Journal of Developments in Sustainable Agriculture 7: 134–147 (2012)

Is Conservation Agriculture a Solution to Dry Land Rain-fed Farming? Experiences and Perceptions of Smallholder Farmers in Laikipia District, Kenya

Daniel Mwangangi Kinyumu*

Ministry of Agriculture, Laikipia District, P.O. Box 1655, 10400, Nanyuki, Kenya

To improve crop production and soil moisture available to crops in dryland rain-fed conditions, such as those in Laikipia District, Kenya, land management practices that minimize soil structure damage, improve soil organic matter content, and extend the duration of soil moisture to crops must be embraced by farmers. Rainfall is inadequate in this region, and most smallholder farmers till land continuously for long periods, leading to depleted soils that are easily eroded. Conservation agriculture (CA), which incorporates the benefits of soil and water conservation, could offer a solution to these farmers. This study evaluated farmers' perceptions of and experiences with CA adoption. Pretested questionnaires were administered to 50 smallholder farmers practicing both CA and conventional farming (CF). Basic data on farmers' gender, age, education, duration of CA practice, and factors that affected their adoption of CA were obtained. Farm yield data for maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.) from 10 smallholder farms cultivated under CF and CA were compared during the 2010, 2011, and 2012 rainy seasons. In-depth focus discussions were held to clarify farmers' responses. The results of the yield comparison showed that grain yield for both crops doubled under CA as compared to CF. This substantial increase in yield could dramatically improve household food security. Despite the benefits of CA and deliberate efforts by the Ministry of Agriculture and stakeholders to promote CA in the district, the adoption rate among smallholder farmers is still low. This study found that, among other factors, lack of tools or equipment and a lack of technical extension staff for CA contributed to its low adoption rate. Because CA can offer increased yield, while also contributing to sustainable agriculture and environmental conservation, CA will remain a viable option for farmers in the district.

Key words: *Conservation agriculture, Crop production*, *Land management practices,* Duration of soil moisture, *Sustainable agriculture*

Introduction

General overview

Increasing farm productivity has gained renewed emphasis from international development organizations since the 2007–2008 food crisis. Africa lags behind compared with global agricultural productivity, and there is long-standing food insecurity across the continent (World Bank, 2008). The Kenya National Vision 2030 identified agriculture as one of the six key economic sectors expected to drive the economy to a projected 10% growth annually over the next two decades (Government of Kenya, 2004).

Biophysical and farming conditions in Laikipia District

The Laikipia District of Kenya covers 972,000 ha, extending from the northeastern foot of the Aberdares to the western foot of Mt. Kenya and lying about 200 km north of Nairobi. The influence of Mt. Kenya produces a steep ecological gradient on the plateau, giving rise to several elevation-related agroecological zones ranging from subhumid (agroecological zone IV) to semi-arid (agroecological zones V and VI;

Received: September 1, 2012, Accepted: November 30, 2012
* Corresponding author: Daniel M. Kinyumu, P.O. Box 6, 60300 Isiolo, Kenya.
Tel: +254 726726638 or +254 734252056, E-mail: dnthusi@yahoomail.com

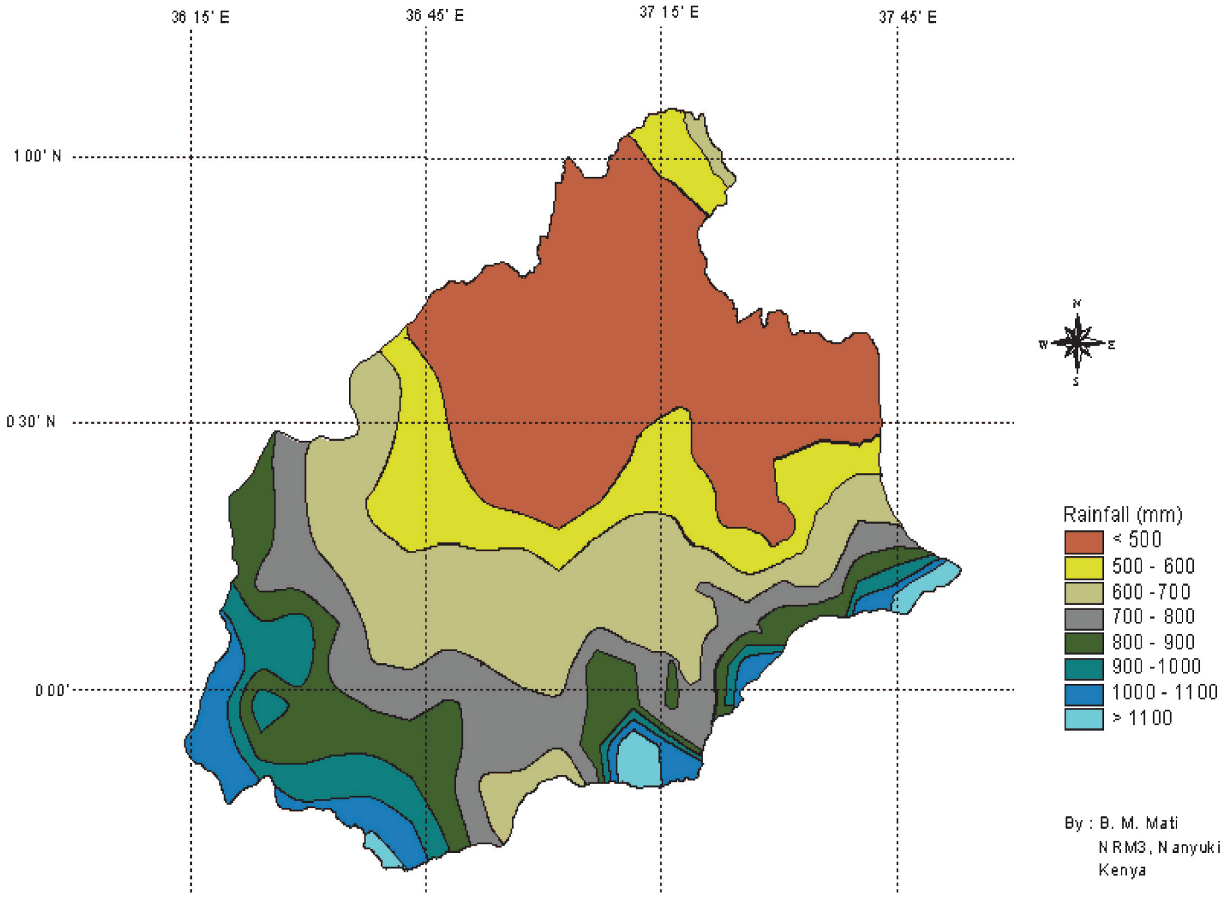

Fig. 1. Rainfall distribution pattern across Laikipia District (Source: District Surveyor, Laikipia).

Jaetzold and Schmidt, 1983). The district has a bimodal rainfall pattern, with peak rainfall in April and October. Temperatures are relatively low, with mean annual temperatures ranging from about 18 to 20℃ (Jaetzold and Schmidt, 1983). The rainfall distribution in the Laikipia District is such that the south-western part and some parts of the southeast receive more rainfall than the northern part (Fig. 1)

The farming system in Laikipia is largely conventional, involving plowing, harrowing, planting, and weeding. Harvested crop residue is collected and stored for livestock because pasture is in short supply (Kaumbutho and Kienzle, 2007). Rain-fed dryland subsistence farming is the main source of livelihood for most households in the district. In recent years, this livelihood strategy has been affected by climate change, prevalent droughts, and seasonality of the rains (C4D, 2010).

A lack of rainfall in Laikipia has led to crop failure, low farm crop yield, and low household incomes. This problem is compounded by the fact that over the years farmers have used cultural practices that expose soils to dry weather conditions, leading to great loss of moisture (Kaumbutho and Kienzle, 2007). The concept of conservation tillage aggregates a number of soil and water management and conservation practices under a single banner for delivery to farmers (Garcia-Torres *et al.*, 2003; Knowler and Bradshaw, 2007). A lack of quality farm inputs and soil infertility have led to low crop yield (Kiteme *et al.*, 1998). The adoption of sustainable agricultural practices was identified in a government strategy paper on revitalizing agriculture as a lasting solution to food insecurity in the arid and semi-arid regions of the country (Government of Kenya, 2004).

Conventional farming versus conservation agriculture

Conventional farming (CF) is defined as farming approaches that have been used over a long period of

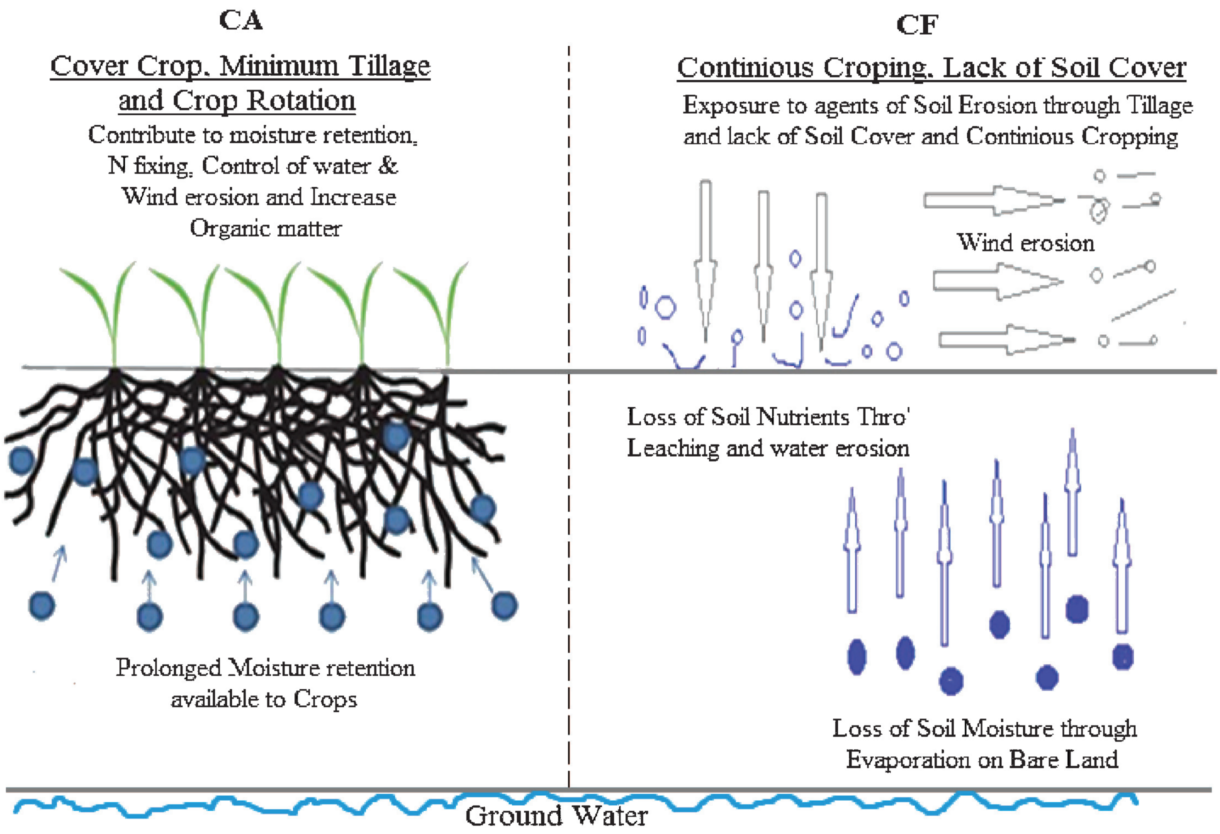

Fig. 2. How conservation agriculture (CA) and conventional farming (CF) differ in terms of the effects of cover crop and tillage on soil erosion and groundwater.

time. CF is characterized by large capital investments; monocropping; use of hybrid crops; extensive use of pesticides, fertilizers, and external energy inputs; and high labor efficiency (Gold, 2012).

Conservation agriculture (CA) has come to mean agriculture that features little or no soil disturbance, no burning, direct seeding into previously untilled soil, crop rotation, and permanent soil cover, particularly through the retention of crop residues (Harrington, 2008). In CA, 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 (FAO, IIRR, and ACT, 2005). Figure 2 illustrates how CA compares with CF.

CA is based on integrated management of soil, water, and agricultural resources (Gichuki *et al*., 1998). Crop rotation promotes biological subsoiling, which facilitates plant root growth and water infiltration, and it breaks the cycles of crop pests and diseases. Plowing and harrowing by farmers are reduced to a minimum or, where possible, abolished altogether (Mazvimavi *et al*., 2010). Soil tillage is the single most energy-consuming farm activity by farmers, so eliminating tillage saves a lot of energy. Soil erosion decreases significantly without tillage because of greater aggregation of soil particles and infiltration of water (Rhoton *et al*., 2002).

Although herbicides have to be applied in the first few years of CA practice, the long-term approach of CA is to manage weeds through agronomic means such as the use of cover crops and minimal mechanical means (superficial weeding with a hoe or machete; FAO, 2006). CA holds tremendous potential for all sizes of farms and agro-ecological systems, but its adoption is perhaps most urgently required by smallholder farmers, especially those facing acute labor shortages (FAO, 2012). CA is widely recognized as a best management practice that improves soil productivity, reduces runoff and erosion, protects water quality, and improves environmental quality (Sullivan *et al*., 2008). CA offers a powerful option for meeting future food demand by improving crop production levels, while conserving resources and protecting the environment (Huho *et al*., 2012).

Stages of CA development

Before analyzing the actual farm benefits of CA, it is important that farmers understand the transition from CF to CA, which is a gradual process that can be divided into four theoretical phases (Fig. 3) (FAO, 2004).

During the first phase, there is improvement of tillage techniques; decreases in labor, time, and use of draught animals or motorized power; and an increase in the use of herbicides to control weeds; no increase in farm output is foreseen. During the second phase, there is improvement of soil conditions and fertility; decreases in labor, time, and draught animal or motorized power use; a reduction of production costs; and an increase in yields and net farm income. During the third phase, there is diversification of cropping patterns, increased and more stable yields, and increased net farm income and soil fertility. In the fourth phase, the integrated farming system is functioning smoothly; production and productivity are stable, and the full technical and economic advantages of CA can be appreciated by the farmer.

Adoption of CA by farmers

Despite being the target of concerted efforts by various initiatives, smallholder farmers have only minimally adopted CA concepts (García-Torres *et al*., 2003). The aim of promoting CA in Laikipia was to bring sustainable farming and rural development to

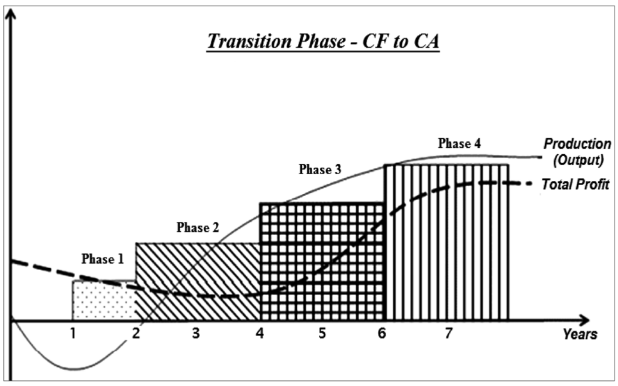

Fig. 3. The phases of transitioning from conventional farming (CF) to conservation agriculture (CA) (Source: Webmaster, FAO, 2004).

farmers through agricultural education (Fig. 4). It is also being promoted as a solution to increase productivity and food security, while preventing erosion and maximizing the ecological functions of the soil (Todaro and Smith, 2009). Although CA is not new for large-scale farmers in Laikipia, some of whom have practiced it for the last three decades, smallholder farmers are struggling to adapt to CA. The average area under CA in Kenya is estimated to be 20 ha for small-scale farmers and about 160 ha for large-scale farmers (Kaumbutho and Kienzle, 2007).

Finding solutions to the farming challenges in Laikipia District

To solve the problems of inadequate rainfall and continuous tillage, which cause land degradation, soil erosion, and low crop productivity, smallholder farmers, the Ministry of Agriculture, researchers, and stakeholders in Laikipia District have engaged in several joint efforts to find lasting solutions to the farming challenges and to improve food security in the district. The findings of research centers, though technically sound, have failed to address the farmers' production challenges, because the practices are developed and tested under researcher-managed conditions and not on smallholder farms, where the actual environmental conditions are found. Unlike the large-scale farmers who have practiced CA for decades, smallholder farmers learned about CA through various donor-funded projects in the district.

The introduction of CA to smallholder farmers in Laikipia occurred in two phases. In the first phase, the Kenya Network for Draught Animal Technology, a non-governmental organization that lasted from 1997 to 1999, worked with various farmers' groups in the district to adopt draught animals and CA. The project provided farmers, on a cost-sharing basis, with subsoilers and rippers as a way of promoting CA. The organization also held several training events for farmers on the CA approach and on-farm data collection techniques.

The second phase started in 2006 on a pilot basis through CA-SARD project and lasted until 2011. The functions during this phase focused on promoting CA through farmer field schools. By 2007 the project had established eight farmer field school groups, with initial membership of 181 smallholder farmers, although these numbers declined over the following few years (Table 1).

Fig. 4. Conservation agriculture (CA) field activities in Laikipia: (1) demonstration of how a jab planter works; (2) pumpkin production under the Tumbukiza CA water harvesting approach; (3) bean crop under CA; and (4) maize crop under CA (Source: District Agricultural Office, Laikipia Central).

The declining membership was found to be related to the abandonment of CA practices by farmers (District Agricultural Office, unpublished data). Unlike other projects, CA-SARD engaged various stakeholders such as policymakers and suppliers of farm inputs, equipment, livestock, and machines. The goal of introducing CA in the district was to encourage alternative farming approaches that could improve crop yields and resilience against drought, while protecting and stimulating the biological function of the soil. Before the introduction of CA techniques in the district, intensive cultivation resulted in the development of hard pans that hindered plant root growth and water infiltration into the soil. Subsequent introduction of crop rotation practices under CA promoted biological subsoiling, which saved farmers the cost of hiring laborers or using mechanical means. Such crop rotation also helped in breaking crop pest and disease cycles.

Few studies have examined farmers' experiences and perceptions in the adoption of the CA approach. Crop yields in Laikipia are very low, even in good years, and there is never enough to guarantee farmers sufficient food and income for one growing season. This means that farmers must put in place strategies and practices that increase household food security or they will be forced to perform off-farm work to supplement farm income.

Materials and Methods

The purpose of this study was to establish in quantitative and qualitative terms the farmers' perceptions and experiences of adopting CA over CF and to examine whether farmers were positive about the benefits

Table 1. Membership in the farmer field school (FFS) groups formed to promote conservation agriculture (CA) in Laikipia District in 2007 and 2010

Farmers' Field School	Location	Membership in 2007			Membership in 2010		
		M	F	**Total**	M	F	**Total**
Jikaze Kilimo Hifadhi FFS	Wiyumiririe	12	3	**15**	12	8	**20**
Mwiyetheri CA FFS	Lamuria	14	4	**18**	18	7	**25**
Marura CA FFS	Marura	14	1	**15**	22	5	**27**
Naitiemu CA FFS	Lkp north	8	2	**10**	8	2	**10**
Mutirithia CA FFS	Daiga	28	6	**34**	5	1	**6**
Magutu CA FFS	Central	21	5	**26**	6	2	**8**
Mazingira CA FFS	Central	25	10	**35**	14	4	**18**
Kileleshwa CA FFS	Central	21	7	**28**	18	2	**20**
Total Farmers				**181**			**134**

Source: Ministry of Agriculture, District Agricultural Office, Laikipia (unpublished data)

of adopting CA. Another aim was to compare the yield of major crops raised by various farmers under CA and CF approaches.

The study consisted of two stages: (1) administration of questionnaires and interviews with the participating farmers, and (2) farm-based assessment of crop yield under the CA and CF approaches. In stage 1, the questionnaire assessed farmers' demographic information and experience in CA practice, author- and farmer-selected factors that may influence the adoption of CA (as elucidated from a preliminary questionnaire), the practices of CA as implemented by farmers, and the suitability of CA based on farmers' perceptions. Stage 2 consisted of analyses of maize and bean grain yield from CA and CF smallholder farms during the 2010–2012 rainy seasons.

During the growing seasons, rainfall data in terms of the amount and number of rainfall days from two weather stations in the CA farming areas of Matanya and Ng'areng'iro in Laikipia were obtained and analyzed (Fig. 5)

Administration of questionnaires and interviews with the participating farmers

Fifty farmers belonging to three farmer field schools at two locations were selected for interviewing and field experiments. The farmers were not chosen randomly within the locations, but rather based on their experience in CA practice which ranged from 1–15 years as indicated in Fig. 6 (4). In May and June 2012, post-experiment questionnaires were administered to the 50 smallholder farmers, including the ones who had participated in the field experimentation. The questionnaire's structure consisted of three parts: (1) basic information about gender, age, education, and number of years in CA practice; (2) farmers' perception of the factors affecting CA adoption based on selected CA factors; and (3) open-ended questions regarding farmers' field experience in CA and CF. The data collected in this research were discussed further and verified during focused group discussions with all participating farmers in attendance.

Farm-based assessment of crop yield under CA and CF approaches

To obtain data on farmers' practical experience, 10 of the 50 participating farmers were asked to participate in field experiments. Farm-based yield experiments were carried out on these 10 farms with the assistance of farmers and field staff using local varieties of maize (*Zea mays* L.) and beans (*Phaseolus vulgaris* L.). Maize and beans are the major staple food crops for the communities living in the study area and hence are planted during the main cropping seasons. Data on crop yields for a period of four growing seasons were recorded by participating farmers. The rainy seasons in which data were collected were the 2010 October to December short rains (SR), 2011 March to May long rains (LR), 2011 October to December short rains, and 2012 March to May long rains growing seasons.

With the help of the extension staff in the Ministry

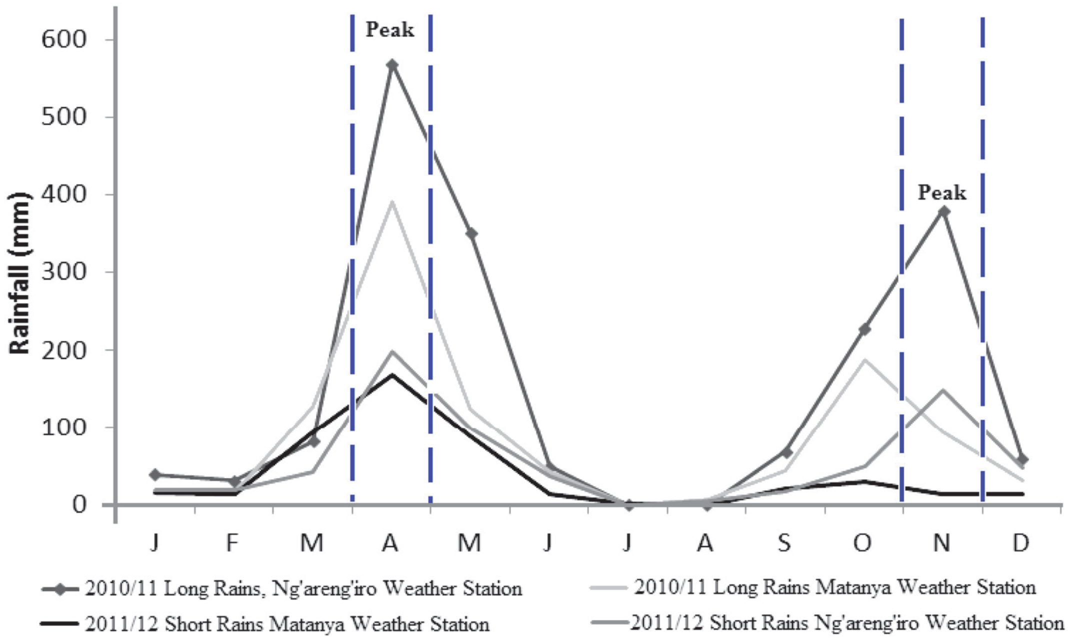

Fig. 5. Temporal distribution of rainfall during the long and short rainy seasons at two weather stations in Laikipia District (Source: District Agricultural Office, Laikipia Central, unpublished).

of Agriculture, four locations were selected based on their potential to practice CA. The farmers participating in this study were trained in farm record keeping, with an emphasis on accurate data entries for crop grain yields. The farmers agreed to participate in an evaluation of crop yield by recording and keeping farm data records for four rainy seasons. The farmers signed a memorandum of work and agreed to abide by all terms and conditions of the memorandum.

One of the conditions was that farmers would divide their farming areas into two equal plots for the yield experiment, one for maize and another for beans. The plots were further divided into two equal portions for CA and CF for each of the crops. The plot sizes were not standardized among the 10 farms because the farms varied in size.

Another condition was that farmers, in collaboration with the author and various assistants, would keep accurate records of the grain yield data from the CF and CA plots at each harvest. To help them achieve this, a data collection sheet was designed. To assist the author with the field experiment and data collection exercises, there were two field extension officers, one divisional extension officer, and one district subject matter specialist. The divisional extension officer and one of the field extension officers had been trained in the CA-based curriculum for farmer field schools, and the district subject matter specialist and the other field extension officer were CA compliant (FAO certification training). Farmers expected technical advice and linkage between the different farmers involved in this study. The author was expected to visit farmers on a fortnightly basis during the growing seasons, whereas the agricultural field extension officers were expected to visit the farms once every week during the growing seasons, otherwise they were expected to stay at predetermined strategic places where the participating farmers could reach them whenever necessary. They also ensured that the participating farmers strictly adhered to all the necessary cultural practices and the terms and conditions of the memorandum of work. Among the technical extension information provided to the farmers during the field interactions was information on timely planting, farm record-keeping, management of cover crops and mulch, tillage practices, the use of CA tools and equipment, crop rotation, and weed control. The harvesting dates were planned so that the author could participate in as many of the harvesting exercises as possible. At least one field extension officer was supposed to be present during the recording of yield data at the time of crop harvesting at the 10 farms.

Daniel's XL Toolbox a free, open-source add-in for Microsoft Excel® was used to analyze and present the quantitative and qualitative data generated in this study.

Results and Discussion

Administration of questionnaires and interviews with the participating farmers

Farmers' basic information and experience in CA practice

Figure 6 presents the data on gender, age, education, and duration of CA practice for the participating farmers. Although both male and female farmers practice CA and both genders were involved in this study, more male farmers participated in this study (68%). The majority of the farmers (76%) were between 45 and 54 years of age. In terms of academic qualifications, 82% of respondents had been educated up to primary level, 12% had secondary education, and 6% had a bachelor's degree. Most of the respondents (78%) had practiced CA for less than 6 years.

Assessment of author-selected factors that may influence adoption of CA

I selected factors that I believed would influence the adoption of the CA approach based on the experiences and perceptions of the farmers, and the farmers' scores of these factors were grouped into three broad categories (Table 2). Those who strongly agreed or simply agreed were grouped as those who "do agree," those who were not sure were classified as "uncertain," and those who disagreed or strongly disagreed were classified as those who "do not agree."

Fifty-six percent of the farmers agreed and 32% did not agree that lack of skills in CA practice contributed to low adoption of the CA approach. Twelve percent agreed and the remaining farmers did not agreed that the low adoption of CA by farmers was because farm inputs are expensive. The farmers were evenly split on the next factor, with 50% agreeing and 50% disagreeing that resistance to change contributed to low adoption of CA. Sixty percent of the farmers agreed and 38% did not agree that a lack of CA extension materials contributed to low adoption of the CA ap-

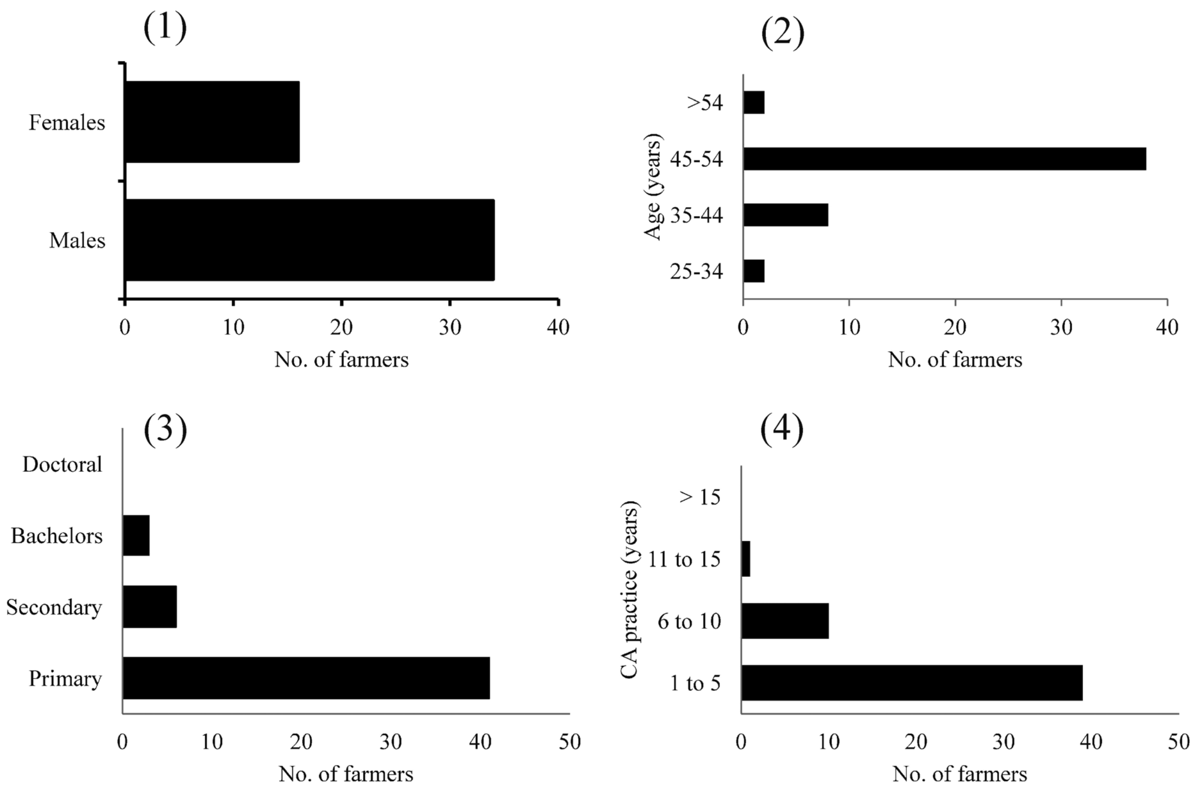

Fig. 6. Frequency histograms representing the number of participating farmers by (1) gender, (2) age, (3) education level, and (4) years of conservation agriculture (CA) practice.

Table 2. Farmers' assessment of author-selected factors that may influence the adoption of conservation agriculture (CA)

Factors	No. of farmers scoring each factor							
	Do agree			Uncertain		Do not agree		
	SA	A	**% TS**	NS	**% TS**	D	SD	**% TS**
Lack of skills	3	25	**56**	1	**2**	15	1	**32**
Farm inputs are expensive	2	4	**12**	0	**0**	41	3	**88**
Farmer resistance to change	7	18	**50**	0	**0**	22	3	**50**
Lack of CA extension materials	2	28	**60**	1	**2**	16	3	**38**
Average % TS			**45.6**		**1.0**			**53.4**

$n=50$
SA, strongly agree; A, agree; NS, not sure; D, disagree; SD, strongly disagree.
% TS (total score) sum of the number of farmers who agree, are uncertain, or do not agree divided by n and then multiplied by 100

Table 3. Farmers' assessment of farmer-selected factors that may influence the adoption of conservation agriculture (CA)

Factors	No. of farmers scoring each factor							
	Do agree			Uncertain		Do not agree		
	SA	A	**%TS**	NS	**%TS**	D	SD	**%TS**
Herbicides are expensive	10	25	**70**	0	**0**	13	2	**30**
Inadequate CA tools and equipment	8	32	**80**	1	**2**	8	1	**18**
Lack of CA training manuals	2	28	**60**	1	**2**	15	4	**38**
Farmer views are not considered	3	30	**66**	2	**4**	8	7	**30**
Average % TS			**69**		**2**			**29**

$n=50$
SA, strongly agree; A, agree; NS, not sure; D, disagree; SD, strongly disagree.
% TS (total score) equals the sum of the number of farmers who agree, are uncertain, or do not agree divided by n and then multiplied by 100

proach. The majority of the respondents (53.4%) did not agree that the factors selected actually affected CA adoption.

Assessment of farmer-selected factors that may influence adoption of CA

Seventy percent of the respondents agreed that herbicides being expensive contributed to low CA adoption, whereas the remaining farmers disagreed (Table 3). The majority of farmers (80%) agreed that the low adoption of CA was due to inadequate tools and equipment. Sixty percent of farmers agreed that a lack of CA training manuals contributed to the low adoption of CA, whereas 66% agreed that failure to consider farmers' views in CA development contributed to the low adoption rate. In total, 69% of the respondents agreed that farmer-selected factors affected CA adoption.

Practices of CA as implemented by farmers

In addition to the three practices that usually define CA—no or minimum tillage, use of cover crops and mulch, and use of crop rotation—farmers have been implementing other practices as a way of adapting the

Table 4. The number of farmers implementing certain conservation agriculture (CA) practices

Practices	Farmers implementing	% Score	Farmers not implementing	% Score
No tillage or minimum tillage	50	**100**	0	**0**
Use of cover crops or mulch	50	**100**	0	**0**
Use of crop rotation	50	**100**	0	**0**
Water harvesting for CA	32	**64**	18	**36**
Agro forestry	26	**52**	24	**48**

$n=50$

Table 5. Farmers' perceptions of factors related to the suitability of adopting CA with regard to its sustainability and benefits to farmers

Issues Mentioned by farmers on sustainability and benefits of adopting CA	Mentioned		Did not mention	
	No.	***Score***	No.	***Score***
Sustainability				
Nil/minimum tillage is employed	49	***98%***	1	***2%***
Cattle manure is readily available	40	***80%***	10	***20%***
Benefits				
Saves on time and energy in tillage	48	***96%***	2	***4%***
Has reduced labour requirement	44	***88%***	6	***12%***
Yields are higher	43	***86%***	7	***14%***

$n=50$

CA approach. All 50 farmers responded that they did not or only minimally tilled the soil and that they used cover crops and mulch and crop rotation (Table 4). Sixty-four percent of farmers used water harvesting for CA, and 52% practiced agroforestry. The last two have been introduced by farmers as additional practices, based on discussions between the CA promoters in the district and the farmers.

Assessment of the suitability of CA in terms of its sustainability and benefits based on farmers' perceptions

The farmers assessed factors underlying the suitability of adopting CA based on the sustainability as a farming practice and the perceived benefits to the farmers. Ninety-eight percent of the farmers agreed that CA was sustainable because it requires no or minimal tillage, whereas 80% agreed that CA was sustainable because cattle manure was available in most farm households. With regard to the benefits to farmers, 88% of farmers said that time and energy are saved in tillage, whereas 12% disagreed that this factor is important as a benefit associated with CA practice, 86% of farmers agreed that CA is beneficial because yields are higher than in CF.

Farm-based assessment of crop yield under CA and CF approaches

Analysis of maize grain yield from CA and CF smallholder farms during the 2010–2012 rainy seasons

Table 6 shows the results of the farm experiments comparing maize grain yield under CF and CA farming approaches during the 2010 SR, 2011 LR and SR, and 2012 LR cropping seasons. Farm sizes ranged between 2 and 9.6 ha (mean 3.6 ha). Each farm was divided into 4 equal plots, with the following treatments; one for beans under CA, one for beans under CF, one for maize under CA and one for maize under CF.

Taking farm 1 (F1) under maize crop for ~~as an~~ example, the maize grain yields from the 1-ha plot was 12.0 and 11.6 bags/ha under CF (each bag holds 90 kg

Table 6. Maize grain yield data from conventional farming (CF) and conservation agriculture (CA) plots in four rainy seasons: 2010 short rains (SR), 2011 long rains (LR) and SR, and 2012 LR

Farm	Farming system	*Plot size (ha)	2010 SR	2011 LR	2011 SR	2012 LR	Avg. yield/ha
F1	CF	1	12.0a	12.4a	11.6a	13.0a	12.3A
	CA	〃	24.0b	24.2b	22.6b	26.0b	24.2B
F2	CF	2.4	24.0a	24.4a	24.6a	24.0a	10.1A
	CA	〃	48.0b	47.0b	47.8b	48.1b	19.9B
F3	CF	0.8	12.2a	12.0a	12.2a	12.4a	15.3A
	CA	〃	24.1b	26.0b	24.3b	22.4b	30.3B
F4	CF	0.8	12.0a	12.6a	12.3a	12.0a	15.3A
	CA	〃	23.3b	24.1b	22.7b	24.2b	29.5B
F5	CF	0.9	12.6a	13.1a	12.0a	13.8a	14.3A
	CA	〃	23.0b	23.8b	23.2b	25.0b	26.4B
F6	CF	0.5	8.4a	7.7a	8.4a	9.8a	17.2A
	CA	〃	15.6b	14.8b	14.8b	18.2b	31.7B
F7	CF	0.6	7.8a	8.4a	7.3a	8.6a	13.4A
	CA	〃	14.4b	17.5b	14.1b	17.2b	26.3B
F8	CF	0.6	7.2a	8.3a	7.8b	8.4a	13.2A
	CA	〃	14.4b	14.1b	14.8a	16.2b	24.8B
F9	CF	0.8	9.8a	10.2a	9.4b	12.8a	13.2A
	CA	〃	18.6b	21.1b	18.2a	25.2b	26.0B
F10	CF	0.6	7.8a	8.4a	8.1b	9.1a	13.9A
	CA	〃	14.4b	17.2b	15.8a	19.6b	27.9B

Different lower-case letters indicate significant yield differences between the farming methods within each season, and different capital letters indicate a significant difference in the mean yield per unit area or season between farming methods, according to Tukey's HSD test for post-hoc pairwise comparisons in two-factor ANOVA at the 5% level.
* = Each plot size is 1/4 of the actual farm size

of grain) and 24.0 and 22.6 bags/ha under CA during the 2010 and 2011 SR seasons, respectively. On the same farm, the yield of maize grain was 12.4 and 13.0 bags/ha under CF and 24.2 and 26.0 bags/ha under CA during the 2011 and 2012 LR seasons. On all the farms evaluated, the maize performed better under CA than under CF, and the yield doubled in most cases. The lowest and highest average maize grain yields under CF were 10.1 bags/ha on farm 2 (F2) and 17.2 bags/ha on F6, whereas those under CA were 19.9 bags/ha on F2 to 31.7 bags/ha on F6. With regard to seasonal yield, the lowest and highest average maize grain yields under CF were 7.9 bags/season on F8 and 24.3 bags/season on F2, whereas those under CA were 14.9 bags/season on F8 and 47.7 bags/season on F2. The crop yield tended to be greater in LR seasons as compared to SR seasons on most of the farms studied.

Analysis of bean grain yield from CA and CF smallholder farms during the 2010–2012 rainy seasons

Taking F4, with a plot size of 0.8 ha, as an example, the bean grain yields was 4.3 and 5.2 bags/ha under CF (each bag holds 90 kg of grain) and 8.1 and 9.9 bags/ha under CA during the 2010 and 2011 SR rainy seasons, respectively (Table 7). On the same farm, the yield was 4.5 and 5.1 bags/ha under CF and 9.2 and 9.4 bags/ha under CA during the 2011 and 2012 LR seasons. The bean grain yield under CA showed improvement over that of CF on all farms evaluated, and the yield doubled in most cases. The average bean grain yield under CF ranged from 4.9 bags/ha on F5 to 7.0 bags/ha on F10, whereas the values under CA ranged from 10.1 bags/ha on F9 to 16.5 bags/ha on F10. There tended to be a greater bean grain yield during the LR season as compared to the SR season,

Table 7. Bean grain yield data from conventional farming (CF) and conservation agriculture (CA) plots in four rainy seasons: 2010 short rains (SR), 2011 long rains (LR) and SR, and 2012 LR

Farm	*Plot size (ha)	Farming method	2010 SR	2011 LR	2011 SR	2012 LR	Av yield/ha
F1	1	CF	5.2a	6.8a	5.4a	6.6a	6.0A
	„	CA	10.0b	13.5b	11.3b	12.7b	11.9B
F2	2.4	CF	12.0a	12.2a	12.0a	13.2a	5.1A
	„	CA	26.0b	28.0b	24.3b	24.7b	10.7B
F3	0.8	CF	4.1a	4.2a	4.8a	4.6a	5.5A
	„	CA	8.2b	9.0b	8.2b	9.3b	10.8B
F4	0.8	CF	4.3a	4.5a	5.2a	5.1a	6.0A
	„	CA	8.1b	9.2b	9.9b	9.4b	11.4B
F5	0.9	CF	4.4a	4.5a	4.3a	4.6a	4.9A
	„	CA	9.0b	10.0b	8.6b	10.2b	10.5B
F6	0.5	CF	2.5a	3.3a	3.6a	4.0a	6.7A
	„	CA	5.2b	7.0b	7.1b	7.8b	13.6B
F7	0.6	CF	3.1a	3.7a	3.0a	3.4a	5.5A
	„	CA	6.4b	7.3b	6.4b	6.7b	11.2B
F8	0.6	CF	3.3a	3.1a	3.6a	3.2a	5.5A
	„	CA	6.2b	7.1b	6.8b	7.5b	11.5B
F9	0.8	CF	4.2a	4.4a	4.0a	4.6a	5.4A
	„	CA	8.3b	8.7b	8.2b	7.2b	10.1B
F10	0.6	CF	3.1a	4.0a	4.4a	5.4a	7.0A
	„	CA	8.2b	11.0b	8.9b	11.6b	16.5B

Different lowercase letters indicate significant yield differences between the farming methods within each season, and different capital letters indicate a significant difference in the mean yield per unit area or season between farming methods, according to Tukey's HSD test for post-hoc pairwise comparisons in two-factor ANOVA at the 5% level.
* =Each plot size is 1/4 of the actual farm size

likely as a result of differences in precipitation.

Conclusion and Recommendations

The central component of rain-fed agriculture by smallholder farmers in Laikipia is the planting season when seeds are sown in prepared land by farmers at the start of each rainy season. In this study, the plots used for CA and CF yield comparisons ranged from 0.5–2.4, (2–9.6 ha actual farm sizes). Except for farm F2 which was the largest, the rest of the farms were small enough to prepare using hand hoes or draft animals without having to use heavy machinery to plow the field. According to the farmers' perceptions and experiences, practicing CA has benefits such as reduced labor and farm-power requirements, because the soil is not tilled or is only minimally tilled in CA. This is important given that the majority of smallholder farmers in the district do not have mechanized farming equipment and not all of them have draft animals.

Although smallholder farmers perceived several benefits associated with CA adoption, and despite the fact that deliberate efforts have been made to promote and disseminate the CA approach in Laikipia, the adoption rate of this approach is still low. In fact, at present there are fewer farmers practicing CA as compared to the number of original adopters (Table 1), as farmers in the district have been abandoning CA practice. This study revealed that farmers are confronted with constraints in terms of a lack of skills, inadequate extension materials and a lack of CA field staff, and a lack of CA training manuals, which may explain this declining trend in participation and low adoption of CA. Furthermore, FAO demonstrated that, prior to 3years of CA practice, the benefits associated with CA adoption and especially yield are not substantial enough to convince most conventional farmers to adopt it (Fig. 3). This is an important factor to be considered when promoting CA among the newly adopted farmers in the district. Farmers must therefore understand that CA does not provide benefits immediately and there is a lag period between the time a farmer adopts CA and the time he actually gets the benefits associated with CA practice.

This study showed that there are inadequate tools and equipment in the district, which could be due to a lack of local manufacturers of tools and equipment for small-scale CA farming in nearby urban centers. These are important concerns mentioned by farmers as major constraints in the adoption of CA. Thus, CA promoters must encourage the fabrication of CA implements and tools among the farm input and implement shops in the district. The study also revealed that farmers' views and experiences are rarely taken into consideration when introducing new technologies and that farm inputs are expensive; farmers see these as important factors that hinder the adoption of the CA approach. These concerns must be addressed, and they may determine the strategies and approaches for better promotion and dissemination of the approach to farmers in Laikipia District in the future.

Data from farm records showed that, on average, the yield from subsistence farming in Laikipia is low. Yields ranged from 10.1 to 17.2 bags/ha for maize and from 4.9 to 7.0 bags/ha for beans under CF, whereas CA improved these yields to 19.9 to 31.7 bags/ha for maize and 10.1 to 16.5 bags/ha for beans. Thus, the yield from CA showed a tremendous increase that, in most cases, was double that from CF. These results are comparable to those reported by FAO (2005). This substantial yield increase in the region's staple foods would provide an important step toward household food security and farm income. Policy-makers and researchers, therefore, need to consider the findings of this study.

This study did not investigate the causes for the differences in yield between the CA and CF approaches. However, it is likely that this increase is due to improved soil management practices by CA farmers that conserve soil moisture and improve soil quality. There is a need to carry out further research on the effect that each CA practice has on crop yield in this region.

Acknowledgments

I thank Mr. Muchangi Njagi, a CA-compliant trained officer and a district subject matter specialist at the District Agricultural Office, Laikipia Central, for his participation in the field activities and for the extensive insights he provided about CA and its promotion in Laikipia District. Likewise I am grateful to Mr. Hutu, the divisional agricultural extension officer in Lamuria who also provided highly professional field assistance. Mrs. Zipporah Mburu, the location agricultural extension officer in Marura, who provided highly professional field assistance in conducting our on-farm experiments as well as in the administration of questionnaires and interviews to farmers; and Mr. Mungai, the field extension officer in Daiga, for his cooperation and for providing useful information during this study. I am grateful to Professor Hiroshi Gemma of the Faculty of Life and Environmental Sciences, University of Tsukuba, and the entire organizing committee of the Ag-ESD Symposium for their invitation and facilitation to participate and present this paper during the 2012 Ag-ESD Symposium, held at University of Tsukuba, Last but not least, I thank my family for their enormous support during the writing of this paper.

References

Canadian Coalition on Climate Change and Development (C4D), Kenya, 2010. Increase Community Resilience to Drought in Sakai Sub-location. http://www.iisd.org/climate/vulnerability/adaptation.asp, accessed June 2012.

FAO, 2004. Conservation of Natural Resources for Sustainable Agriculture: Training Modules. FAO Land and Water Digital Media Series.

FAO, 2005. Conservation Agriculture: Emergency and Rehabilitation Programme in Southern Africa, Regional Interagency Coordination Support Office (RIACSO). http://www.fao.org/ag/ca/doc/FLYER_Conservation_Agriculture.pdf, accessed June 2012.

FAO, 2006. Conservation Agriculture for SARD and Food Security in Southern and Eastern Africa (Kenya and Tanzania). AG: GCP/RAF/390/GER (KEN/URT) Terminal Report, June 2004 to August 2006. http://www.fao.org/ag/ca/doc/CA_SARD_web.pdf, accessed July 2012.

FAO, 2012. Conservation Agriculture. Agriculture and Consumer Protection Department. http://www.fao.org/ag/ca/, accessed January 2013.

FAO, IIRR, and ACT, 2005. Conservation Agriculture for Soil Moisture. Briefing Notes: Production Systems Management. FAO, Rome.

Garcia-Torres *et al.*, 2003; Knowler and Bradshaw, 2007. Conservation Tillage and its Impact on Land and Labor productivity in Central Ethiopia. As quoted in http://www.

webmeets.com/files/papers/EAERE/2011/133/CA%20paper %20Jan%202011.pdf

Gichuki, F.N., Liniger, H.P., MacMillan, L., Schwilch, G., Gikonyo, G., 1998. Scarce water: exploring resource availability, use, and improved management. In: Resources, actors and policies-towards sustainable regional development in the highland-lowland system of Mount Kenya. “G” (Nairobi) 8, 15–28.

Gold, M.V., 2012. Sustainable Agriculture: Definitions and Terms. http://www.nal.usda.gov/afsic/pubs/terms/srb9902.shtml, accessed August 2012.

Government of Kenya, 2004. Strategy for Revitalizing Agriculture, 2004–2014. Ministry of Agriculture Policy Paper.

Harrington, L.W., 2008. A Brief History of Conservation Agriculture in Latin America, South Asia, and Sub-Saharan Africa. Conservation Agriculture Newsletter, Issue 2. Department of Crop and Soil Sciences, Cornell University, Ithaca, NY.

Huho, J.M., Ngaira, J.K.W., Ogindo, H.O., Masayi, N., 2012. The changing rainfall pattern and the associated impacts on subsistence agriculture in Laikipia East District, Kenya. J. Geograph. Regional Planning 5 (7), 198–206.

Jaetzold, R., Schmidt, H., 1983. Farm Management Handbook of Kenya. Vol. II/C. Ministry of Agriculture, Nairobi, Kenya.

Kaumbutho, P., Kienzle. J., eds., 2007. Conservation Agriculture as Practised in Kenya: Two Case Studies. African Conservation Tillage Network, Centre de Coopération Internationale de Recherche Agronomique pour le Développement, Nairobi, and FAO, Rome. http://www.fao.org/ag/ca/doc/Kenya_casestudy.pdf, accessed June 2012.

Kiteme B.P., Wiesmann U., Kunzi E. and Mathura J.M., 1998: Knowledge about High-Lowland integration: A highland-lowland system under transitional pressure: A spatio-temporal analysis. In: Resources, Actors and Policies; Towards Sustainable Regional Development in the Highland lowland System of Mount Kenya, ESAGJ. Vol. No. 8.

Mazvimavi, K., Ndlovu, P.V., Nyathi, P., Minde, I.J., 2010. Conservation Agriculture Practices and Adoption by Smallholder Farmers in Zimbabwe. Poster presented at the Joint 3rd African Association of Agricultural Economists and 48th Agricultural Economists Association of South AfricaConference, Cape Town, South Africa. http://agecon search.umn.edu/bitstream/96822/2/130.%20Conservation%20Agriculture%20Practices%20in%20Zimbabwe.pdf, accessed July 2012.

Rhoton, F.E., Shipitalo, M.J., Lindbo, D.L. 2002. Runoff and soil loss from midwestern and southeastern US silt loam soils as affected by tillage practice and soil organic matter content. Soil Till. Res. 66, 1–10.

Sullivan, D.G., Lee, D., Beasley, J., Brown, S., Williams, E.J., 2008. Evaluating a crop residue cover index for determining tillage regime in a cotton-corn-peanut rotation. J. Soil Water Conserv. 60, 24–35.

Todaro, M., Smith, S., 2009. Economic Development. 10th ed. Pearson Education, Upper Saddle River, NJ.

World Bank, 2008. World Development Report: Agriculture for Development. http://siteresources.worldbank.org/INTWDR 2008/Resources/WDR_00_book.pdf, accessed August 2012.