion from both Lake Victoria and Lake Kanyaboli.

One hundred twenty thousand farm families, 80% of the district's population, engage in crop and livestock production. In addition, 60% of the household income comes from agriculture and rural self-employment activities (Siaya District Development Plan 2002–2008). Overcultivation, monoculture and poor land management have increased pressure on land.

Most farmers practise conventional farming and prepare the land by ploughing with an ox-drawn mouldboard plough or digging with hoes. Planting is mainly by broadcasting, then ploughing under. Weeding is by hoeing. On average only 2 farmers out of 10 practise crop rotation and fallow systems. Few avoid monoculture. Some farmers grow a maize, sorghum and bean intercrop, while other farmers intercrop cowpea with maize or plant it as pure stand. The crop provides soil cover and fixes nitrogen. Cowpea farming deters livestock from grazing on the farm, even after harvest, because cowpea is known to be a delicacy and is high valued. A heavy penalty is imposed on a person who grazes livestock in a field planted with cowpea.

Most households in the district grow sweet potato on tiered ridges that help collect water, while the sweet potato leaves provide cover and conserve moisture. Fields for sweet potato are usually left fallow to reduce infestation by potato weevils. Farmers also grow pumpkin on sloping areas to reduce the rate of runoff. The leaves cover the soil to conserve moisture and the fruits are used as vegetables. Cereals have always been the rotation crop after pumpkin.

Traditional farming practice, *nyalgonglo*, planting without ploughing, is used where labour is limited and planting time running out. This practice enhanced local water harvesting and minimizes soil disturbance. Farmers on horticultural farms use thatching grass from abandoned houses as mulch during dry spells to conserve soil moisture. The mulch also provides soot, acting as an insect repellent. Using thatching grass as mulch has declined as most people build houses with iron sheet roofing. Basins are used in banana plantations to harvest water and to accumulate fertile topsoil from runoff. Farmers use a special hand hoe, a *khasiri*, for shallow weeding, especially during a dry spell. These agricultural practices are some of the interventions farmers have developed to counter the declining crop yields. Farmers have practised some conservation agriculture, such as cover crops and crop rotation, without external involvement.

However, some traditional practices in the district have a negative effect on agricultural development. For instance, in the setup of an extended family living in one homestead, the oldest household has to prepare land, plant, weed and harvest first, before any other member of that family can follow suit. This practice deprives other family members who farm as their only livelihood from performing such activities in time to use the seasons effectively. Conflict between crop and livestock is a major threat to agricultural development; livestock are permitted to graze freely on harvested fields, which increases soil degradation.

Generally, modern agricultural practices, such as applying fertilizer and using good certified seed, have not been adopted by most farmers. Crops are mainly for subsistence, with little finding its way into local and wider markets. Work in the fields is mainly done by women and children. Men are usually responsible for clearing land, ploughing with an ox plough and marketing produce. Women and children do most of the planting, weeding, harvesting and processing.

Land use in the district

Land use in Siaya may be divided into pasture or crops. Land consolidation was never carried out any divisions except Yala and Ukwala. This means that most farmers have several pieces of land scattered all over. Fencing all these pieces is difficult. Pastureland may be grazed by any animal. The right to cultivate a crop lies with the landowner. Similarly, perennial trees found on pastureland belong to the owners. In Yala and Ukwala, land was consolidated so each farmer has all the pieces around the homestead. Communal grazing is restricted. Often one has to pay to graze cattle on another farmer's land. This system provides farmers with better control to manage their land (Siaya District Socio-cultural Profile Report 1987). Table 4 give details of agricultural practices in the district, and table 5 classifies families by wealth indicators.

Land tenure in Siaya

Land ownership in Siaya is strongly based on paternal kinship. The land is owned by the male head of the household. Land inheritance is from father to son. Where there is no son, the next closest male relative takes over. A woman has no right to land at her place of birth. Upon marriage, she is assigned a piece of land by her husband to cultivate and to be inherited by her sons. Unmarried sons have a right to inherit their mothers' assigned land. As long as the father lives, a son cannot claim any ownership until he is married. In a polygamous home, the male head of the household may sometimes shift pieces of land from one wife to a newly married son of another wife or to his own newly married wife. However, once he dies the pieces of land held by the various wives stay with them and each wife can assign various pieces of land to her sons. A wife does not have disposal rights. When she does not have sons of her own or her sons have not come of age, a male relative of her late husband can restrain her from selling the land or disposing of it for whatever reason. Traditionally, women are not involved in making decisions regarding land disposal. However with the introduction of title deeds, land gets more personalized and a widow may assume the rights to dispose of land belonging to her deceased husband.

Farming systems and agricultural production

Crop production

Crop production is the most important agricultural activity in the area. Principal crops include cereals, legumes, vegetables, oils, fibres, roots, fruits, sugar cane, tobacco, cotton and coffee.

Cereal and root crops. Maize and sorghum are the major cereals crops. Both are used to make the popular cereal dish *ugali*, the staple food in the district. Fresh green maize may also be eaten, either boiled or roasted. In order of importance, beans, cowpea and green grams are the main green legume crops. Many local varieties are commonly grown, intercropped with maize and sorghum. The only other legume crop found in Siaya is pigeon pea, but it is rarely grown as a field crop. Rather it may be found along fences and hedges. It rarely appears in the local diet. Groundnut is the most important oil crop. It is grown usually as a monoculture or mixed with maize. While yields are low, groundnut is one of the area's most profitable crops. Cassava, the major root crop, is found in all the Siaya divisions, but it does not do well in poorly drained black cotton soils. Its drought-resistant properties enable it to flourish in less fertile soils, as long as they are well drained.

Cassava is commonly regarded as the famine crop, providing starch during periods

Table 4. District agriculture fact sheet

Agriculture	
Average farm size	1.05 ha
Main food crops	maize, sorghum, beans, cassava, sweet potato, vegetables
Main cash crops	sugar cane, cotton, robusta coffee, arabica coffee
Total acreage under food crops	71,229 ha
Total acreage under cash crops	1,500 ha
Main storage facilities (on and off farm)	houses, granaries, cereal stores
Population working in agriculture	120,000 families
Main livestock types	local zebu cattle, dairy cattle, sheep, goats, bees
Carrying capacity of the land	cattle: 4 acres/livestock unit (free grazing); 1 acre/livestock unit (zero grazing)
Main species of fish catch	tilapia (*ngege*), catfish (*mumi*), *Protopterus acthipus* (*kamongo*), *Haplochomis* spp. (*fulu*)
Fish farmers (no.)	163
Fish ponds (no.)	227
Gazetted forests (no.)	none
Non-gazetted forests (size)	463 ha
Main forest products	timber
People in wood products (sawmills, furniture works)	35%

Source: Siaya District Development Plan 2002–2008

of low grain yields. Some farmers peel and cut the cassava into small pieces, dry it, mix it with sorghum and maize, and then mill it to make flour for *ugali*. Sweet potato, although seldom grown, is boiled and eaten with tea. Subsistence cereals and root crops are grown for family consumption. Some households sell the surplus to meet other family needs.

Horticultural crops. Horticultural crops are also getting prominence in various parts of the district owing to emerging markets in Luanda, Kisumu and Bondo. Such crops include tomato, cabbage, kale, soybean, onion, bird's eye chilli and watermelon. Farmers use both rainfed and bucket irrigation, depending on the market and timing. Vegetables are usually planted in the backyard for household use. Kale, commonly known as *sukuma wiki*, has become the most popular vegetable in Siaya, even though it is not indigenous. Other vegetables include cowpeas, *Crotalaria* spp, S*olanum nigrum, Gynandropis gynandra,* commelina and amaranths. Large-scale fruit production does not occur in Siaya. One or two fruit trees, such as mango, orange, lemon, lime, guava and banana are frequently found by a home. Bananas are the most common. Other fruit crops, such as pineapple and papaya, are also grown.

Table 5. Classification of families by wealth indicators

Indicator	Groups					
	1	2	3	4	5	6
Farm size	at least 1 ha (2 acres); own other land	0.6 ha (1.5 acres); hire land	0.3 ha (0.8 acre); does not hire land	<0.2 ha (<0.5 acre)	<0.2 ha (<0.4 acre); rent out land	<0.2 ha (<0.4 acre)
Cattle	at least 3 grades or crosses	at least 3 crosses or no zebus	1–2 zebus	1–2 zebus	some own 1 zebu	no cattle
Soil fertility	fertile soil. use a lot of manure	fertile soil. some buy manure	declining soil fertility	declining soil fertility	declining soil fertility	declining soil fertility
Farm inputs	buy fertilizers, certified seeds and pesticides	some buy fertilizers, certified seeds and pesticides (75%)	some buy fertilizers, certified seeds and pesticides	do not use fertilizers and pesticides. some use certified seeds	do not use farm inputs	do not buy farm inputs
Income source	good income from other sources	income from formal employ-ment and pension	artisans and local brew	local brew and provide labour for pay	provide labour	inactive in all ways
Education	educate their children in high-cost schools	children up to form 4	most form 4	std 4	up to std 4	up to or less than std 4
Labour	at least 2 permanent employees	1–2 permanent employees	provide own labour and hire out labour	provide own labour and hire out labour	provide own labour and hire out labour	provide own labour and hire out labour
Age	45–65 years	45–60 years	30–50 years	50–70 years	>65 years	

(Source: Department of Statistics 2001)

Sugar cane. Sugar cane is mostly grown for milled sugar and jaggery and to chew raw. The crop yields an average of 35 tonne/ha without fertilizer and 40–45 tonnes/ha annually with fertilizer and improved farm practices. In parts of northern Yala and Ukwala it is often grown in large commercial units for sale to sugar or jaggery millers. It is grown in the rest of the district on a small scale. Sugar cane is considered one of the leading security crops available to farmers in the sugar belt and it is one of the best in financial returns.

There are four main jaggery factories in the district with an average cane crushing of 30 tonnes each day.

Cotton. Fibre crops in the district are cotton and sisal. Cotton is a drought-resistant crop and can do well in poor soils. This probably explains why it is popular in low-potential areas, such as Boro, and less popular in high-potential areas, such as Yala. Sisal is grown all over Siaya, mainly as hedges on farm boundaries. The crop is mainly used locally to make ropes to tether animals. Siaya District has been a cotton-growing area. In the early 1970s, the cotton ginnery at Ndere in Boro Division was vibrant and served the greater Siaya District, which included the current Bondo and Busia Districts. However, from the early 1990s demand for cotton declined in both local and export markets. The textile industry declined because sale of new clothes dropped when people instead bought *mitumba*, used clothes, which were getting popular at the time. Many farmers in Siaya abandoned cotton and ventured into other crops.

Concerted efforts by different stakeholders, led by Ministry of Agriculture, have been persuading farmers back into cotton farming as part of the strategy to alleviate poverty in the district. Since 2001, the district has been increasing its cotton production. The two ginneries in the district, at Ndere and Ugenya, are back in operation. The local cotton farmers are trying to meet the demand created by the two companies. The Alego Usonga Cotton Farmers Society was being formed to lobby for district cotton farmers in production and marketing of their cotton.

Tobacco. Another cash crop taking root in the district since 1996 is tobacco, which is being promoted by British American Tobacco through the constituency development office. This office was set up using the Constituency Development Fund (CDF) to identify community needs, following the introduction of the fund through an act of the parliament in 2003. Tobacco is currently grown in substantial quantities in all the divisions in the district. Tobacco growing came with the opportunity to raise tree nurseries in all the sites, which has reinforced a district reforestation programme.

Coffee. Some district farmers have ventured into coffee farming, and there are 10 ha of arabica coffee and 170 ha of robusta coffee. However, due to poor payments to farmers through the Boro Coffee Farmers Society, coffee conditions in the fields are deteriorating and hectares reducing annually. The district had two coffee factories, at Sirunga and Yala. They have since closed down. Farmers still growing coffee are forced to take their harvest to either Busia or Kakamega Districts for husking and drying. However, the Kenya Planters Cooperative Union (KPCU) in collaboration with the Siaya Farmers Training Centre have developed a way to upgrade robusta coffee to arabica, which yields better and fetches a good price for its high quality.

Crop calendar

Figure 4 is a seasonal calendar for Siaya District for selected crops.

J	F	M	A	M	J	J	A	S	O	N	D
H					H						H
LP			W				LP		W		
		P						P			

LP = Land preparation; H = Harvesting; W = Weeding; P= Planting

Figure 4. Seasonal calendar for maize, sorghum, millet and beans (source: participatory rural appraisal interviews; Tumaini and Mariwa farmer field schools).

Livestock production

Major livestock kept in the district are cows, sheep and goats. Livestock trade is traditional. Many farmers in the district keep livestock both for domestic purposes and for business. It is common practice for the community to use livestock as security during recurrent droughts. Problems are

- lack of reliable markets
- high cost of inputs and services
- insecurity
- lack of processing facilities
- lack of good quality breeding stock

Fishing

Great opportunities exist for fishing in the district. The communities around both Lake Victoria and Lake Kanyaboli do fishing. In Lake Kanyaboli fishing *dwela* has gained popularity, while in Lake Victoria tilapia and nile perch are the popular catches. Fishing from both lakes drastically declined when most households turned to crop production. Strategies to rehabilitate Yala Fish Farm to provide fingerlings and regularly restock Lake Kanyaboli fish have been put in place by the district Ministry of Livestock and Fisheries Development.

Sources of farm power

Draught animals, particularly oxen, are the main power source for agriculture. Oxen are trained to plough, plough plant or harrow, and weed with the plough. The prevailing poverty in the district makes it difficult for farmers to afford a tractor. In an attempt to overcome this problem, the government, through the Rural Technology Development Centre, tried to make tractors available for hire through the Tractor Hire Scheme. However, this scheme was dogged with numerous problems, including poor management and uncoordinated maintenance and repair services. The government is currently reviewing the scheme to address these problems. Animal power is much cheaper than tractor power and is available for hire in Siaya. Table 6 shows rates for hiring farm power in seven Siaya divisions. Animal power for hire is usually available within divisions and locations. Tractors for hire, from the Rural

Technology Development Centre, the Siaya County Council Livestock Department, the Constituency Development Fund and individual farmers, are located in Siaya town, in Karemo Division. The cost of tractor power depends on the distance the tractor must travel, while the cost of animal power depends on the agricultural potential of the division or location. The rate for tractor power for divisions outside Karemo is calculated by subtracting 25 km from the actual distance, then multiplying the difference by the cost of fuel per litre and adding the calculation to the constant Karemo rate, KES 2000 per acre (0.4 ha).

Table 6. Rates for hiring animal and tractor power (1 acre = 0.4 ha)

Division	Distance from Karemo (km)	Amount				
		Animal power (KES/acre)		Tractor power (KES/acre)		
		1st plough	2nd plough	Weeding	1st plough	2nd plough
Yala	60	1500	1000	800	4100	3700
Wagai	40	1500	1000	—	2900	2500
Ugunja	40	1500	1000	800	2900	2500
Ukwala	70	1500	1100	800	4700	4300
Boro	32	1500	1200	—	2420	2020
Karemo	25	1500	1000	800	2000	1600
Uranga	40	1500	1200	—	2900	2500

Source: Rural Technology Development Centre, Siaya)

at exchange rate of KES (Kenya shilling 72 = US dollar 1

no figures available for harrowing with animal power; — no figures available

In all divisions, ploughing virgin land with an ox-drawn plough costs KES 2000 per acre and the farmer has to prepare tea and lunch for the operator, which is an added cost.

Innovation and entrepreneurship

The declining agricultural productivity in the country has not spared Siaya District. Most traditional cash crops, such as cotton and sugar cane, have been abandoned because of poor infrastructure and weak institutional capacity. Farmers have diversified to generate income for their families. Most farmers work on the farm in the morning and in the afternoon attend to other enterprises. They sell vegetables, cereals, livestock and a wide range of merchandise. Some are *jua kali*, selling their artisan work in district market centres. A few farmers embrace farming as a business by diversifying agricultural enterprises and adding value through processing.

In the beginning of 2002, the district got a boost when the Dominion Group of Companies from the USA ventured into reclaiming Yala swamp. This group is a major producer of cotton, soybean, artemisia, maize and some horticultural crops. The total land under the reclamation programme is 12,000 ha, with 6000 ha already reclaimed and put under cultivation. The group also farms caged and channel fish in Lake Kanyaboli. However, their initial main objective was to produce rice on a large scale and they are currently constructing irrigation canals.

The company has a special arrangement with the surrounding communities for maize, soybean and cotton production; the company undertakes all farm operations for maize production for individual farmers then shares the yield with seven parts for the company and three parts for the farmer, a 7:3 ratio. The company stores the maize for later sale to the local community at subsidized rates, reducing food insecurity in the area. The company has created jobs for residents, economically empowering the community. The company's field operations are highly mechanized and geared towards minimal tillage. They have grown desmodium as a cover crop and practise crop rotation and association.

Availability of development incentives

The district has a commercial bank and some microfinancing institutions that offer credit. However, many farmers have not explored this option and many are not aware of the services. Authorities of Siaya's three constituencies have agreed to dedicate up to 35% of their allocated Constituency Development Fund to agricultural development through organized groups.

The Dominion Group of Companies is supporting local welfare groups by providing them with grants for district projects. They offer market opportunity for farmers producing soybean and cotton. The Algenya Society conducts on-farm trials for cotton production with farmers and extension services to organized groups. Dominion provides farmers with seeds, and it buys, gins and markets the cotton. The Ministry of Agriculture has been training farmers in cotton production and has been offering them free seeds and extension services. Some stakeholders in agricultural development promote specific techniques in different district regions. They provide farm supplies and grants and build capacity for organized farmer groups to disseminate technology and concepts. The Kenya Agricultural Research Institute (KARI) and the International Centre for Insect Physiology and Ecology (ICIPE) are promoting push-pull technology to control stem borers in maize. Farming in Tsetse Controlled Areas (FITCA) has provided information on using draught animals. Monsanto and Bayer East Africa advise on weed management using herbicides. CARE Kenya promotes household food security through the vegetable crops and community social issues.

Infrastructure development

Infrastructure in Siaya District is not well developed (table 7). The district has a network of earth and murram roads that are inaccessible during the rainy seasons, hindering transportation and marketing. Farmers use bicycles, common in the district, to transport their produce to market. Telecommunication is inadequate. The few telephone booths are only in major urban centres. And for the public telephones that exist, vandalism and poor maintenance has limited their use. However, the mobile telephone has come in handy in serving district residents, especially the middle class. Email and Internet facilities are not yet fully developed and are restricted to the post office and selected government offices. Rural electrification is not well developed. Electricity is limited to urban centres and important institutions in the outskirts of towns. Piped water is available only in urban centres; rural areas depend on sources of untreated water. There is no proper sewerage system in urban centres. Private developers have developed their own systems. Since 2004, the Dominion Group of Companies is currently grading some roads and building churches and schools for the neighbouring community. They are also working to generate hydroelectric power from the Yala River. They have a private airstrip to import cotton from Tanzania, which they process before transporting it to Nairobi. The three airstrips, in addition to Dominion's, are in Boro and Ukwala Divisions.

Table 7. District infrastructure

Roads (kilometres)	
Tarmacked	90.9
Gravelled	400.6
Earth	300.6
Airstrips: Siaya and Sega (no.)	2.0
Communications	
Households with telephone connections	459.0
Private and public organizations with telephones	494.0
Telephone booths	94.0
Mobile phone service: Siaya, Yala, Ugunja, environs	
Post offices	9.0
Sub-post offices	20.0
Email outlets (commercial)	4.0
Households with electricity connections	1062.0
Trading centres with electricity	15.0
Trading centres	45.0
Households with access to piped water	6005.0

Source: Siaya District Development Plan 2002–2008

The marketing structure for agricultural production is fairly developed in the district. The Kenya Agricultural Commodity Exchange is a marketing agency for farm produce with a countrywide network and operates in Ugunja and Ukwala divisions. Other agencies, such as the Kenya National Federation of Agricultural Producers, also have local branches in all district divisions. It is an umbrella organization that brings together individuals and farmers' groups. Formed in 2003 to replace the Kenya National Farmers Union, it is the voice of the Kenyan farmer. It articulates issues affecting farmers and the agricultural sector in the country. Its mandate includes ensuring timely intervention in resolving agricultural issues and enabling effective farming community representation by expressing views to the government and the public. It is also charged with conducting research into agricultural production and marketing, and with strengthening lobbying and advocating for farmers. It provides farmers with agricultural information to enable them to have improved, sustainable livelihoods. Cotton farmers in the district also have their own cooperative society, which owns the Ndere ginnery.

Market access for agricultural products

The larger intertribal markets include the larger and older markets, such as Akala in Gem, Boro in Alego and Nzoia in Ugenya. Each market is known for a particular commodity. For instance, Ngiya in Alego is known for pottery, Nyadorera in Alego is known for baskets and Nzoia in Ugenya and Akala in Gem are known for livestock. Ugunja in Ugenya is known for fish. Specialization in one commodity does not mean that other commodities are excluded. These markets invite salespersons and customers far away to buy the commodities the markets are famous for. This specialization keeps trade alive in different parts of the district. Table 8 shows details about markets in the district.

Table 8. Major and minor markets in Siaya District

Division	Major market	Minor market	Market day
Wagai	Nyangweso	Wagai	Friday
Yala	Yala	Kodiaga Rabuor	Friday
Ukwala	Ukwala Nzoia	Aboke	
Ugunja	Ugunja	Sigomre Got Nanga	Tuesday Friday
Boro	Boro	Ndere Uhuru Kadenge	Friday
Uranga	Nyadorera	Mwer Kodiere Uranga	Sunday
Karemo	Siaya Ngiya	Ramba Nyan'goma	Saturday Wednesday Tuesday

Source: Siaya County Council

Agricultural institutions

Several agricultural institutions are involved in district projects. The Ministry of Agriculture offers extension services and training to farmers through various departments:

- The Ugunja Community Resource Centre in Ugunja Division promotes intensive farming, provides training and information to farmers on sustainable farming.
- CARE Kenya in Siaya town promotes household food security and helps farmers build capacity on several community issues.
- The Sustainable Community Development Programme is an agricultural stockist serving the whole district. It collaborates in on-farm trials on technologies before they are promoted.
- The Siaya Farmers Centre at the district headquarters in Siaya is a farming stockist and supplier of certified seed.

3 Methodology

The case study framework was developed in Nairobi at the Kenya Commercial Bank Management College during the conservation agriculture case study start-up workshop, held 30 January to 4 February 2005. A five-person case study team was formed and briefed on how to do the case study. The framework was instrumental in guiding the team in researching the literature, doing field visits, interviewing informants, and conducting focus group discussions and participatory rural appraisals.

Literature search

The case study team got literature by visiting institutions within and outside the district. The Ministry of Water and Natural Resources office in Siaya provided rainfall data. The Siaya district agricultural officer and district information and documentation centre provided literature on Siaya District's administration, geography and physical description. The district agricultural officer, Mrs Phoebe Muchele, provided information and a list of institutions involved in conservation agriculture in the district. The district information and documentation centre provided the Siaya District Development Plan 2002–2008 for Effective Management for Sustainable Economic Growth and Poverty Reduction, which contained a map of Kenya showing Siaya District and a map of Siaya District with the administrative boundaries, population and division settlement patterns, poverty status and HIV/AIDS status. Population statistics came from the Ministry of Planning in its Department of Statistics in Siaya. Not obtained were adoption figures for conservation agriculture technologies promoted by various institutions and organizations, except for the Conservation Agriculture for Sustainable Agriculture and Development Project. Most of the institutions did not provide written literature because of protocols or because they were unwilling to do so. Most had not yet documented their activities.

Field visits

Team members visited the institutions, demonstration plots or farmer groups that worked with the institutions. This was to confirm the information collected and to collect more information.

ICIPE Maseno had literature on push-pull technology to control stem borer and striga in maize and sorghum. In push-pull technology, ICIPE was collaborating with the Kibos and Kisii branches of KARI. Team members visited some farmers trying improved fallows in Bar Sauri village. A visit to the Anduro farmer field school, a Technical Cooperation Programme site, provided information on the cover crop *Dolichos lablab*. Farmer field school members used conservation agriculture equipment, such as a ripper, subsoiler, animal-drawn sprayer and pedestrian pull sprayer. The officer in charge of the rural technology development centre, Mr. Philip Obuya, assisted in mobilizing the farmers. Farmers spoke about the challenges they faced in producing lablab, controlling pests during flowering and podding and managing lablab when grown as an intercrop with maize.

At the Dominion farm, the farm manager, Mr Siage, took team members around the farm to see the cage fishing introduced at Lake Kanyaboli, fishing pods to breed fish, irrigation canals, fish farming under construction, weirs to generate electricity under construction, stored beans for cereals, and farm machinery (colour section).

Team members visited six CA-SARD farmer field schools to see their trial plots. The project's district coordinator and facilitators assisted in interviewing the farmers about the conservation agriculture they were doing.

The case study team held participatory rural appraisals and focus group discussions with district farmer groups and were able to confirm the information gathered, get more insight on the grey areas and, most importantly, get first-hand information. The discussions included most farmers, researchers and all conservation agriculture collaborators. Some farmers infected with HIV volunteered to document how they were carrying on with conservation agriculture. The team also learned more about conservation agriculture equipment, especially how the hire system challenges their availability and their use when conditions are wet.

Informant interviews

The case study team interviewed key informants: farmers, researchers, Ministry of Agriculture extensionists, and people from institutions involved in district agriculture. This helped fill in gaps in the literature and confirm the information.

Site selection

Siaya District was selected because it is in western Kenya. Small-scale farmers do most of the district's farming. For many years the district had been faced with food insecurity, mainly attributed to bad farming practices and labour shortage from rural–urban migration, compounded by HIV and AIDS: the district has the highest prevalence in the country.

4 History of conservation agriculture in Siaya District

Various institutions have been involved in conservation agriculture or simply soil and water conservation work in Siaya. Poor and declining soil fertility has been an issue most agricultural projects have tried to address. Listed are some of the main conservation agriculture and soil and water conservation initiatives undertaken in the districts in the last few decades.

Farming in the Tsetse Controlled Area Project

The Farming in Tsetse Controlled Area Project was funded by the European Union and implemented in Siaya and four other districts in western Kenya during 2001–2003. It promoted conservation tillage and was implemented through the Ministry of Agriculture. In collaboration with Kenya Draught Animal Technology and Triple W Engineering, the project initiated the Draught Animal Programme. Other collaborators included Monsanto and Bayer East Africa, who brought in the herbicide component, mainly Round-Up, Lasso Atrazine, Sencor and Lasso EC. The project provided farmers with equipment and organized training. The project also organized regional farmer visits; farmers from Siaya visited their counterparts in Uganda. They also provided cover crop seeds such as mucuna and canavallia. Farmers were also provided fertilizers. The Draught Animal Programme was mainly used to promote sorghum farming. It initially targeted 14 farmers in seven divisions (Draught Animal Technology of Rural Technology Development Centre Report 2001; M. Ochieng 2002).

The Farming in Tsetse Controlled Areas work was oriented toward no-till and chemical weed control. 'Spray gangs' were trained by the project and supported with spraying equipment and chemicals. The project ended in 2003. Except for where the rural technology development centres continued supporting a few groups, most groups have simply collapsed.

Consortium for Scaling-Up Options for Farm Productivity

The Consortium for Scaling-up Options for Farm Productivity is an umbrella body involving organizations such as ICRAF, KARI, Tropical Soil Biology and Fertility, the Kenya Forestry Research Institute (KEFRI) and the Ministry of Agriculture. The network helped scale up conservation agriculture in the district since early 1990s by collaborating with private businesses important in post-harvest technology and in marketing agricultural produce.

The consortium aimed to increase soil fertility through legume fallow crops, enhance striga control, and disseminate best farming practices and skills to farmers. It organized field days and trade fairs for collaborating farmers, bringing in supporters and policymakers. One of its most notable projects was the Soso River Development Women Group at Bar Sauri in Yala Division. In this project 35 farmers improved soil fertility by using legume fallow crops, such as tephrosia and crotalaria. The farmers used fallow periods in rotation with the main crop for eight months. The fallow crops could be used as relays within the main crop. Fallows were then harvested for firewood and the residue. It was estimated that over 30,000 farmers in 25 districts of western Kenya adopted the fallow technique. Bar Sauri is currently a model Millenium Development Goal village pilot project in Kenya, undertaken by the ICRAF-MDG Centre initiative in close collaboration with the Njaa Marufuku Kenya Programme.

Adoption of fallow cover crops has been high, mostly because the improved fallows are effective in controlling striga. Some institutions in the consortium did scientific research on other conservation agriculture. For instance, KARI established the weed suppression capacity of many cover crops under different conditions. This included work to establish the allelopathic effects of cover crops on weed species. Based on this work, KARI recommended using *Dolichos lablab*, mucuna and canavallia as cover crops suitable in the region, although lablab is widely used because its seeds are edible.

International Centre for Insect Physiology and Ecology

ICIPE initiated its research programme in Siaya in 2000. The main objectives were controlling striga weed and stem borer and improving soil fertility. They introduced

Desmodium uncinatum as a cover crop to combat maize stem borer and striga weed and to improve soil fertility through the push-pull technology.

FAO Technical Cooperation Programme

FAO funded and operated the Technical Cooperation Programme in Siaya District from 2001–2004. This was the first initiative to drive Siaya agricultural development initiatives to accommodate full conservation agriculture principles of reduced tillage, crop rotation and permanent soil cover. In collaboration with the Rural Technology Development Centre staff, the project centred on one farmer group at the Anduro farmer field school in Karemo division. Technical cooperation work in the district was aimed at scaling up Farming in Tsetse Controlled Areas in the district. It brought in using animals for direct seeding with animal-drawn no-till planters and promoted using cover crops, particularly *Dolichos lablab*. The project also introduced jab planters for direct seeding. The project trained the farmer group in conservation agriculture technical principles and skills, group dynamics and equipment use and maintenance.

At the conclusion of the Technical Cooperation Programme in December 2004, several observations, lessons, and recommendations were made (Ong'ayo 2005):

- Farmers listed good group qualities that would steer their growth and development in conservation agriculture as follows: unity, love, adherence to procedures and regulations, clear objectives, commitment, good leadership (transparent, visionary, democratic, trustworthy, punctual, self-disciplined), cooperation (teamwork, respect) and tolerance of people's beliefs and politics. They agreed that the lack of these qualities would kill any group participating in conservation agriculture.
- One vision of the farmer groups, which was relatively amorphous at that time, foresaw that organizational ingredients were in place to allow for
    - current groups to expand, thus increasing group memberships
    - more women to train others in conservation agriculture
    - the current conservation agriculture groups to eventually have savings and credit schemes and provide credit to their members
    - conservation agriculture groups, if strengthened, to be entry points for other development activities
- Changes were foreseen for the community:
    - Conservation agriculture will be increasingly adopted by the community, reducing the workload for women, men and children.
    - More youth, both women and men, will acquire new skills and positive attitudes that will enable them obtain gainful employment, for themselves or by others.
    - There will be increased food security, improving chances for more people in the community, including orphans, to have food throughout the year and possibly surplus food that would be sold to other areas.
    - Conservation agriculture is an opportunity to increase sensitivity to gender and women's issues: more consultation within the family on the use of resources, greater acceptance for women leaders, more women in leadership and decisionmaking positions.

- Improved environment meant improved soil fertility, more trees planted and well managed, improved agricultural practices and increased awareness on the importance of environmental conservation.

- The consultant concluded that groups felt that the 'dreams' they articulated would be achievable through conservation agriculture. However, they recognized there could be barriers to overcome, such as lack of equipment, marketing constraints, inadequate leadership and management skills, limited access to credit and inadequate skills for credit management. They suggested training on leadership and credit management and support by the project in acquiring conservation agriculture equipment.
- Conservation agriculture technology with the knowledge, skills, lessons and experiences acquired through a well-organized and well-run conservation agriculture group would affect members by improving their soil fertility, increasing yields and improving living standards. Farmers judged their success by good health, increased income, improved nutrition, food security and surplus, improved environment (trees planted, erosion controlled, water conserved), reduced workload, engaged youths, improved production skills, more children in school at all levels, increased use of indigenous crops, better leaders, happiness and self-sufficiency.

The Technical Cooperation Programme concluded that conservation agriculture influenced gender issues and group dynamics:

- Training conducted in the project not only empowered the farmers, but gave them a new insight into agricultural production. Farmers demonstrated ability and pride in training others in conservation agriculture.
- The farmers realized they were becoming real, if not yet credible partners, with other stakeholders in agricultural development. Conservation agriculture farmers under the technical cooperation project were able to link conservation agriculture to improved soil fertility, which translated to increased yields and improved living standards.
- Farmers saw conservation agriculture as the solution to handling poor and unreliable rains, poverty and food shortage.
- Strengthening farmer and stakeholder partnership is important to increase conservation agriculture adoption, improve farm productivity and help the economy grow.

The group dynamics assessment and training recommended that up-scaling and disseminating conservation agriculture should target farmers in other regions and empower them with conservation agriculture knowledge and facilitate adopting conservation agriculture. Applicable technology in different regions could reverse the decrease in land fertility and crop productivity and improve food security and farmer livelihoods in Kenya.

At the conclusion of the technical cooperation project, weed control stood out as the single most challenging issue of concern for conservation agriculture. Several observations, lessons and recommendations were made regarding weeds and their management (Mwangi 2005):

- Most farmers were afraid to use herbicides for weed control because they thought the chemicals would leave residue on their crops. Timing, chemical mix and uniform application when weeds were green and growing vigorously were concepts that farmers were yet to relate with. Farmers learned that timely weed control would eventually eliminate the need to use chemicals for weed control; this was the ultimate goal. They were trained how to do relay cropping and plant cover crops a week or more after the main crop had been planted, to avoid competition. Farmers were also trained not to plant cover crops in the same row as maize, but between the maize rows.
- Common weeds in the technical cooperation sites were reported to include but were not limited to the following: *Acanthospermum hispidum*, *Bidens pilosa*, *Commelina benghalensis*, *Cynodon dactylon*, *Digitaria abbysinica* (couch grass), *Digitaria veluntina*, *Eleusine indica*, *Euphorbia hirta*, *Galinsoga parviflora*, *Oxygonum sinuatum*, *Pennisetum clandestinum*, *Schkuhria pinnata*, *Senecio discifolia* and Mexican marigold.
- Many common annual grasses and broadleaf weeds are easily managed by herbicides and mechanical means, hand pulling or shallow weeding. It is important that weeds be removed before they produce seed, which would add to the ground weed seed bank.
- The *Dolichos lablab* cover crop was popular with farmers. However, there was reported a general shortage of seed. Demand for seed increased as more farmers adopted conservation agriculture at all participating sites. Other cover crops, such as mucuna, needed to be introduced where the concept of covering the soil has becoming clear.

The technical cooperation project introduced the animal-drawn Fitarelli planter for direct seeding. This unit had major advantages over the Magoye ripper, which when used with a planter was not able to incorporate fertilizer. As the project ended farmers had only tried, not perfected, using the jab planter.

At the end of the Technical Cooperation Programme and entry of CA-SARD project, conservation agriculture principles were getting deeply engraved among farmers in the district. However, many needs were not filled, such as access to equipment. Some reported achievements by the technical cooperation project regarding engineering and equipment issues include the ones listed below (Kenya National Draught Animal Technology 2005). At the conclusion of the technical cooperation project in December 2004, several observations, lessons and recommendations were made (Kenya National Draught Animal Technology 2005; Mwangi 2005; Ong'ayo 2005):

- It was evident that conservation agriculture was becoming popular with farmers because it had clearly increased yields and saved labour. Extension workers and farmers from the pilot areas actively propagated conservation agriculture. It became apparent that it was important to educate farmers on basic concepts of conservation agriculture to further advance its practices.
- For rapid and widespread adoption of conservation agriculture, available equipment at affordable prices was a requisite. More advanced and relatively sophisticated direct seeders had been introduced from Brazil, but their use was still a new venture and sustained supply from Brazil was not assured. The Brazilian Fitarelli animal-drawn, direct seeder with a fertilizer

applicator had proved efficient, but it was relatively complicated for artisans to produce. At the end of the Technical Cooperation Programme, it was not one of the units local artisans considered reproducible. Concerns would have centred on sacrificing quality and functionality.

- Further support was needed in seeding techniques, residue management, weed control and cover crops and their management.
- Although some *jua kali* artisans had been trained to produce the ripper and subsoilers, they had not yet tried manufacturing them in their own workshops. This was mostly because the artisans needed jigs, which were not available to them at the conclusion of the training. Support to artisans to start producing equipment would ease the demand for basic equipment, such as rippers and subsoilers. As demand grows, arrangements such as facilitating local manufacture by medium- to large-scale manufacturers or by direct importation of complete machinery will be necessary.
- Training on specifications to produce rippers and subsoilers needed to be ensured. Otherwise this would lead to poor quality equipment for farmers. A certification programme for trained local equipment fabricators needed to be put in place to ensure farmers get quality conservation agriculture equipment.
- To ensure success and avoid farmers falling back to conventional tillage, regular support by trained extension workers needed to continue.
- In spite of the enthusiasm expressed by farmers towards conservation agriculture, adoption was not as rapid as expected. Since conservation agriculture eventually requires an investment in new equipment, in addition to new inputs, the severe poverty in the intervention areas will require support in acquiring equipment.
- Cover crop seeds were also not readily available to farmers, although some farmers planted their own seed.
- Subsoiling is best done soon after harvest, when the ground is still soft. This reduces draught power requirements. Ripping can then be done during planting, just before rain. Subsoiling should be necessary only if hardpan is found when digging profile pits.
- Subsoiling or ripping between rows was still practised by farmers who continued to plough. Weeding between rows with heavy hoes or by animal drawn ploughs is contrary to conservation agriculture and was not recommended. Instead slashing and leaving the space between rows covered was recommended. Soil cover protected soil from erosion and direct heat from the sun, increased water infiltration and improved soil structure.
- Farmers would need credit to acquire conservation agriculture technology. By forming common interest groups, farmers could purchase equipment for use by the groups and hire it out to others.
- The Technical Cooperation Programme concluded there were more queries than answers in managing residues, controlling weeds, and choosing and managing cover crops. Soil cover was seen as the single most critical aspect to the success of conservation agriculture.

The echnical cooperation project saw the way forward around a clear conservation agriculture policy. The project concluded that unless and until the Kenya government and all stakeholders were adequately exposed to conservation agriculture at all implementation stages, sustained impact would remain elusive. The government was challenged to provide subsidies, credits and markets by reviving and strengthening agricultural institutions, such as Kenya Farmers Association shops, the National Cereals and Produce Board and others, with new focus on the many small farmer groups now forming.

Conservation Agriculture for Sustainable Agriculture and Rural Development (CA-SARD) Project

At the conclusion of the technical cooperation work (later taken over by the CA-SARD project, except for Rachuonyo and Machakos sites), farmers reported they needed access to equipment, since the few units available were insufficient. They requested more training in group dynamics and gender issues and on cover crops. The Conservation Agriculture for Sustainable Agriculture and Rural Development project added cover crops to the project. The Technical Cooperation Programme emphasized minimum tillage, mainly by using the Magoye rippers from Zambia and subsoilers.

The CA-SARD project was funded by the German government through the FAO Trust Fund. It was implemented in Kenya and Tanzania in 2004 and is expected to end in late 2006. The project promoted conservation agriculture in the district by encouraging farmers to adopt its three principles: no tillage, permanent soil cover, and crop rotations and associations.

In Siaya, one of the five districts where the project was implemented in Kenya, the project established 10 farmer field school groups in Boro and Uranga divisions. Each group has 25 to 30 farmer members. It is estimated that over 300 farmers are directly or indirectly benefiting from the project. In partnership with the UN Millennium Project, the project supported setting up two conservation agriculture demonstration sites at Bar Sauri in Yala Division.

Within the district the project developed an animal and equipment hire system. The amount of conservation agriculture equipment increased. The district had 13 animal-drawn planters and 28 jab planters. All farmer field school members and the district community had access to the equipment through the hire system. Farmers learned more about conservation agriculture either by bringing in a consultant on a special topic or by sending farmer groups for training elsewhere. The project strengthened the private sector by training local artisans to fabricate rippers and subsoilers and by involving stakeholders in field days and farmer exchange visits. The demand for conservation agriculture equipment within the district increased. The project initiated talks with large-scale manufacturers about copying or importing Brazilian equipment for farmers to purchase. Training in gender and group dynamics, farming as a business and farmer field school management were important project results, empowering farmers in Siaya.

5 Conservation agriculture technology

Reduced soil turning and direct seeding

Farmers adopting conservation agriculture make basins or holes for seeds with a hand hoe at intervals for plant spacing. They plant in furrows if they have animal power. Jab planters, introduced by the project, became popular direct planting tools because no basins or furrows were necessary. A farmer experienced in using a jab planter was able to plant one acre (half a hectare) in six hours. An animal-drawn direct planter could plant it in two hours. Ordinary ploughing with hand hoes required eight adults two days to complete one acre and another day to plant with hand hoes. It took two days for a pair of oxen to plough an acre using a mouldboard plough.

Farmers used an animal-drawn subsoiler to break the hardpan. Farmers with no access to one broke the hardpan by double digging with hand hoes.

Farming with permanent soil cover

Farmers achieved soil cover in arable fields mainly by using living cover crops and mulch made from crop residue and prunings from trees and shrubs. Farmers started using a combination of mulch and living crops. Some planted cover crops during the cropping season or after removing the main crop to cover the whole field. Some cut and brought in field grass and plant material such as leaves from outside their fields. Most annual crops are good sources of mulch. After harvest the cereal stalks can be cut and spread evenly over the soil to provide cover. Farmers who adopted conservation agriculture started leaving crop residue in their fields as mulch and no longer grazed livestock in their fields after harvest.

Conventionally, the practice was to let the animals graze fields immediately after harvest. Those who had fields far away from the homestead cut and carried the crop residue to feed livestock at home. Some people used maize stover as fuel, and farmers complained of their neighbours stealing their crop residue for fuel or livestock feed.

In Siaya, the most widely grown cover crop was *Dolichos lablab*. However, lablab is prone to insect pests, especially at flowering, calling for use of pesticides. This was an extra cost, but cover crops did not seed for farmers who did not use pesticides. After the lablab formed a dense cover, farmers were afraid to walk through it for fear of being bitten by snakes or other animals that might hide beneath the canopy. Farmers with livestock used lablab leaves to feed livestock, especially when milking.

During the two seasons of March 2005–January 2006, most of Siaya experienced drought and subsequent crop failure. Farmers were forced to feed their livestock crop residue such as maize stover and lablab vines, since there was no other feed. Most farmers did not set aside any land for grazing or planting fodder such as napier grass for livestock feed. As a result farmers fed the animals crop residue rather than leaving it as mulch in the fields. This resulted in conflict between crop and livestock.

With poor cover crop management lablab sometimes smothered the maize, killing it completely, as if it were a weed. When the lablab and maize were planted at the same time, lablab grew faster and covered the maize crop. As a result some farmers abandoned lablab and started growing canavallia, pumpkin, groundnut, desmodium, cowpea, sweet potato and improved fallows such as tephrosia as cover crops. Farmers who used cover crops reported that labour for weeding went down and soil fertility increased in subsequent seasons.

Siaya has potential for other cover crops as well as lablab. Other legume cover crops have been tried. ICRAF promoted improving soil fertility through fallows such as crotalaria and tephrosia. Tropical Soil Biology and Fertility trained farmers on organic and inorganic fertilizers.

Handle with care! Cover crops can smother

Mr Anthony Owino Malowa of the Mariwa Farmer Field School and who is practising conservation agriculture is HIV positive. Although he is weak, he farms with conservation agriculture because it requires less labour. He no longer ploughs his field but uses the jab planter to plant directly. Since he adopted conservation agriculture, the weeds in his half-acre field were greatly reduced by intercropping maize with *Dolichos lablab*. However, in the 2005 long rains his farm, where he intercropped lablab with maize, never gave him any yield because lablab smothered all the maize. He discarded lablab as a cover crop even though it suppresses weeds, calling it a very dangerous weed.

Mama Benta Odipo of the Tumaini Farmer Field School decided to plant beans as her main crop during the 2005 short rains. But after two weeks she decided to plant mucuna in between the rows, believing that after a short while, she would harvest her beans and have her soil covered with mucuna. It was a mistake. She never harvested any beans and there was no sign they had even been planted. This made her rethink using cover crops and she is contemplating leaving it out of her farming.

When selecting a cover crop, most farmers prefer one with the following qualities:

- can improve soil fertility
- can be used as animal feed
- has edible seeds and vegetables
- suppresses weeds
- grows vigorously to form a ground cover in a short time

It is important to plant the cover crop at the same time as the maize. As most farmers have only small pieces of land they cannot commit to pure cover crop stands, and the soil after planting urgently needs cover. Since rainfall in Siaya is unpredictable, planting the cover crop at the onset of rain makes better use of the moisture.

Cover crop management

Cover crops that are climbers need to be cut or vines uncoiled from the main crop or they may overgrow the main crop and smother it (Telmo 2005). This happened in Onalo Boke Farmer Field School and some farmers' fields where maize was intercropped with lablab. The lablab completely covered the maize and the farmers harvested none, although the season was good. Consequently, some farmers perceived lablab as a weed and grew it only as a pure stand or simply abandoned it. Some farmers cut the lablab 15 mm (6 inches) above the ground before planting maize. This allowed it to grow back. If regrowth was not needed, they cut it at the base, left it to dry and then planted maize.The KARI Legume Research Network Project provided farmers with 10 varieties of good legume cover crops. The farmers evaluated them to determine the best ones.

Pests and disease control in cover crops

No disease attacked the crops during the project at any of the sites. However, there were pests—many bean flies and caterpillars. Some farmers who did not spray the lablab with the pesticides had flower abortion and empty pods. But this was minor, since most areas overcame the problem without any pesticides. Mucuna had minor insect pest problems and more seed formation than the lablab.

Rotating and associating crops

Intercropping cereals with legumes is not a new concept among the farmers. The practice has existed from time immemorial. Traditionally, farmers planted beans, sorghum or maize and cowpea in one field. The following season they planted tubers, such as cassava or sweet potato, then back to beans and maize or beans and sorghum. Some farmers planted beans, sorghum, maize and cowpea together. The only difference with conservation agriculture was that farmers either intercropped lablab and mucuna with maize or planted them as pure stands to fix nitrogen, conserve moisture and provide soil biomass. Where lablab was established as a pure stand, the following season farmers slashed it and planted maize.

In Siaya, the most problematic weed is witch weed, *Striga hermonthica*, which is a parasite on maize, millet and sorghum but can be controlled by rotating them with other crops. Maize smut is a disease that can be controlled by rotating maize with crops such as legumes and vegetables. In fields where maize was rotated or intercropped with either lablab or desmodium, striga was rare and if present, few plants in number. This has convinced many farmers to rotate and associate crops.

Planning a rotation

Farmers within the conservation agriculture farmer field schools intercropped maize with lablab. After harvesting the maize, they let the cover crop grow. In the subsequent season they slashed the cover crop and planted maize or sweet potato or cassava.

Weeding

In conventional farming, hand hoeing, which turns the soil, controls the weeds. After planting and when the crop has germinated, some weeds come up. Conservation agriculture farmers mainly controlled weeds by manually uprooting them, slashing them with a panga or scraping them with a hand hoe. Farmers have not used herbicides to control weeds because of financial constraints and the community has not fully accepted using herbicides in their fields. Many farmers considered chemicals to be unsafe for them and the environment, if not expensive and out of reach.

After harvesting maize, conservation agriculture farmers cut the maize stovers and spread them evenly on the field for mulch and to prevent weed seeds from germinating. Most farmers planted lablab either as a pure stand or as an intercrop with maize. After 45–60 days, the cover crop almost completely covered the ground, suppressing weeds. It was a challenge to maintain soil cover after cutting the maize stovers and lablab; the mulch was short lived as termites quickly consumed it.

6 Adapting and diffusing

Understanding and adapting conservation agriculture

Conservation agriculture is a set of principles that can be adapted to suit local conditions. It is important for farmers to experiment, to learn and to share their results with their neighbours. Deliberate promotion of conservation agriculture in Siaya can be traced back about 15 years, when the district started experiencing food shortages because of declining soil fertility and poor farming practices. A few, 0.58%, farmers in the district adopted conservation agriculture because they hoped their crop yields would improve and ended up practising conservation agriculture without understanding its concepts.

Collaborators in conservation agriculture established projects in the district that helped farmers understand conservation agriculture through participatory extension; their involvement continued through farm trials. Participatory technology development in farmer field schools emphasized the three conservation agriculture principles. The most notable and accepted conservation agriculture principle in the district was the legume cover crop because it improved soil fertility and suppressed weeds. Intercropping legumes and cereals was an old practice in the district, but it gained momentum with the introduction of conservation agriculture. The practice of *nyalgonglo*, planting without ploughing, where labour was limited and planting time running out, and *khasiri*, shallow weeding during dry spells with a special hand hoe, are traditional farming techniques that closely link to conservation agriculture. Farmers modified and diversified some prescribed conservation agriculture concepts to fit their own farms.

Farmers at focus group discussions offered varied understanding of conservation agriculture principles: 'Conservation agriculture is about using the brain and not the thorax' (Boro); '. . . is working very little and getting more' (Boro); '. . . is *Dolichos lablab*' (Uranga); '. . . is slash, lay and plant' (Karemo); '. . . is using few resources and getting more yield' (Boro); '. . . is farming in God's way' (Obambo); '. . . is for the lazy' (Karemo); '. . . is witchcraft' (Uranga).

Farmers not within the farmer field schools had a different understanding: 'Conservation agriculture is organic farming'; '. . . is fallows', '. . . is planting in rows', '. . . is agriculture', '. . . is a new improved technology'.

Farmers were aware of conservation agriculture opportunities. Conservation agriculture was only understood and practised by field school farmers; other farmers practised some aspects of conservation agriculture without referring to them as such.

Conservation agriculture equipment, such as an animal-drawn planter and a jab planter, is hard to find locally, but local artisans could copy existing designs or make their own. An artisan in Siaya Rural Technology Development Centre started fabricating jab planters to meet local demand. The artisan was trained to fabricate rippers and subsoilers but has not fabricated any due to lack of demand.

Some conservation agriculture farmers could not keep livestock away from their fields, especially during drought. It was impossible for farmers with poor soil to grow sweet potato and cassava under conservation agriculture, since harvesting the tubers required disturbing the soil. But farmers with improved soils did not have a problem growing the tuber crops because it became very easy to uproot the tubers without digging.

Rationale of conservation agriculture adoption

Farmers in Siaya District have practised several agricultural options without much success. Declining soil fertility, unreliable rainfall, limited land size, lack of capital, and declining labour as a result of AIDS and youth migrating to towns have led to low yields, low production and increased food insecurity. This has made farmers look for other farming options, such as conservation agriculture, which could reverse the negative trend.

Farmers have resorted to rotating crops, intercropping cereals with legumes and leaving land fallow to improve soil health. Unreliable rainfall has prompted farmers to plant cover crops such as lablab to conserve soil moisture. The youth have slowly been getting interested because conservation agriculture is not laborious, although making basins, especially in the first few years, can be labour intensive. The aged have also adopted conservation agriculture because it requires much less labour than the traditional digging and manual planting.

Conservation agriculture has offered farmers an opportunity to see their farms as a business. Farmers produced more than they needed to subsist and grew new crops to sell. A market and trading orientation enabled farmers to find a pathway out of poverty. This attracted many farmers to conservation agriculture.

Ways to promote conservation agriculture

Farmer field schools

The field schools are a participatory extension approach. Farmers get together to study farming in their own fields. Farmers meet weekly and learn about conservation agriculture. They do it and apply the concepts on their own farms.

The farmers learn the agroecological analysis system during their meetings. Agoecological analysis, studying the interaction between plants, soil and the environment, is the cornerstone of farmer field schools. It identifies strengths, weaknesses, opportunities and threats, erosion and pests, within an ecosystem. Farmers learn to use agroecological analysis to make regular field observations, analyse problems and opportunities, and improve farm management. By carrying out agroecological analysis regularly in the field schools, farmers develop a mental checklist to use in monitoring farm practices. Agroecological system analysis has four stages:

- making observations in the field
- detailing field observations in a presentation paper
- presenting results and decisions by subgroups
- synthesizing the presentations to implement the decisions

Agroecological analysis enabled field school members to analyse crop development from planting to harvest. This gave them an opportunity to learn and try new ideas to improve crop yields. The approach promoted conservation agriculture, since farmers found it interesting and saw it as knowledge they could use for their own plots. Most farmer field schools in the district have done quality agroecological analysis and enhanced their understanding of conservation agriculture.

Ten farmer field schools have been established in two divisions in Siaya District over the last two years. These key institutions directly promoted conservation agriculture

Mrs. Margaret Ogola, 72 years old and a Mariwa Farmer Field School member, started conservation agriculture in October 2004 on a half acre (quarter hectare). She could not cultivate all her five acres, mostly bushland, because of her age and financial constraints. She had been farming conventionally for 15 years and could get scarcely more than one bag of maize. She slashed the weeds in her plot with a machete (panga), and planted maize by pitting. For two consecutive seasons she had harvested nothing because of drought.

In September 2005, she planted maize and lablab with the animal-drawn mulch planter. The lablab established good cover and she had no weed problem. She harvested 11 bags of maize. She cut and left the maize stovers. The lablab continued to grow. On March 2006, she slashed the cover crop. She also increased her cultivated acreage to one acre by slashing bushes and planted maize and lablab using the animal-drawn mulch planter. She uprooted the few weeds by hand. She expects to harvest not less than 24 bags of maize. She says the weed population has gone down and her soil fertility has improved because of the lablab. Despite her age, she now finds farming easy, since less labour is required to prepare land and weed. She intends to go full blast and use conservation agriculture on her five-acre plot because the maize yield has increased. The money she will get from selling maize will help her hire labour to clear the remaining bush land and to buy supplies.

technology, since farmers learned by doing and discovering. The field schools were facilitated by trained personnel. After two seasons the farmers were evaluated by an external party, and based on the recommendation of the evaluator, the field school members were graduated.

All the active members of the Conservation Agriculture for Sustainable Agriculture and Rural Development farmer field schools graduated and were issued certificates. Most of the graduates could facilitate a farmer-led field school but could not yet train trainers. Some farmers not in the field schools adopted conservation agriculture with the assistance of field school members.

Field days and farmer exchange visits

A field day is an event organized for farmers to celebrate their success, share information and show their results. Stakeholders in agriculture are invited so farmers learn more. In all the field days the government was represented by local administrators. Most field days had 350–500 participants.

To farmers, 'Seeing is believing'. In Siaya, farmer exchange visits were made a day before the field day. Farmers visited other farmers within and outside the district; they shared ideas and learned more about conservation agriculture. Most often, farmers were divided into groups of seven. Each group filled in questionnaires during the visits. At the end of the field day the questionnaires were presented to judges, who scored marks. Three winners were selected and agricultural prizes, such as seeds, fertilizers, equipment, herbicides and pesticides, were awarded. Farmers from neighbouring districts participated in the field days, learning more about conservation agriculture.

Farmer extension

Farmer groups provide a valuable opportunity for farmers to learn from each other, test new technology and share knowledge, experience and farm inputs. Farmers can influence change among fellow farmers. Groups increase access to technology. Women farmers often exchange information through informal and formal contacts and influence each other to try new technology and methods.

Farmer champions

It is usually possible to find several farmers in an area who have tested and developed some sort of conservation agriculture on their own, however incomplete. Other farmers hear about conservation agriculture and may be eager to try it to improve their farm. These farmers are a precious resource for conservation agriculture programmes. They are highly motivated and may have already adapted conservation agriculture principles to local conditions. They can be excellent partners for extension agents and researchers to develop further options. Many farmers are happy to share their experiences with fellow farmers. These farmers can become champions of conservation agriculture in their communities. They can become magnificent trainers and motivators, through their enthusiasm and success. They also have the ability to convince politicians and policymakers about the value of this approach.

Trained equipment hirers have been instrumental as farmer champions. They have understood and adopted all the conservation agriculture principles and offered ripping, subsoiling and direct planting for hire to any farmer. They have converted many into conservation agriculture by helping them understand conservation agriculture and supporting them regularly.

Demonstrations

Demonstrations let farmers see a new technology before they risk trying it. ICRAF, KARI, the Technical Cooperation Programme, and the CA-SARD project have held demonstrations in farmer fields.

Government role in promoting conservation agriculture

The Ministry of Agriculture was the main agent promoting conservation agriculture through extension agents who facilitated the field schools. The chief's *barazas* also played a major role in creating awareness about conservation agriculture. Research institutions such as KARI have played a major role in managing weeds and cover crops. The Ministry of Agriculture has always provided a centre through which various collaborators in conservation agriculture can link up and complement efforts. The Farmers Training Centre in Siaya town has provided an environment for farmers to learn and be trained in new technology, such as conservation agriculture. The rural technology development centre in Siaya town played a leading role in disseminating conservation agriculture equipment. It is the local supporter of conservation agriculture equipment and provides technical supervision and quality control to local artisans fabricating Magoye rippers, subsoilers and jab planters.

Others

Local churches and chief's *barazas* also provided platforms to promote conservation agriculture, especially during the formation of farmer field schools. Most local administrators (chiefs and subchiefs) attended field days and some started practising conservation agriculture. Whenever they had barazas they invited local field school members to speak about conservation agriculture.

Some farmers, aware of conservation agriculture, had reasons for not practising it:

- lack of supplies
- no seed produced by lablab in some areas
- scarce equipment
- lack of knowledge on managing cover crops
- problem with finding cover crop seeds or where available, too expensive

7 Adopting conservation agriculture and its impact

Adoption extent

Every active member of a farmer field school in the district adopted conservation agriculture technology. Of 385 members who registered at the project's inception, 271 members continued practising conservation agriculture. Over 90% adopted a cover crop because it had obvious benefits and it matured quickly and visibly. The cover crop attracted other farmers, especially when it was planted next to the road. In farms infested by termites, the cover crop reduced termite damage to the main crop, such as maize, since the pests preferred the cover crop leaves (participatory rural appraisal: Onalo Boke, Luanda and Nyal Gunga Farmer Field Schools). Farmers were ready to plant the cover crop so they could save their main crop. Such farmers benefited immensely, since they also improved their soil fertility and did not have to subsoil. Table 9 shows farmers who have adopted or are aware of conservation agriculture.

The jab planter was getting popular because it conveniently and efficiently placed fertilizer and seeds. Farmers were impressed with how crops planted with it germinated better. The animal-drawn planter was not as common because there were few trained draught animals. It gained popularity among groups farming in tsetse-controlled areas and was used in the draught-animal programme for sorghum and other cereals. Though there were trained hirers who had draught animals to pull the mulch planters, most field school members chose to plant their crops by pulling the equipment themselves to avoid the charges by the hirers. Most hirers mainly planted maize for non-members and charged KES 800 per acre.

Effects

Agronomic and environmental aspects

Siaya District is predominantly a small-scale farming region where new farming techniques have been integrated with traditional farming practices, leading to more environmentally friendly practices. Farmers applied conservation agriculture principles to address environmental concerns, which have led to degraded soil and low yields.

Weed control

Witch weed, *Striga hermoenthica*, is a predominant parasitic weed that had devastated crops in the entire district. Farmers uprooted the weed by hand, then buried it in deep pits or burned it. Some farmers uprooted the weed and then dumped it on the road. Numerous research efforts in managing this weed have yet to offer workable solutions. *Dolichos lablab*, planted for soil cover, helped control striga. It appeared to provide a false host by producing chemicals that induced striga to emerge but failed to support it to maturity.

Table 9. Farmers practising or aware of conservation agriculture and acreage

Farmer field school and start date	Male	Female	Farmer field school members	Neigh-bours	Others	Total practis-ing	Number aware	Total area
Bahati 18.02.05	10	20	30	37	25	92	>500	14.5 ha (36 acres)
Cham Luchi 07.01.05	18	11	27	10	7	34	>500	4 ha (9 acres)
Dhier 08.09.04	16	8	24	7	5	26	>150	4 ha (9 acres)
Kinda 07.09.04	5	21	26	6	5	37	>500	6 ha (15 acres)
Luanda 09.09.04	3	24	27	15	25	67	>1000	10 ha (25 acres)
Mariwa 23.09.04	16	9	25	16	40	81	>1500	16 ha (40 acres)
Nyal Gunga 12.01.05	3	27	30	65	40	135	>2000	20 ha (50 acres)
Onalo Boke 07.09.04	6	15	21	11	30	62	>1000	5 ha (12 acres)
Tumaini 07.09.04	9	21	30	35	42	107	>500	26 ha (63 acres)
Wuoroya 02.01.05	16	15	31	15	12	58	>100	3 ha (7 acres)
Total	102	171	271	217	231	699	>7650	266

Source: District coordinator and facilitators of Conservation Agriculture and Sustainable Agriculture and Rural Development, June 2006

Other control technologies, such as push-pull, were tried. *Desmodium uncinatum* and Napier grass were used to control the stem borer moth. In push-pull, a technology developed by ICIPE and KARI, desmodium is intercropped with maize and Napier grass is planted alongside the field. Desmodium exudes chemicals that repel the stem borer moth and induces the striga to grow but fails to support its growth. Napier grass attracts the stem borer moth, but exudes a sticky residue that suffocates it.

The district has other common weeds: datura (*Datura stramonium*), black jack (*Bidens pilosa*), Macdonald eye (*Parviflora garinsoga*), oxalis (*Oxalis latifolia*) and couch grass (*Pennisetum clandestinum*). Lablab or mucuna easily smothers these weeds.

Dolichos lablab cover crop

Dolichos lablab as a cover crop attracts a wide range of both beneficial and devastating pests. It provides a good habitat for beneficial spiders and ladybirds; the high moisture in the soil increases the number of earthworms. On the other hand, it provides habitat for devastating rodents, aphids, African bollworm and bean fly. Before adopting conservation agriculture, farmers had problems with termites feeding on a growing crop, especially maize. After farmers started leaving stover in the field as mulch, the termites had enough to feed on and no longer fed on the growing maize. Lablab's falling leaves also provided termites with a lot of food.

Effect on yields

Conservation agriculture brought some adjustments in some agronomic practices. Interrow spacing increased to create room for the cover crop, reducing the amount of cereal crop planted. But through the symbiotic association of the two crops, the cereal crop yields dramatically increased. The planting calendar in conservation agriculture fields changed; farmers did dry planting.

Effect on compacted soil

Farmers in Siaya have relied on surface runoff to detect hardpan in their fields. In some cases, farmers detected hardpan when crops were stunted and the roots ran on the surface. Continued trampling by livestock on cropping fields has been the major cause of hardpan. To reverse it, farmers have resorted to subsoiling with cover crops and equipment such as subsoilers. Those who had access to animal-drawn subsoilers and rippers used them to break the hardpan. They also reserved some of their land for livestock to avoid conflict with crops.

Socio-economic aspects

Agriculture is the main economic activity for people of Siaya District. Local farmer groups, such as farmer field schools, have increased farmer bargaining power through training, marketing produce and accessing credit from local microfinance institutions. The farmer field schools were established by the Conservation Agriculture and Sustainable Agriculture and Rural Development project. Upon graduation, field school members became qualified trainers positioned to facilitate new farmer field school groups for a fee. Field school members participated in farmer exchange visits, enabling them to diversify farming techniques to make farming more profitable.

Establishing field schools was not difficult because of family links and cohesive communities. Field schools for conservation agriculture had a well-developed curriculum. Farmers associated with a field school or any other group in the district had received extension services from Ministry of Agriculture staff and other service providers. Other stakeholders with funded projects found easy entry into the community through the farmer field schools.

Through participatory technology development and agroecological analysis farmers had the opportunity to analyse conservation agriculture. However, this was limited to farmer field schools. Conservation agriculture school groups in the district formed an umbrella farmer field school network to transform the schools into a non-governmental organization to spearhead farmer interests nationally and internationally.

Effect of conservation agriculture on HIV/AIDS consequences

One of the disasters facing the district is the scourge of HIV and AIDS. The high HIV prevalence, 38.4%, threatens the existence of the district population. This disease has increased poverty by directing nearly all family resources towards treating and supporting the infected. Increasingly widows and children head households. Youth drop out of high school. The effect on the youth and other economically active people in the district is worrying. The affected families spend most of their time attending to the sick and have little time for farming. This inhibits agricultural production because fewer people work. In some families, only the elderly have been left to take care of the children after their parents died. The elderly and the children, in most cases, cannot carry out farming successfully because it is labour intensive.

Conservation agriculture presents a ray of hope to affected households by providing a farming practice that is not labour intensive. Farmers can use the extra time available from conservation agriculture to generate other income. The high yield generated by conservation agriculture farming has led to improved nutrition for HIV and AIDS patients. Lablab especially is very high in protein.

Extent farmers used conservation agriculture and its limitations

Dolichos lablab was one of the most popular cover crops among those who adopted conservation agriculture in the district. This crop was preferred over mucuna, since farmers ate both the leaves and the seeds (bean). One farmer in the Onalo Boke Farmer Field School liked the lablab cover crop so much he would not cut it down to pave the way for other crops. Farmers managed to plant mucuna and lablab in relay to suppress nematodes, which thrive if lablab is planted as a pure stand. Intercropping lablab with maize led to improved soil fertility and reduced termites, a menace in maize fields, resulting in increased yield. Biological subsoiling with lablab, mucuna and cowpeas reduced costs by eliminating mechanical subsoiling.

Farmers who did not belong to a farmer field school had access to conservation agriculture equipment through trained equipment providers and animal hirers, who could prepare land and plant in time for the season.

Factors that hindered conservation agriculture

- Lack of adequate conservation agriculture equipment and training for farmers to operate and maintain equipment has limited conservation agriculture.
- Lack of enough draught animals limited their use. Tractor power in the district was scarce, mainly limited to a few private operators. They charged KES 2000–4700 per acre for first ploughing and KES 1600–3700 for second ploughing, which many smallholder farmers viewed as exorbitant.
- Free grazing in harvested fields greatly hampered conservation agriculture. The animals fed on crop residue, reducing biomass and compacting soil, but animals directly provided manure as they grazed, improving soil fertility.
- The land tenure system favoured men in land ownership. Women willing to adopt conservation agriculture could not do it without consent of their male kinsmen.
- Inadequate extension support from the Ministry of Agriculture and other organizations limited extension services. In the whole district, only three extension agents were trained on conservation agriculture.
- Conventional ploughing was promoted by the private hirers who owned tractor- and animal-drawn ploughs.

8 Gaps, challenges and the way forward

Gaps

Conservation agriculture in the district was not completely successful due to missing links between farmers and service providers.

- Information on improved farming was inadequately disseminated. Established structures to acquaint the farmers with market information were limited.
- The district lacked links between farmers and suppliers. Suppliers did not meet farmers' needs and gave the farmers little information on the inputs. Farmers who needed a particular input did not know where to get it; stockists did very little to let farmers know the range of inputs they had.
- Available and accessible conservation agriculture equipment was inadequate. Local manufacturers, artisans and suppliers did not stock equipment for farmers to purchase.
- Government policies to guide collaborators and stakeholders on conservation agriculture were unclear. A forum for all conservation agriculture stakeholders was not established.
- Most collaborators in conservation agriculture in the district worked with government extension staff. They were often transferred, creating a vacuum in implementing the technology.
- Agriculture is considered a risky venture. Financial institutions usually hesitated to offer credit to farmers.
- Cooperative societies, which could promote crops grown in the district, were inadequate.
- Stakeholders only targeted maize and lablab for conservation agriculture, leaving out other crops. Farmers took a step ahead and tried tuber crops, such as sweet potato and cassava.
- Conservation agriculture was promoted in only two divisions in the district and restricted to a few locations.

Challenges

Conservation agriculture in the district faced a number of challenges:

- One of the greatest challenges was selecting and managing cover crops. So far, *Dolichos lablab* was the most prevalent. Getting seed, crop mixes and associates were a challenge. District farmers realized that if lablab was intercropped with maize, it would require special management, which meant more labour to ensure it did not smother the maize. In some plots, where timely management was not carried out, maize yield drastically reduced. However, when planted in rotation as pure stand, it became easy to manage, since it did not require much attention.
- Lablab required regular spraying to control insects that feed on its foliage, making it expensive and difficult for most farmers to sustain.
- Conservation agriculture technology recommends using *Dolichos lablab* as a cover crop because it is resistant to drought, its leaves cover the soil, it fixes

nitrogen, it biologically subsoils, and its seeds and leaves are edible. Because it was a new legume promoted under conservation agriculture, there was a seed shortage and farmers were not able to buy seeds in bulk to sell to others. Lalab was becoming popular, but its spread was hindered by limited supply.

- Illiteracy affected the quality of agroecological analysis. Farmers became innovative in their conservation agriculture but could not relate the ideas to practical application.
- Sustaining the farmer field schools after the grants run out posed a challenge, since conservation agriculture benefits were not immediate. Farmers received grants only in their first season and continued to do the participatory technical development on their own. This made some members drop out.
- Siaya farmers and facilitators agreed that conservation agriculture was a very good technology, which could turn around the food security situation in the district. However, they said it was quite expensive for an ordinary farmer to adopt and practise. Many farmers in the district could scarcely afford anything that could improve yield. They resorted to poor agricultural practice not by choice but by circumstance. With great poverty in the district, organizations promoting conservation agriculture in Siaya had a daunting task of ensuring that conservation agriculture became normal agricultural practice.
- Some conservation agriculture equipment was brought in by technical cooperation programmes and sustainable agriculture and rural development projects. These were not sufficient and were provided to farmer field schools in only a few divisions. Farmers who were not field school members, but had heard about the technology and were interested in it, could not gain access to conservation agriculture equipment. Each farmer field school had between 25 and 30 farmers. Each farmer field school averaged one or two different pieces of conservation agriculture equipment. Farmers had to share the few tools available. Animal-drawn mulch planters were not locally available, even where individual farmers wanted to buy them.
- The personnel trained in conservation agriculture and in a position to offer adequate extension services to farmers in Siaya were very few. The Conservation Agriculture and Sustainable Agriculture and Rural Development project trained only three facilitators, and one district coordinator offered local technical support on conservation agriculture. This number, compared with the district area and population, was not enough to have substantial impact. The third World Congress in Conservation Agriculture, which took place in Nairobi in October 2005, created a lot of awareness in the country. The congress was attended by all district agricultural officers, including those not in Sustainable Agriculture and Rural Development project districts, especially those neighbouring Siaya. The neighbouring districts needed facilitators to train their district extension staff, so conservation agriculture could trickle down to farmers. Lack of a scaling-up mechanism hindered promotion in non-project regions.
- Farmers in Siaya District used to allow their livestock to graze on the farm after harvest. This degraded the soil since livestock consumed all the plant residue and compacted the soil, creating hardpan. Land was not adequately

consolidated in the district, so there is no clear dividing line between grazing land and cropland. The challenge was to try to change farmer mindset to come up with a plan to rear livestock and continue conservation agriculture.

- Striga weed was still a major threat to cereal crops.
- Even though there was an increase in conservation agriculture equipment from the technical cooperation project, it was still minimal.
- The schools established to promote conservation agriculture were few and in only two divisions. The impact created was still below expectations because there were too few schools.
- Farmer field days and farmer exchange visits were key activities that aided promoting conservation agriculture in the district. However, the events were too few to create a strong impact.
- Some families followed cultural beliefs in the order in which planting and harvesting were allowed. The eldest person in a homestead had to plant, weed and harvest first, before the rest of the family. This adversely affected conservation agriculture, which required timely planting.
- Men controlled family assets, such as land, in Siaya. Women had no control, despite actively participating in creating wealth. This posed a very big challenge.

Way forward

Conservation agriculture presents the only sustainable agricultural practice with the potential to address food insecurity in the region. The following suggestions present some ways to promote conservation agriculture in the district:

- Invest heavily in research and development.
- Scale up conservation agriculture to other district divisions to make an impact.
- Diversify some aspects of conservation agriculture to accommodate other crops.
- Make conservation agriculture equipment available from manufacturers and farm suppliers.
- Establish a conservation agriculture resource centre in the district to promote the technology.
- Encourage government to put in place policies that promote conservation agriculture, such as including conservation agriculture in primary and secondary schools, colleges and universities.
- Encourage the Ministry of Agriculture to train all its extension staff in conservation agriculture and to facilitate the trained staff to reach as many farmers as possible.
- Have collaborators in agriculture come together and address challenges affecting farmers in respect to conservation agriculture.
- Organize adequate and harmonized conservation agriculture extension services covering the seven divisions in Siaya, especially in Boro, Wagai and Karemo. This would ensure that most farmers had information on conservation agriculture to make a decision on whether or not to adopt the technology.

- Make conservation agriculture equipment available in major markets within every division in Siaya, so farmers who have information on how to operate them can easily purchase them from local traders. To achieve this, more artisans need to be trained to fabricate simple conservation agriculture equipment, while more complicated machinery should be made by local manufacturers at a cost affordable to the farmer. Before the equipment is made, create demand by extensive marketing, so farmers will want to acquire the equipment.
- Encourage stockists to stock farm supplies and offer them at affordable cost. They should also be spread throughout the district, not just in the major urban centres. To achieve this, there should be an extensive campaign to educate the farmers on the value of using certified seed to reap maximum benefit from their farms.
- Train farmers on better storage techniques, so they do not have to accept very low prices but instead wait until prices are better.
- Hold district conservation agriculture field days not just once in a project's lifetime, but every season and even after the project's end. All stakeholders should continue supporting field days, so that education about conservation agriculture can continue.
- Form a conservation agriculture stakeholder forum in the district, so different institutions can be aware of the technology available to farmers. The same forum should be organized so that farmers are not exposed to too many technologies at the same time. Stakeholders should coordinate to avoid conflicting technology, which may confuse farmers.

Conservation agriculture farmers recognized the importance of farmer extension and were keen to expand it. The following suggestions were given for strengthening extension:

- To create more conservation agriculture groups, farmers in the pilot groups can become facilitators of new groups, so more farmers can be trained in conservation agriculture.
- Current conservation agriculture farmers should make an effort to train and support their neighbours to take up conservation agriculture. They can organize farm demonstrations and invite neighbouring farmers. They can assist interested neighbours in trying out conservation agriculture.
- Organize farmer field days, where conservation agriculture farmers demonstrate the technology.
- Inform the wider community about conservation agriculture through formal meetings, such as *barazas* (gatherings organized by the chief), farmer field schools and other development meetings.
- Support, encourage and organize exchange visits within and outside the districts to strengthen farmer learning.

9 Conclusions

Farmers can increase their crop production by adopting conservation agriculture and eventually reduce their production cost. Successful conservation agriculture was evident only among a few committed farmers in the farmer field school groups adopting conservation agriculture. Most farmers adopted using a permanent lablab soil cover, although a few have started using mucuna and desmodium as cover crops. Conservation agriculture will make food insecurity in districts like Siaya a thing of the past.

Striga is the most detrimental parasitic weed in Siaya District. Conservation agriculture has brought a natural way to eradicate striga by using cover crops, which also enhance soil fertility.

Farmer field schools, field days and farmer exchange advanced conservation agriculture in Kenya. When farmers learn from one another the knowledge gained is immediately translated to action. Fortunately, conservation agriculture shows visible benefits within one season and develops farmer confidence.

Adopting conservation agriculture can bring back life to degraded soils, assuring farmers their soils will produce for them without compromising its ability to produce for future generations. Crop residues are left in the field to improve soil fertility, unlike the past when they were burned or grazed.

Conservation agriculture technology needs both short-term support from institutions and organizations and a long-term commitment by the local communities, although most farmers need short-term benefits and minimal risks.

The major constraint to adopting conservation agriculture by farmers is reluctance to change. Very few farmers showed the foresight, flexibility and innovation necessary to meet the challenges posed by soil degradation, deterioration of on-farm ecology and declining yields caused by conventional farming.

Labour is short due males moving to town in search of formal employment. This is aggravated by the scourge of HIV and AIDS, which kills many people daily. It has led to children and older people predominating in many homesteads, and some households are child headed. This situation hampers adopting conservation agriculture.

All the government agriculture extension staff should be trained so they can offer conservation agriculture extension services to farmers in the whole country. Staff also need to be able to go where the farmers live and farm. Artisan training will ensure that farmers can buy the equipment, spare parts and repair facilities they need within their area.

Conservation agriculture has the potential of getting youth back to the farm. It is as simple as using a machine and literally sitting back and watching the crop grow. This will cut down on youth migrating to towns in search of employment.

To address the various challenges facing agriculture the government needs make some concerted effort to help farming communities take advantage of existing opportunities:

- Invest in irrigation agriculture to improve productivity and reduce effects of adverse weather on crops.
- Increase competition in agricultural supplies to reduce prices.
- Improve rural infrastructure, particularly roads and electricity, to spur agricultural development.

- Improve technology development, transfer and adoption by improving links between research, extension and farmers.
- Encourage agribusiness to make agriculture more attractive and competitive through processing and adding value.
- Develop an effective agricultural information system to improve agricultural production, processing and trade.
- Improve access to financial services and credit to increase equipment use and improve productivity.
- Promote internal and external trade by increasing agricultural market competitiveness.
- Diversify agricultural production by targeting niche markets, such as horticulture, organic farming and medicinal and aromatic plants.

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Appendix 1 Key informants interviewed

Key informants	Institution or organization	Information provided
District agricultural officer	Ministry of Agriculture	collaborators in conservation agriculture and work done in the district
Department of Statistics	Ministry of Planning and National Development	settlement patterns, wealth category and resource distribution
Mr Wilson	stockist	farm supplies available, sourcing and pricing
Dr GD Odhiambo	Maseno University	striga weed control through push and pull promoted by International Centre for Insect Physiology and Ecology
Ms Carroe Shikuku	formerly with Farming in Tsetse Controlled Areas	conservation tillage, draught-animal technology and crush pens promoted by farming in tsetse controlled areas
Noordin Quiresh	ICRAF	improved fallows and consortium activities related to conservation agriculture
Farmer field school facilitators	Conservation Agriculture and Sustainable Agriculture and Rural Development and Ministry of Agriculture	farmer field school methods, application and challenges
Farm manager	Dominion Group of Companies	farming systems practised on the farm
Some individual farmers	Farmer groups	conservation agriculture tillage operations, equipment hire system and HIV/AIDS impact on agriculture
Farmer field school	Conservation Agriculture and Sustainable Agriculture and Rural Development	understanding conservation agriculture, challenges, equipment, cover crops, weeding and field school methods
Equipment hirers	Conservation Agriculture and Sustainable Agriculture and Rural Development	hirer system, hire charges, clients and acreage

Appendix 2 Striga (witch weed)

The genus *Striga* (witch weeds) consists of several parasitic species that infect the major food crops in sub-Saharan Africa. There are about 40 *Striga* species; 11 attack cultivated crops and 3 cause serious problems, *Striga hermontheca*, *S. asiatica*, *S. generoides* (Musselman 1987; Roynal-Roques 1991, 1996). Most of the *Striga* species are native to Africa; the infestation extends from West Africa to the east of southern Africa. The livelihood of some 300 million people is affected by the problem (Lagoke et al. 1994). *S. hermonthica*, commonly known as the giant or purple witch weed, is the most destructive species and is considered the principal biological constraint to cereal production in sub-Saharan Africa (Musselman 1987; Parker 1993).

Unfortunately, food security in this region needs to be addressed because most of the habitants are poor. For instance, in eastern and southern Africa most farmers have cash incomes of less than USD 1 per day. Farm families are large, suffer three to five hunger months when they eat little, have malnourished children, and an HIV prevalence of 25%. Women do most of the farm work, gather fuelwood and fetch water—all very hard work. Men do most of the off-farm work. Maize, the staple food, yields about 1 tonne/ha. The areas badly affected by striga are where many of the poorest people live, who depend mostly on cereals for food.

Given the magnitude and importance of the striga problem, both national and international agricultural research and development institutions working in western Kenya have put considerable effort over the last 10–15 years in developing control measures.

Promising options are emerging: tolerant and resistant crops; herbicide-tolerant crop varieties; hand-pulling; crop rotations using trap crops, grain and herbaceous legumes, trees and shrubs; improved soil fertility through nitrogen-fixing legumes, fertilizers and livestock manure. In addition, the institutions have been involved in developing participatory tools to disseminate the information.

Striga biology and crops infected

Striga is a genus within the family Scrophulariaceae. It consists of several obligate root hemi-parasites that attack most food crops in Africa including sorghum (*Sorghum* spp.), upland rice (*Oryza sativa*), millet (*Pennisetum americanum*) sugar cane (*Saccharum officinarum*) and cowpea (*Vigna unguiculata* **(**M'Boob 1986**).** The genus consists of approximately 35 species—11 that attack cultivated crops and 3 that are problematic: *Striga hermontheca*, *S. asiatica*, *S. gesneroides* (Musselman 1987; Roynal-Roques 1991, 1996). Striga attaches itself to the host roots and survives by siphoning off minerals and water, causing serious damage and reducing yield in the infested crop (Shah et al. 1987; Stewart and Press 1990). In addition, the parasite exerts phytotoxic effects on the host crop that often results in stunted growth (Ransom et al. 1996). The causes of the phytotoxic effects are not yet clearly understood. Removal of large amounts of nutrients, particularly N, P and K (Braun et al. unpublished data) could be important factors.

Striga life cycle

Striga completes its life cycle simultaneously with its host, producing numerous minute, dustlike seeds (0.2–0.3 mm). A well-established *S. asiatica* is capable of producing up to 58,000 seeds and *S. hermontheca* 200,000 seeds (Parker and Riches 1993). The seeds require an after-ripening stage and will germinate only in the presence of a germination stimulant produced by roots of host plants (and sometimes non-host plants) after they have been preconditioned and exposed to moisture at an appropriate temperature (Parker and Riches 1993; Gbèhounou 1998).

Striga seed bank

Effective control of striga is difficult mainly because of its inherently enormous reproductive ability and seed longevity in the soil. On average, the striga seed bank can increase by 340% if no control measures are undertaken; as few as three plants per square metre can sustain the striga seed bank in the soil (Delft et al. 1997). The seeds can also remain viable in the soil for more than a decade awaiting a suitable host (Bebawi et al. 1984; Eplee 1998). However, natural striga seed demise has been observed in certain soils (Odhiambo and Ransom 1995; Ransom 1996). Factors contributing to the natural seed demise are not clear but Pieterse et al. (1996) and Odhiambo (1998) associated it with the soil micro-organism's activities and Gbèhounou (1998) with soil moisture. Identification of factors contributing to this phenomenon and their exploitation would be a major breakthrough in solving the problem of striga.

Source: GD Odhiambo, KARI

No-till pneumatic direct seeder on display at Lengetia Farm

No-till pneumatic direct seeder in action on one of the Lengetia fields

Mr Session of Lengetia Farm explains the operation of the pneumatic direct seeder to small-scale farmers at one of the farmer field days in the district

Brazilian direct seeder planting on a small-scale farm in Laikipia District

A field of barley under conservation agriculture in Lengetia Farm

Sorghum field planted using CA methods on Lengetia Farm

A Lengetia Farm employee (right) showing study team members wheat grown using conservation agriculture methods

Mr Session of Lengetia Farm displaying moist and fertile soil in one of the fields left fallow

Mr Session of Lengetia Farm displaying resistant watergrass in one of the canola fields

Amaranthus weed emerging in a crop field in Lengetia Farm

Mr Maina, an employee at Lengetia Farm, points out an amaranthus plant in a crop field

A wheat and barley farm under conservation agriculture in Wangu Farm

Heavy tine harrow implement operating on Wangu Farm

Pneumatic direct planter manufactured by Ndume, on Wangu Farm

A pneumatic direct planter on Wangu Farm

Light tine harrow in operation at Wangu Farm

Small-scale farmer demonstrating animal-drawn direct planter to participants during Kisima field day

Farmer Muriuki demonstrating an animal-drawn direct planter during a farmer field day organized on Kisima Farm

Farmer Muriuki, who hires out equipment, on a field of wheat he planted with an animal-drawn direct planter

Crop residue heaped in store for livestock—a common practice among small-scale farmers in Laikipia

Thome Farmer Field School members meeting in their self-built 'school' structure

A Thome Farmer Field School trial plot intercropping maize and Dolichos lablab

Esther Muthoni practising conservation agriculture on her farm

Maize intercropped with desmodium

Artisans during a training session

Locally manufactured Magoye ripper and subsoiler, which can fit onto the same frame as the plough

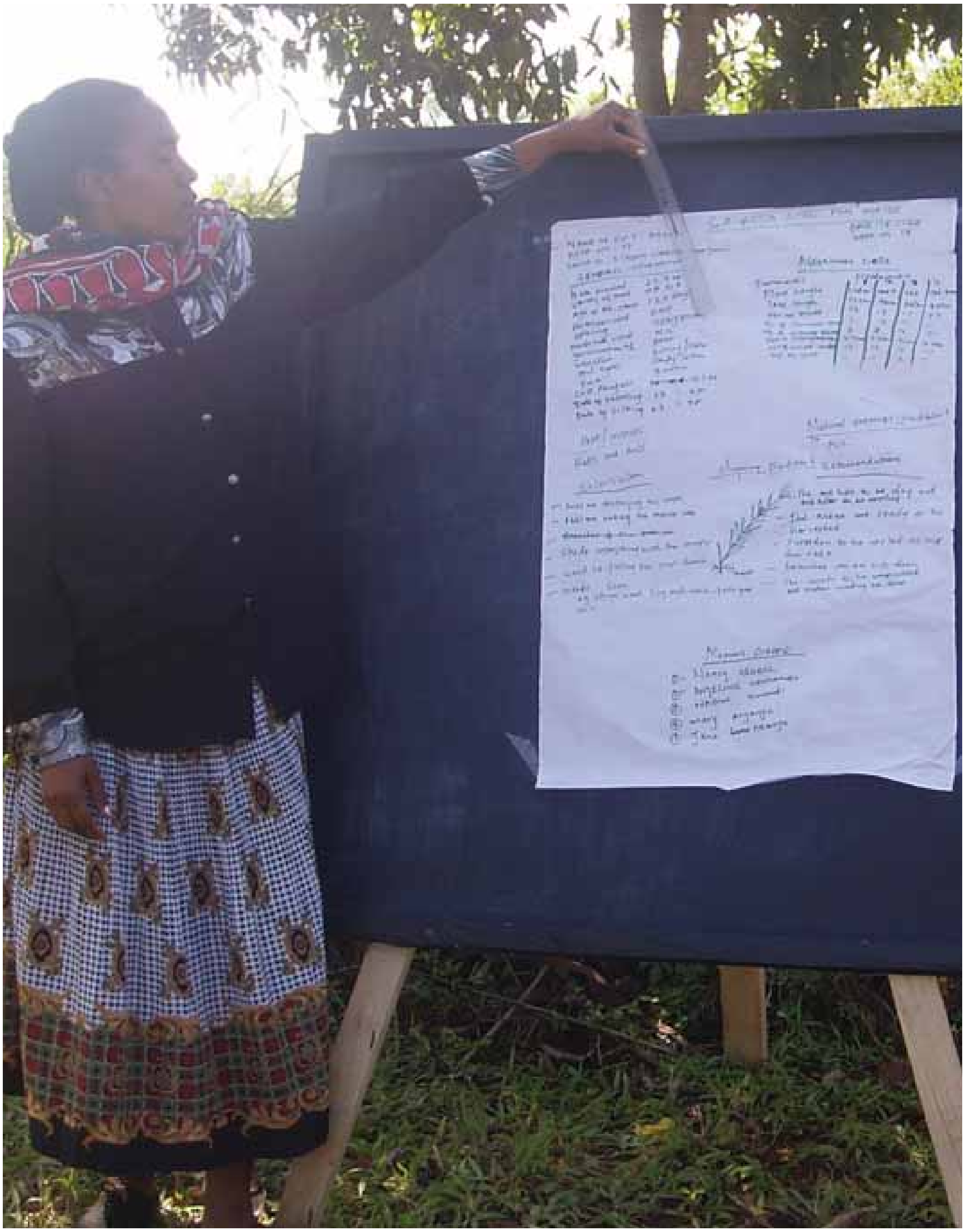
Reduced tillage and direct seeding conservation agriculture equipment

Demonstration planting using an animal-drawn Fitarelli mulch planter

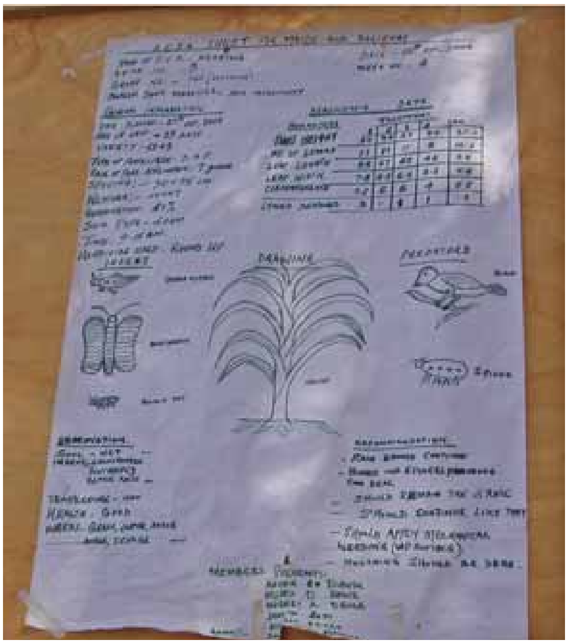
A pure stand of Dolichos lablab

Participants in a Siaya farmer field school in the field

Dolichos lablab *after slashing*



A farmer making a presentation at a farmer field school



A typical teaching tool at a farmer field school

Mariwa Farmer Field School during a training session


Mr Okelo explaining to participants how a Fitarelli mulch planter works at Bar Sauri Field Day