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Moti Jaleta[a], Martins Odendo[b], James Ouma[c], Menale Kassie[d], and Fred Kanampiu[d,e]

[a] International Maize and Wheat Improvement Center (CIMMYT), Addis Ababa, Ethiopia
[b] Kenyan Agricultural and Livestock Research Organization (KARLO), Kakamega, Kenya
[c] Kenyan Agricultural Research Institute (KARI), Embu, Kenya
[d] International Maize and Wheat Improvement Center (CIMMYT), Nairobi, Kenya
[e] International Institute of Tropical Agriculture (IITA), Nairobi, Kenya

CIMMYT MR
International Maize and Wheat Improvement Center

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Acronyms

CA	Conservation Agriculture
CIMMYT	International Maize and Wheat Improvement Center
EIAR	Ethiopian Institute of Agricultural Research
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
IFAD	International Fund for Agricultural Development
KARLO	Kenyan Agricultural and Livestock Research Organization
SIMLESA	Sustainable Intensification in Maize-Legume Cropping Systems for Food Security in Eastern and Southern Africa
SSA	Sub-Saharan Africa
TLU	Tropical Livestock Unit

Acknowledgments

This study was conducted as part of the project titled: 'Enhancing Total Farm Productivity in Smallholder Conservation Agriculture-Based Systems in Eastern Africa'. Its purpose is to inform agronomists and other project partners on the existing crop and livestock production setups in the project intervention sites and to help determine to what extent the interaction between crop and livestock subsystems could potentially facilitate or hinder the adoption of conservation agricultural practices. A number of institutions and individuals contributed in various ways in the production of this baseline information and deserve acknowledgement. The authors would thus like to acknowledge EU-IFAD for funding the project, the Kenyan Agricultural and Livestock Research Organization (KARLO)-Embu and Kakamega Centers for facilitating the overall implementation of the study, which involved household and community surveys on which this report is based. The authors also acknowledge the contributions of respondent farmers in providing the necessary data gathered during the survey process, Ministry of Agriculture staff for logistic support and the enumerators for their commitment in data collection.

1. Introduction

The benefits of Conservation Agriculture (CA)[1] in maintaining and improving crop yields, attaining more resilient farming with reduced risks and hazards, while also protecting and stimulating the biological function of the soil, are well documented (FAO, 2008). However, whether CA fits in most farming systems in sub-Saharan Africa is still debatable (Gowing and Palmer, 2007; Giller *et al*., 2009; Giller *et al*., 2011). Giller *et al*. (2009) argue that CA practices fit more where there are steep slopes, sandy/loam soils, in areas that have abundant biomass and fewer livestock holdings and in contexts where there are wealthier farmers who can afford inputs (fertilizers and herbicides). It is also fit for farmers operating secured land tenure systems and who have good access to markets and other enabling institutional environments. Other studies associate the adoption and adaptation of CA principles in a given farming system and at the farm level with the existence of lower labor and farm-power inputs, more stable yields and improved soil nutrient exchange capacity (FAO, 2001), the availability of trade-offs in the allocation of resources in the specific system (Giller *et al.,* 2011) and the socio-cultural and socio-economic setups influencing resource use and farmers' decisions (Umar *et al.,* 2011).

Although CA was introduced to a number of SSA countries several decades ago, the overall adoption of CA by smallholder famers in the region has been too low (Ekboir *et al.,* 2002; Baudron, 2005). Kenya is one of the countries where CA was introduced by commercial farmers a long time ago though the adoption and expansion of CA practices as a complete package by smallholder farmers in mixed crop-livestock systems is still minimal (Kaumbutho and Kenzle, 2007).

In a mixed crop-livestock system, the use of crop residues as livestock feed, manure for the management of soil fertility, and draft power in land preparation and cultivation practices are the main sources of interaction between crop and livestock sub-systems. These interactions could have either a competitive or complementary effect on the three CA principles: minimum soil disturbance, permanent organic soil cover, and crop rotation and association. The extent to which these crop-livestock interactions facilitate or impede the adoption and expansion of CA practices and the potential opportunities and constraints that may exist under the crop-livestock systems of Kenyan highlands towards the promotion of CA practices thus warrant investigation.

Thus, the main objective of this study report is to assess and document the existing crop-livestock interactions in eastern and western Kenya and examine their implications to the adoption and expansion of conservation agricultural practices in maize-based systems.

This study report is structured as follows. Section 1 (above) provides a brief introduction on CA and explanations about the objectives of the study followed by Section 2, which presents the conceptual framework of the study. Section 3 describes the study area and data used, including the analysis method while Section 4 deals with the nature of crop and livestock productions in the study area. Section 5 discusses crop-livestock interactions and its implications towards the adoption and expansion of conservation agricultural practices. Finally, Section 6 presents a synthesis of the overall results and the major conclusions drawn from the analyses.

[1] As defined by FAO (2008), conservation agriculture is a resource-efficient agricultural crop production concept which relies on an integrated management of soil, water and biological resources combined with external inputs and achieved through three principles (minimum or no mechanical soil disturbance, permanent organic soil cover, and diversified crop rotations) that enhance biological processes above and below the ground.

2. Conceptual Framework

The level of crop-livestock interactions at household and community levels could influence the type of agricultural practices used in a farming system. For instance, households which have no draft animals or cannot afford to hire or borrow draft animals for land preparation may opt for hoe-culture or zero tillage practices. Moreover, households with only a few or no livestock are more likely to retain crop residues on their plots. This, however, depends on the opportunity cost of using crop residues both on internal (within the household) and external (in the surrounding) contexts. If there is shortage of livestock feed in the community, households may decide to sell their crop residues even though they may not own livestock. There is also the possibility that the residues are browsed by animals from the neighborhood.

Under imperfect rural markets for draft power and where zero-tillage practices are not common, households owning larger farms usually keep many draft animals for land preparation. These animals are usually fed on crop residues unless alternative feed sources are opted for. In maize-based systems and in particular, in places where maize is grown year after year or season after season, intercropping maize with legumes or rotating legumes after maize could help in enhancing soil nutrient levels and crop yields. In addition to grain yield, the increased crop biomass production resulting from enhanced soil nutrient and efficient water use could contribute to increased supply of crop residues that could be used as livestock feed. The diversity in crop types grown could also contribute towards more diverse and balanced food and feed supplies.

3. Description of the Study Sites and Data

3.1. Study sites

This study was undertaken as part of the "Enhancing Total Farm Productivity in Smallholder Conservation Agriculture Based Systems in Eastern Africa" project. The main purpose of the study is to provide and share baseline information on crop-livestock interactions and their implications for conservation agriculture in eastern and western Kenya. The study focuses on five, pre-selected project intervention districts located in the eastern and western parts of Kenya namely; Embu, Meru South and Imenti South from the Eastern Province, and Bungoma and Siaya from the Western and Nyanza Provinces, respectively. The districts are known for the maize industry covering a large proportion of their economies but they also have contrasting agro ecologies and farming systems that could help to make a comparison of the intensity of crop-livestock interactions and their role on the adoption and adaptation of conservation agriculture practices. In the Eastern Province, the agroecology is more of a mid-highland with lower rainfall. The province is densely populated and farmers practice intensive farming systems. However, the western part (Western and Nyanza Provinces) is relatively sparely populated and receives better rainfall and there is extensive farming. Figure 1 shows the geographical locations of the study districts in the Eastern, Western, and Nyanza Provinces of Kenya.

3.2. Data

Data for this study were collected in 2011 by experienced and trained enumerators through face-to-face personal interviews of household heads or, in their absence, senior household members well versed with farming activities using a structured questionnaire. The data collection process was closely monitored and supervised in the field by experts from KARLO-Embu and KARLO-Kakamega Centers as well as CIMMYT socio-economists. A four-stage sampling procedure was applied in the selection process. In the first stage, two districts in Western Kenya (Bungoma

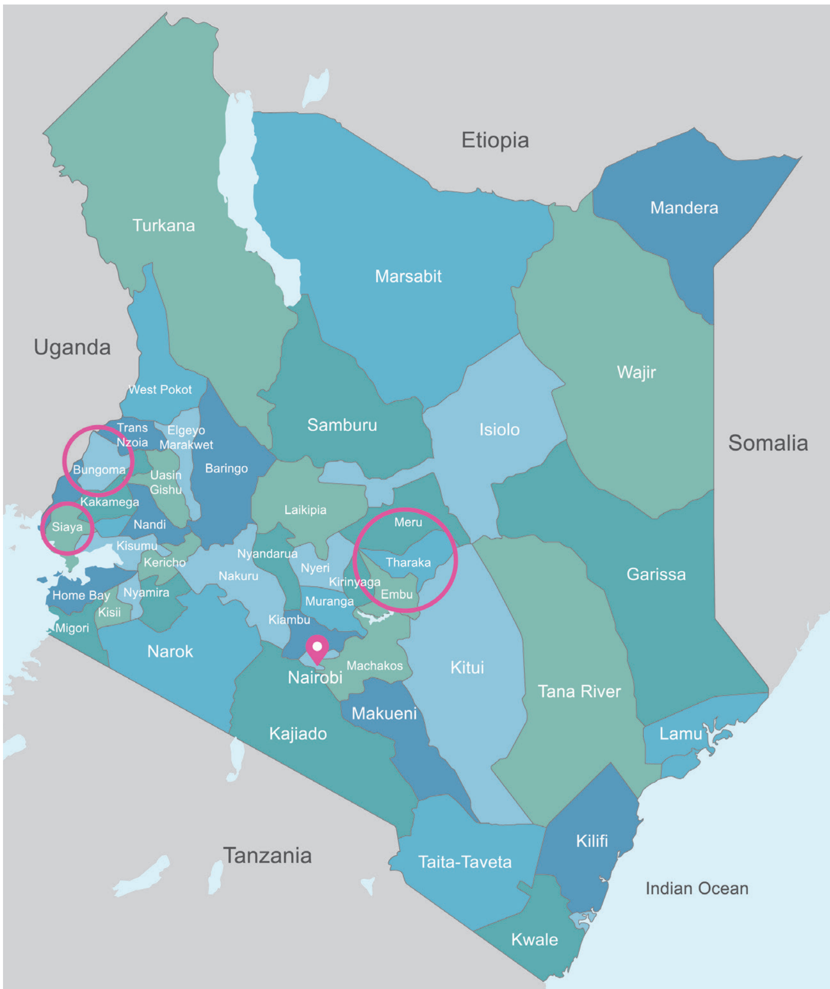

Figure 1. Geographical location of the districts under this study.

and Siaya) and three in Eastern Kenya (Embu, Meru South and Imenti South) were purposely selected. In the second stage sub-locations were randomly sampled from the districts in numbers proportionate to the number of sub locations in the districts based on the 2009 population census listing of sub locations (GoK, 2010). In the third stage, the villages to be surveyed were randomly picked from the list prepared for each selected sub-location in each district. The number of villages to be surveyed in each sub-location was, thus, proportional to the total number of villages in each of the selected sub-location. Finally, a list of households was drawn up from each of the selected villages, from which sample households were randomly picked for the survey, and which is proportional to the number of households in that village. In total 613 households comprising 494 and 119 male- and female-headed households, respectively, were surveyed (Table 1).

Table 1. Distribution of the sample households surveyed by district and sex.

District	Male-headed	Female-headed	Total
Bungoma	131	19	150
Siaya	110	39	149
Embu	82	28	110
Meru South	84	18	102
Imenti South	87	15	102
Total	**494**	**119**	**613**

The survey data includes household demography and characteristics, access to markets and institutions, social capital of the households, assets (livestock, farm equipment and land holding), plot characteristics, plot level input use and outputs produced, outputs utilization and marketing, crop residue utilization, income and expenditure at the household level, as well as access to credit and extension services.

Sample households were asked to estimate and report their crop-specific residues produced in both the cropping seasons of the 2010/11 production year and how they allocated the residues to the different alternative uses. Different techniques were used to assist the sample households in making the estimations and convert the estimations into percentages.

Household characteristics

The average age of the household heads was 50.3 years and 81% of the sample households are male headed. Both the household head and spouse had an average of seven years of schooling and average household size was six persons. Farming was the main occupation for 74% of the sample household heads and one active labor force in a household supported 0.96 dependents (Table 2).

Table 2. Household characteristics.

		Bungoma (*N=150*)		Siaya (*N=150*)		Embu (*N=110*)		Meru South (*N=107*)		Imenti South (*N=103*)		Total (*N=613*)	
Variables	**Unit**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Age of household head	Year	49.07	15.39	53.32	14.31	52.31	14.66	44.48	13.24	51.38	14.37	50.31	14.761
Gender of household head (1=Male)	Ratio	0.87	0.33	0.74	0.44	0.75	0.44	0.82	0.38	0.85	0.36	0.81	0.4
Education of the household head	Year	8.89	3.91	6.23	4.00	6.85	4.02	7.12	3.42	7.69	3.84	7.38	3.97
Education of spouse	Year	7.95	3.18	6.1	3.26	7.06	3.89	6.86	2.95	7.08	4.23	7.04	3.54
Family size	Number	6.57	2.74	6.99	3.09	4.49	1.99	4.91	1.67	4.89	1.94	5.74	2.65
Dependency ratio	Ratio	1.35	1.09	0.95	0.78	0.69	0.67	0.86	0.62	0.8	0.81	0.96	0.86
Main occupation of the head (*1=Farming; 0=Non-farming*)	Ratio	0.64	0.48	0.75	0.44	0.75	0.43	0.82	0.38	0.77	0.42	0.74	0.44

Source: Authors' computation based on SIMLESA Kenya household baseline survey data, 2011.

4. Crop and Livestock Production

In this section, the nature of crop and livestock production practices in the selected districts is sequentially presented. Thus, farm size and tenure type, type of crops produced by households and area allocation to the specific crops, experience in conservation agriculture-related practices like zero/ minimum tillage, intercropping, rotation and retaining crop residues on fields are discussed in the crop production subsection below. The livestock production sub-section examines livestock holdings together with levels of diversity within livestock holding.

4.1. Crop production

4.1.1. Farm size

The level of crop-livestock interaction could vary depending on household farm size (Baltenweck *et al.,* 2003). Households with larger farm sizes are able to grow alternative feed sources (like forage grasses and trees) and depend less on crop residues as a source of livestock feed. For such households, land productivity is not an issue and the intensity of manure use for field crops could be low. However, in mixed crop-livestock farming, demand for oxen power could increase with farm size.

Data show the existence of slight variation in the size of farmland operated in different seasons of a given year. On average, sample households operated 1.90 and 2.02 acres of farmland during season one (March-June) and season two (September- November), respectively (Table 3). Of these average farmland operated, 1.65 acre in season one and 1.80 acre in season two were own plots. The rest was either rented-in or borrowed-in for use for the season or beyond.

4.1.2. Land use by district and seasons

For each district under this study, the average operated land per household was almost similar in both seasons of the year (Tables 4 and 5). This shows that cultivated land is used at least twice a year. Therefore, unless proper soil nutrient management practices are put in place, continuous use of farm plots throughout the year could potentially deplete soil nutrients and degrade the farmland. Tables 5 and 6 present cultivated land use by the sample households in each district and by cropping season in the 2010 production year.

Table 3. Average land size operated by tenure type and season (acre/household).

	Season 1 (March-June)			Season 2 (September-November)		
Type	Mean	Std.dev	Max	Mean	Std.dev	Max
Own land used	1.65	1.65	15	1.80	2.02	24
Rented-in land	0.23	0.57	4	0.22	0.59	5
Rented-out land	0.09	0.60	9	0.15	1.69	40
Borrowed-in land	0.02	0.13	1.5	0.03	0.15	1.5
Borrowed-out land	0.04	0.32	4	0.04	0.32	4
Total owned land	1.76	1.87	15	1.89	2.26	27
Total operated land	1.90	1.68	15	2.02	2.03	24

Note: N=611 (obs. 97 and 315 were dropped due to inconsistency with the remaining datasets).

Table 4. Cultivated land use during season 1 (March-June) by district.

Type	Bungoma (*N=150*)		Siaya (*N=148*)		Embu (*N=110*)		Meru South (*N=102*)		Imenti South (*N=101*)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Own land	1.64	2.24	1.29	1.11	1.61	1.24	2.20	1.94	1.70	1.17
Rented in land	0.12	0.44	0.18	0.55	0.23	0.49	0.38	0.81	0.30	0.57
Rented out land	0.16	0.82	0.04	0.18	0.02	0.19	0.06	0.29	0.19	1.00
Borrowed in land	0.01	0.06	0.05	0.22	0.02	0.14	0.00	0.05	0.00	0.00
Borrowed out land	0.03	0.26	0.04	0.34	0.00	0.00	0.07	0.40	0.06	0.43
Total owned land	1.80	2.47	1.35	1.19	1.62	1.32	2.32	2.08	1.90	1.78
Total operated land	1.76	2.24	1.53	1.24	1.86	1.37	2.60	1.86	1.97	1.15

Note: SD=Standard deviation (Survey data, 2011).

Table 5. Cultivated land use during season 2 (September-November) by district.

Tenure type	Bungoma (*N=150*)		Siaya (*N=148*)		Embu (*N=110*)		Meru South (*N=102*)		Imenti South (*N=101*)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Own land	2.28	3.21	1.31	1.12	1.57	1.25	2.15	1.91	1.67	1.16
Rented in land	0.15	0.61	0.17	0.52	0.18	0.46	0.36	0.78	0.28	0.56
Rented out land	0.38	3.29	0.04	0.19	0.02	0.19	0.06	0.29	0.17	0.99
Borrowed in land	0.02	0.11	0.06	0.23	0.03	0.16	0.01	0.08	0.00	0.05
Borrowed out land	0.02	0.25	0.04	0.34	0.00	0.00	0.07	0.40	0.06	0.43
Total owned land	2.45	3.52	1.33	1.17	1.55	1.31	2.29	2.07	1.86	1.76
Total operated land	2.39	3.18	1.52	1.24	1.81	1.38	2.53	1.83	1.95	1.18

Note: SD=Standard deviation (Survey data, 2011).

4.1.3. Crop types produced

During both seasons of the year, maize and haricot beans were the major field crops grown. In addition, farmers grew other field crops such as pigeon-pea, cowpea, soya beans, groundnuts, barley, sorghum, and finger millet. However, these were either intercropped with maize and/or haricot beans or grown on small plots, if grown as a sole stand. Moreover, households also grew sweet potatoes, vegetables, Irish potato, cassava and other root and tuber crops. Some of the plots used for the production of field crops are also used for growing perennial crops/fruit trees such as mango, bananas, sugarcane and the like.

4.1.4. Area allocation

A major portion of the farm was allocated to maize and haricot beans production (Tables 6 and 7). However, the proportion of land allocated to these two crops varied across districts and by season. Compared to other districts, a relatively larger area is allocated to maize production in Bungoma and Meru South, though less than 27% of the sample households in Bungoma grew maize in season 2 (September-November). Overall, maize took the largest share in area allocation followed by haricot beans and other legumes. There could be other crops intercropped with these major crops in the same plots. Details on intercropping are discussed in section 4.1.5.

Table 6. Area allocated to maize and legumes as major crop (acres in season 1).

	Maize			Haricot Bean			Cowpea			Soyabean			Pigeon pea			Groundnut		
District	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD
Bungoma	146	1.55	1.84	8	1.01	0.98	29	0.28	0.26	0			0			9	0.46	0.34
Siaya	146	1.26	0.99	5	0.35	0.14	2	0.25	0.00	1	0.25	-	0			21	0.51	0.61
Embu	105	1.14	0.84	52	0.87	0.62	4	0.31	0.13	2	0.13	0.01	2	0.31	0.27	0		
Meru South	85	1.67	1.94	46	1.07	0.76	14	0.48	0.31	0			2	0.63	0.53	0		
Imenti South	101	1.08	0.76	83	0.86	0.54	12	0.29	0.13	0			4	0.28	0.16	0		

Note: In Siaya, there were 15 sample households allocated 0.53 acre (average) for sorghum..

Table 7. Area allocated to maize and legumes as major crop (acres in season 2).

	Maize			Haricot Bean			Cowpea			Soyabean			Pigeon pea			Groundnut		
District	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD	Obs	Mean	SD
Bungoma	40	0.97	0.95	17	0.65	0.69	38	0.50	0.67	2	0.60	0.57	0			15	0.51	0.42
Siaya	137	1.29	1.05	4	0.30	0.14	2	0.25	0.00	1	0.25	-	0			14	0.63	0.71
Embu	102	1.11	0.95	49	0.91	0.75	5	0.33	0.17	2	0.31	0.26	1	0.13	-	0		
Meru South	80	1.11	0.65	43	1.00	0.67	12	0.44	0.28	0			2	0.88	0.88	1	0.75	
Imenti South	94	0.96	0.58	89	0.94	0.73	12	0.38	0.27	0			4	0.41	0.28	0		

4.1.5. Experience in conservation agricultural practices

Of the three principles in conservation agriculture- minimum soil disturbance, retaining crop residue for soil mulching, and crop rotation and intercropping- the first two are strongly associated with the framework of crop-livestock interactions. Minimum soil disturbance could save the cost incurred by using draft power for land preparation and relieves smallholders from keeping draft animals for ploughing purpose on scarce land and other resources. Retaining crop residue on farm plots for soil mulching also competes with the alternative use of residue as livestock feed which could be seen as one of the indicators in crop-livestock interactions (Baltenweck *et al., 2003*). Crop rotation and intercropping are linked more with intensification and sustainable nutrient management and less with crop-livestock interactions unless the intercropped or rotated crops are purposively grown as forage for livestock. The intensity of conservation agricultural practices across the study districts is briefly discussed below.

4.1.5.1. Zero/minimum tillage practices

The experience of zero or minimum tillage practices in field crops production is limited in both the eastern and western parts of Kenya. Considering Bungoma and Siaya districts, only about 0.7% of the total plot area allocated to field crops during season one were under zero or minimum tillage. In Bungoma, there was no plot under zero or minimum tillage in season two. Similarly, no plots in Imenti South district were operated under zero or minimum tillage during the 2010 production year. Relatively, the practice is reported more at Embu and Meru South districts but is still minimal both in size and share of field crop plots (less than 0.3 acre per household and less than 11% of the plots under field crops in both seasons). Details related with plot size and share under zero or minimum tillage practices are presented in Table 8.

Maize and haricot beans were the two main field crops grown on plots with zero or minimum tillage. Plots with perennial crops like banana, mango, cassava, and others could also be under zero tillage

Table 8. Size and share of field crop plots under zero or minimum tillage during the 2010 production year (by season and District).

Season [a]		Bungoma				Siaya				Embu				Meru South			
		Obs	Mean	Std. Dev	Max	Obs	Mean	Std. Dev.	Max	Obs	Mean	Std. Dev.	Max	Obs	Mean	Std. Dev.	Max
1	Size (acre)	147	0.003	0.041	0.5	146	0.010	0.124	1.5	105	0.02	0.148	1.5	94	0.25	0.84	4
	Share (%)	147	0.68	8.25	100	146	0.69	8.28	100	105	1.27	10.3	100	94	10.64	31.00	100
2	Size (acre)	78	0	0	0	139	0.004	0.042	0.5	103	0.08	0.390	3	92	0.08	0.48	4
	Share (%)	78	0	0	0	139	0.72	8.48	100	102	4.58	20.5	100	92	4.35	20.50	100

Note: [a]Season1=March-June/July; Season 2=September-November.
In Imenti South, there were no plots of field crops under zero or minimum tillage during the 2010 production year.

but are not reported here as this study report focuses mainly on the agronomy of field crops. From the total 613 sample households, only 10 (five in Embu, four in Meru South and one in Siaya) reported their experience in practicing zero/minimum tillage in field crops production. Interestingly, these households had no oxen during the production year under this study. Whether the use of zero/minimum tillage was necessitated by the lack of oxen or vice versa warrants further investigation.

4.1.5.2. Intercropping and crop rotation

Intercropping and crop rotation are the most common agronomic practices farmers use to maximize grain and biomass production by enhancing soil fertility and breaking the life cycle of disease-causing organisms/micro-organisms and pests. Survey results from both the eastern and western parts of Kenya also confirm a wider use of these agronomic practices.

Accordingly, 72% of the 847 maize plots operated by the sample households during the long rainy season that lasted throughout the 2010 cropping seasons were intercropped. About 57% of the maize plots were intercropped with haricot beans and 6.5% were under haricot bean and other legumes together. Overall, maize-haricot bean intercropping constitutes 90.2% of the intercropped maize plots during the same season.

During the short rainy season of the same production year, there were 645 plots allocated to maize as a major crop. Maize was intercropped with haricot bean in 49.2% of these plots, with haricot bean and other legumes in 6.1%, with other legumes in 7.8%, while about 36% of the plots were covered solely with maize. Wider use of maize-legume intercropping is observed more during the long rainy season and this indicates efficient utilization of the available soil moisture.

Crop rotation is also practiced but not as commonly as intercropping applied in both the seasons. Only 25.7% and 22.2% of the maize plots respectively, were used to grow non-maize crops (mostly legumes) in the long and short rainy seasons, that spanned the previous cropping season (Table 9 and 10). Most of these plots were used to grow either haricot bean alone, haricot bean intercropped with other legumes (food or feed), with other non-haricot bean legumes, or with non-legume field crops. The details for the long and short rainy seasons are presented in tables 10 and 11, respectively.

Similar cropping patterns and land use are observed season after season in both these tables. For instance, 80.7% of the maize-haricot bean intercropped plots in the long rainy season had been covered with the same cropping patterns observed in the past. There were a considerable number of haricot bean plots from the previous season/year used for sole maize. Growing maize only again and again is also common. Overall, the existence of intercropping and crop rotation practices indicates that households are aware of the importance of intercropping and crop rotation in enhancing farm productivity and making it more sustainable. The distribution, by cropping patterns, of maize plots for each specific season and the cropping patterns observed on the same plots during the previous season/year is presented in tables 9 and 10 below.

Table 9. Distribution of maize plots by cropping pattern in the long rainy season and the season/year preceding.

Long rainy season (1) cropping pattern	Unit	Previous season/year cropping pattern: Mz	Mz + Hb	Mz + Hb + OLg	Mz + OLg	Hb	HB + OLg	OLg	NLg	Oth	Total
Mz	Freq	106	25	2	1	86	5	3	7	12	247
	%	42.9	10.1	0.8	0.4	34.8	2.0	1.2	2.8	4.9	100.0
Mz + Hb	Freq	8	392	1	12	9	1	9	32	22	486
	%	1.6	80.7	0.2	2.5	1.9	0.2	1.9	6.6	4.5	100.0
Mz + Hb + OLg	Freq	1	14	23	1		3	6	5	2	55
	%	1.8	25.5	41.8	1.8		5.5	10.9	9.1	3.6	100.0
MZ + OLg	Freq	1	8	1	26	2	10				48
	%	2.1	16.7	2.1	54.2	4.2	20.8				100.0
Mz + Oth	Freq	1	4		1	1			1	3	13
	%	7.7	30.8		7.7	7.7			7.7	27.3	100.0
Total	Freq	117	443	27	41	98	19	18	45	39	847
	%	13.8	52.2	3.2	4.8	11.5	2.2	2.1	5.3	4.6	100.0

Note: Mz=Maize; Hb=Haricot bean; OLg=Other legumes; NLg=Non-legume field crops; Oth=other crops or fallow land.
Some of the maize plots also have perennial crops planted on them.
Previous season refers to the season/year immediately preceding the current one when the plot was used for crop production

Table 10. Distribution of maize plots by cropping pattern in the short rainy season and the season preceding it.

Sort rainy season (1) cropping pattern	Unit	Previous season/year cropping pattern: Mz	Mz +Hb	Mz +Hb +OLg	M +OLg	Mz +NLg	Hb	HB +OLg	OLg	NLg	Oth	Total
Mz	Freq	116	26	1	2		77	5	4			231
	%	50.2	11.3	0.4	0.9		33.3	2.2	1.7			100.0
Mz + HB	Freq	8	270	6	4	1	5		5		18	317
	%	2.5	85.2	1.9	1.3	0.3	1.6		1.6		5.7	100.0
Mz + Hb + OLg	Freq		6	27					4		2	39
	%		15.4	69.2					10.3		5.1	100.0
M + OLg	Freq	1	4		29		3	7	4	2		50
	%	2.0	8.0		58.0		6.0	14.0	8.0	4.0		100.0
M + NLg	Freq	1									7	8
	%	12.5									87.5	100.0
Total	Freq	126	306	34	35	1	85	12	17	2	27	645
	%	19.5	47.4	5.3	5.4	0.2	13.2	1.9	2.6	0.3	4.2	100.0

Note: Only non-zero frequencies are reported.
Mz=Maize; Hb=Haricot bean; OLg=Other legumes; NLg=Non-legume field crops; Oth=other crops or fallow land.
* Some of the maize plots also have perennial crops planted on them.
** Previous season refers to the season/year immediately preceding the current one when the plot was used for crop production.

4.1.5.3. Residue management

Retaining crop residues on farm plots could help for various purposes such as soil mulching, reducing run-offs, facilitating infiltration, suppressing weed growth and increasing soil organic matter. Farmers might know the importance of retaining crop residues on farm plots, but could find the opportunity cost of such practices to be high enough to force them to divert crop residues for use in other, alternative purposes.

Overall, there are cases where households completely remove crop residues from their farm plots and use them for other purposes. There are also extreme cases where they retain the entire crop residue on farm plots as a soil cover. Details of residue use by district and cropping seasons are presented in section 5.1.

4.2. Livestock production

Livestock production deals with keeping live animals as stock and generating benefits both from the animals and their products. This section briefly discusses the descriptive statistics of the livestock holdings of the sample households by district and diversity in the types of livestock households keep.

4.2.1. Livestock holdings

The average cattle holding of the sample households varied across the districts, except that households in all the five districts owned one cow, which is mostly a milking cow. In Embu and Imenti South, sample households did not own trained oxen. The maximum number of cattle owned by a household in Siaya district was 36. In all districts, there were households with no cattle holdings. Compared to other districts in the Eastern Province, Bungoma and Siaya had higher average numbers of cattle holding per household. However, the average holding size of small ruminants per household was higher for districts in the Eastern Province (Table 11).

4.2.2. Diversity in livestock types

Households usually kept different types of livestock due to several reasons such as efficient utilization of labor and other resources, risk reduction, response to different liquidity requirement levels, as well as for diversified consumption of livestock and livestock products. Such diversity in the type of livestock holdings not only helps to complement crop production through the provision of inputs and services but it could also increase competition on resource use.

Table 11. Cattle holdings of sample households by district.

Type		Bungoma (*N=150*)			Siaya (*N=149*)			Meru South (*N=102*)			Embu (*N=110*)			Imenti South (*N=102*)		
		Mean	SD	Max	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max
Total number of cows		1.3	2.0	20	1.8	2.8	28	0.9	0.8	4	0.8	0.9	4	1.1	1.0	5
Milking cows	Indigenous	0.8	1.8	20	0.7	1.1	8	0.3	0.6	3	0.3	0.6	2	0.5	0.9	4
	Crossed	0.2	0.5	4	0.0	0.2	2	0.4	0.8	4	0.2	0.6	3	0.2	0.5	2
	Exotic	0.1	0.5	4	0.1	0.4	3	0.1	0.3	2	0.1	0.4	3	0.3	0.8	5
	Total	1.0	1.9	20	0.8	1.2	8	0.8	0.8	4	0.7	0.8	3	1.0	1.0	5
Non-milking cows		0.3	0.6	3	1.0	2.3	24	0.1	0.3	2	0.1	0.3	2	0.1	0.3	2
Trained oxen		0.4	0.9	4	0.2	0.9	6	0.0	0.2	2	0.0	0.0	0	0.0	0.0	0
Bulls		0.2	0.5	4	0.4	0.7	3	0.2	0.5	2	0.2	0.5	2	0.2	0.5	2
Heifers		0.3	1.0	11	0.2	0.8	6	0.2	0.5	2	0.1	0.4	2	0.1	0.4	2
Calves		0.7	1.0	4	1.0	1.4	8	0.3	0.6	2	0.2	0.5	3	0.5	0.7	4
Total cattle	Number	2.8	3.3	23	3.5	4.4	36	1.6	1.4	7	1.3	1.4	8	1.9	1.4	6
	TLU	1.7	2.1	16.1	2.1	2.7	23.6	1.1	0.9	4.7	0.9	0.9	4.7	1.3	1.0	5

Note: SD=Standard Deviation.

1 Indigenous cow=0.75TLU; 1 Crossed cow=0.85TLU; 1 Exotic cow=1TLU; 1Oxen=0.75TLU; 1Bull=0.5TLU; 1Heifer=0.0.5TLU; 1Calf=0.3TLU.

A majority of the sample households in all the districts owned cattle, small ruminants, and chicken (Table 13). Of the total, 74.6% owned cattle, 52.4% owned small ruminants, 87.4% owned chicken, 1.6% owned pigs, and just one household in Siaya kept equines.

Looking at the combinations of the average livestock types the sample households kept, each household kept either two or three types of live animals (classified as cattle, small ruminants, equines, chicken and pigs). However, 50% of the sample households in Bungoma, and 30 to 40% in the other districts kept a combination of just two types of livestock as classified above. By contrast, nearly 57% of the sample households in Imenti South owned three types of livestock while a negligible proportion of households in Siaya (1.3%), Meru South (6%) and Imenti South (6%) owned a combination of four livestock types. There were also a number of households in all the five districts that did not own any animals during the 2010 production year. Figure 2 shows the percentage distribution of households by the number of livestock types kept.

Table 12. Summary of livestock holding sizes by livestock category (animal/household).

Livestock category	Bungoma (*N=150*)			Siaya (*N=149*)			Embu (*N=110*)			Meru South (*N=102*)			Imenti South (N=102)		
	Mean	Std. Dev.	Max	Mean	Std. Dev.	Max	Mean	Std. Dev.	Max	Mean	Std. Dev.	Max	Mean	Std. Dev.	Max
Cattle	2.8	3.3	23	3.5	4.4	36	1.3	1.4	8	1.6	1.4	7	1.9	1.4	6
Small ruminants	1.1	2.2	10	2.0	2.9	18	1.6	2.3	13	3.1	3.2	15	2.9	3.0	13
Equine	0.0	0.0	0	0.0	0.1	1	0.0	0.0	0	0.0	0.0	0	0.0	0.0	0
Chicken	7.4	7.5	50	13.0	29.7	260	7.3	7.1	30	11.1	10.4	68	10.2	7.8	30
Pig	0.0	0.2	3	0.0	0.3	3	0.0	0.0	0	0.0	0.3	2	0.2	1.3	13

Table 13. Summary of livestock holdings by livestock category (animal/household).

District	Obs	Cattle		Small ruminants		Equine		Chicken		Pig	
		Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Bungoma	150	112	74.7	47	31.3	0	0.0	121	80.7	1	0.7
Siaya	149	110	73.8	76	51.0	1	0.7	132	88.6	3	2.0
Embu	110	71	64.5	56	50.9	0	0.0	87	79.1	0	0.0
Meru South	102	77	75.5	70	68.6	0	0.0	99	97.1	3	2.9
Imenti South	102	87	85.3	72	70.6	0	0.0	97	95.1	3	2.9
Total	**613**	**457**	**74.6**	**321**	**52.4**	**1**	**0.2**	**536**	**87.4**	**10**	**1.6**

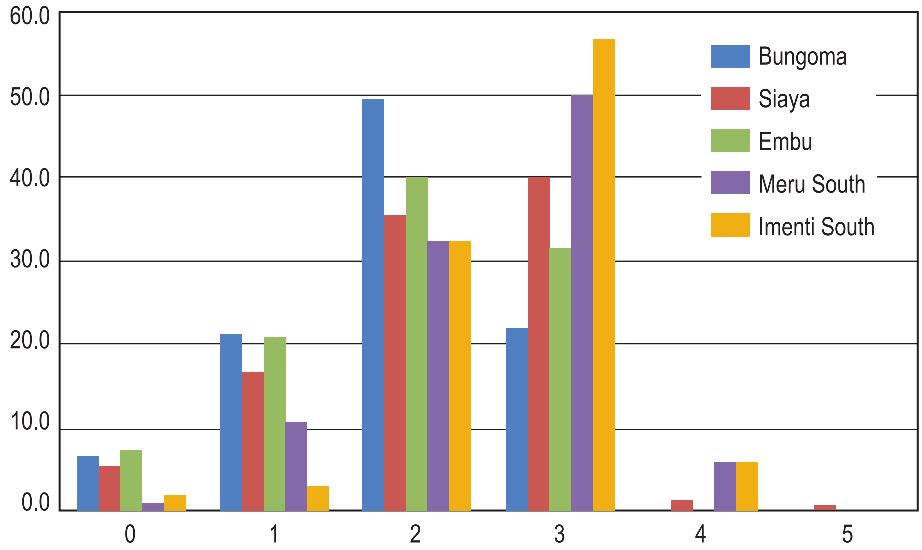

Figure 2. Combination of livestock types kept by sample households.

5. Crop-Livestock Interactions

A more integrated crop-livestock management is crucial in mixed crop-livestock farming systems to maintain sustainability through the recycling of resources, nutrients and energy. Livestock provide draft power and manure that could be used in crop production. Cash income generated from selling livestock and livestock products could also be used for the purchase of external inputs used in crop production. Conversely, crop production provides crop residues, which are used as livestock feed. The use of crop residues by smallholders for feed and other alternative purposes and the level of manure and draft power used in crop production are discussed below.

5.1. Crop residue use

Depending on the crop types, the resulting crop residues could have various uses such as for firewood, for construction purposes, as livestock feed, and to help in soil mulching and nutrient replenishment. The proportion of crop residue allocated to these purposes could vary by agroecology and sample households, the latter based on resource endowment and the availability of other sources for the purposes that crop residues are employed. The proportions in the use of residues from the major crops (maize, haricot beans, cowpea and pigeon-pea) produced in the study areas are presented below.

5.1.1. Maize residues

As shown in Table 14, a large proportion of the residues from maize is mainly used as livestock feed and for soil mulching in both the cropping seasons. For example, on average, more than 50% of the maize residue produced in 2010 was used for livestock feed and above 30% was used as soil cover. On the contrary, only a very small proportion of the maize residue produced during both seasons was used for firewood, burnt on fields and or sold in the market. The average proportion of the maize residue used for construction purposes during the same period is negligible. Interestingly, there were also cases where some of the households allocated their entire maize residue collections to either of the alternative purposes with exceptions to firewood in both seasons and construction purpose in season 1.

Examining maize residue use by District, a distinct use pattern could be observed in the eastern and western parts of Kenya. In the western part, a larger proportion of the maize residue is used for soil mulching (41-66%) followed by use as livestock feed (25-38%) (Table 16). The proportion of the maize residue used for soil mulching during both seasons was relatively higher in Siaya than in Bungoma.

Table 14. Proportion of maize residue use to alternative purposes.

	Season 1 (March - June) (N=580)			Season 2 (September - November) (N=439)		
Purpose/use	Mean [a]	Std.Dev	Max	Mean [a]	Std.Dev	Max
Burnt on plot	4.0	16.7	100	3.1	15.1	100
Firewood	3.5	12.1	90	1.3	7.4	60
Soil mulch	32.3	38.1	100	30.8	37.6	100
Livestock feed	51.3	40.7	100	55.5	40.7	100
Construction	0.0	0.8	20	0.2	4.8	100
Sold	4.6	19.3	100	4.0	17.8	100

Note: [a] Percentage use. N=Number of households produced maize and reported their residue use.

In the Eastern Province, on average, a larger proportion of the maize residue (68-82%) was used as livestock feed followed by use as soil mulch. The proportion of the maize residue left on plots as soil mulch was as low as 8.6% (in Embu and Imenti South) whereas the maximum average proportion used for the same purpose was 14.5% in Embu (Table 16). This does not necessarily mean that some households are not retaining the entire maize residue on farm for use as soil mulch.

The sale of maize residues in the market or and its use for construction purposes were not observed in Bungoma and Siaya Districts. Similarly, the use of maize residues for construction purposes was negligible in the Eastern Province. However, it was marketed in all the three Districts in the Eastern Province. Further analysis on maize residue use by quantity also came up with similar results and has been annexed to this study report (see Tables A1 and A2).

5.1.1.1. Intensity of use of maize residues

Livestock feed and soil mulching are the two major purposes maize residue is used in all the districts covered by the study and further analysis on the intensity of maize residue use in terms of maize plots and cattle owned is presented in Table 17. The results show that intensity of use of the maize residue left on farm plots as soil mulch is high in Bungoma and Siaya Districts. In the Eastern Province, the average amount of maize residue left as mulch on maize plots is between 100 and 137 kg/acre of the total harvest from season 1 (March-June) and between 89.8 and 150.8 kg/acre from season 2 (September-November).

Similarly, the intensity of use of the maize residue as livestock feed is high in Bungoma where farmers, on average, use 2686.5 kg of maize residue per TLU of cattle owned from the harvest in season 1 (March-June) and 1519.1 kg/TLU of that from season 2. The

Table 15. The proportion of use of maize residue in Western Kenya.

	Bungoma						Siaya					
	Season 1 (N=142)			Season 2 (N=36)			Season 1 (N=146)			Season 2 (N=134)		
Purpose/use	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max
Burnt on plot	4.6	17.9	100	1.7	7.0	40	8.3	23.3	100	7.3	22.8	100
Firewood	13.2	20.8	90	11.4	19.3	60	0.6	5.3	50	0.7	5.5	50
Soil mulch	44.0	37.5	100	41.1	33.5	100	65.2	35.7	100	65.9	35.8	100
Livestock feed	30.3	31.2	100	36.7	31.3	100	25.3	28.8	100	24.9	29.7	100
Construction	0.1	1.7	20	0	0	0	0	0	0	0	0	0
Sold	0	0	0	0	0	0	0	0	0	0	0	0

Table 16. The proportion of use of maize residues in Eastern Kenya.

	Embu						Meru South						Imenti South					
	Season 1 (N=105)			Season 2 (N=99)			Season 1 (N=87)			Season 2 (N=79)			Season 1 (N=100)			Season 2 (N=90)		
Purpose/use	Mean (%)	Std. Dev	Max (%)	Mean (%)	Std. Dev	Max (%)	Mean (%)	Std. Dev	Max (%)	Mean (%)	Std. Dev	Max (%)	Mean (%)	Std. Dev	Max (%)	Mean (%)	Std. Dev	Max (%)
Burnt on plot	0.8	7.8	80	1.4	10.0	80	2.3	13	100	1.9	12.5	100	1.5	11.1	100	0.6	5.3	50
Firewood	0	0	0	0.0	0.0	0	0	0	0	0.0	0.0	0	0.5	5.0	50	0.7	5.4	50
Soil mulch	11.6	24.2	100	14.5	26.8	100	9.8	22.5	100	8.6	18.1	100	8.6	16.7	100	11.6	22.4	100
Livestock feed	68.1	40.5	100	67.8	39.6	100	74.0	37.4	100	73.2	36.2	100	81.6	29.0	100	79.4	31.4	100
Construction	0	0	0	0.0	0.0	0	0	0	0	1.3	11.3	100	0.0	0.0	0	0.0	0.0	0
Sold	12.5	31.5	100	8.4	26.0	100	10.1	27.7	100	7.3	23.2	100	4.2	17.5	100	3.9	16.4	90

lowest intensity of use of maize residues as livestock feed was observed in Siaya and it amounted to 476.8 kg/TLU and 432.7 kg/TLU, respectively, of the harvests from season one and two. The co-existence of high intensity of use of maize residues both as soil mulch and livestock feed in Bungoma shows how a potentially large maize biomass production scenario could serve both the essential and the priority purposes of particular households without significant trade-offs.

5.1.2. Residue from Legumes

As is the case with maize, most of the residues from legume crops were used for soil mulching and livestock feed. Residues from cowpeas and pigeon-pea were not marketed, but were used for construction purposes and as firewood both during the short and long rainy seasons (Table 18). Pigeon-pea residues produced during season one were used mainly as livestock feed, soil mulch and firewood, in decreasing order of importance. The same holds true for season two except that, on average, a relatively more proportion was burnt in the fields. The proportions of haricot bean, cowpea and pigeon-pea residues used for different purposes by season are shown in Table 18.

5.2. Manure use

There is a long trend of using manure specially cow dung and other animal droppings, to boost crop production, enhance soil organic matter and improve soil fertility (Rufino, *et al.,* 2007). The importance of manure use in crop production could also increase with the increase in the price of chemical fertilizers. Survey results in Table 19 show the extent to which manure is an important input in crop production in all the five districts under this study. Variations in manure use were observed by district and season. During both cropping seasons, the average amount of manure use in Embu surpassed the amount used by all the

Table 17. Intensity of maize residue use as soil mulch and livestock feed by season and District.

	Soil mulch (kg/acre)						Livestock feed (kg/TLU)					
	Season 1 (March-June)			Season 2 (Sept-Nov)			Season 1 (March-June)			Season 2 (Sept-Nov)		
District	Obs	Mean	Std.Dev	Obs	Mean	Std.Dev	Obs	Mean	Std.Dev	Obs	Mean	Std.Dev
Bungoma	140	3161	8287.9	31	4319.5	16356.1	108	2686.5	15509.6	30	1519.1	5346.2
Siaya	144	1399	2336.3	129	1216.4	2449.0	107	476.8	1139.1	97	432.7	1110.0
Embu	105	106	352.5	95	113.2	369.9	67	971.8	904.2	65	758.3	753.0
Meru South	83	100	279.2	76	89.8	212.2	68	987.7	1019.5	60	858.7	971.3
Imenti South	100	137	396.8	86	150.8	324.5	85	874.2	650.9	78	698.0	499.3

Note: Maize residue used as feed is mainly for cattle and, in this table, the term livestock refers to cattle only.

Table 18. Haricot bean, cowpea and pigeon-pea residue use by season (Kenya).

	Haricot beans						Cowpea						Pigeon-pea					
	Season 1 (N=538)			Season 2 (N=449)			Season 1 (N=123)			Season 2 (N=116)			Season 1 (N=44)			Season 2 (N=60)		
Purpose/use	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max	Mean	SD	Max
Burnt on plot	5.7	20.5	100	5.2	20.1	100	3.4	16.4	100	3.6	14.7	100	0.0	0.0	0	5.0	20.0	100
Firewood	0.7	5.9	100	0.7	6.6	100	0.1	1.0	10	0.5	4.7	50	9.1	20.0	70	16.2	23.5	70
Soil mulch	36.4	42.7	100	36.3	43.2	100	52.8	46.0	100	56.2	44.6	100	34.3	42.1	100	37.0	39.0	100
Livestock feed	45.6	44.1	100	47.9	45.2	100	38.5	45.0	100	31.6	42.7	100	55.5	45.4	100	38.0	35.7	100
Construction	0	0	0	0.0	0.9	20	0	0	0	0	0	0	0	0	0	0	0	0
Sold	1.4	9.9	100	1.8	12.0	100	0	0	0	0	0	0	0	0	0	0	0	0

Note: SD=Standard Deviation; N=Number of households that produced the crop and reported their residue use.

other districts combined by more than four times. On average, a household in Embu applied about 5 tons of manure to its farm plot during each cropping season.

Again, during both seasons, the average intensity of use of manure in crop production was higher in Embu (1536.4 and 1505 kg/acre in season 1 and 2, respectively). This amount is followed by the average intensity of use in Bungoma during season 1 (1051 kg/acre) though the intensity for the same District in season 1 was one tenth lower (i.e., 150.7 kg/acre) (Table 20).

Considering the source of the manure used in crop production, a larger proportion applied to crop fields came from own livestock (Table 21). This shows to what extent livestock holding contributes towards increased crop production and productivity by enhancing soil fertility. A number of the sample households also reported buying manure from other farmers and this shows the potential marketability of manure in the study areas. The largest share (11%) of use of purchased manure per household was observed in Embu in season one. As observed earlier, Embu is also the district with the largest amount of manure used per household.

Table 19. Quantity of manure applied to crop fields by season and district (Kg/household).

	Season 1 (March – June)				Season 2 (September –November)			
District	Obs	Mean	Std. Dev.	Max	Obs	Mean	Std. Dev.	Max
Bungoma	148	757.3	2530.2	22000	95	210.4	612.2	4200
Siaya	148	959.1	2526.0	20000	139	804.9	2402.4	20000
Embu	106	5088.9	46770.8	481960	104	5055.8	47226.4	481960
Meru South	102	1419.4	7245.0	72000	101	652.4	1580.4	14000
Imenti South	102	604.0	731.4	3840	101	555.7	648.5	3000

Table 20. Intensity of use of manure by district and season (kg/acre).

	Season 1 (March – June)				Season 2 (September –November)			
District	Obs	Mean	Std. Dev.	Max	Obs	Mean	Std. Dev.	Max
Bungoma	128	1051.0	7852.7	88000	94	150.7	549.9	4200
Siaya	144	491.9	1071.8	6667	135	383.3	836.1	6667
Embu	105	1536.4	11807.3	121096	102	1505.3	11978.9	121096
Meru South	101	375.8	863.1	6698	100	291.7	576.8	4000
Imenti South	102	414.7	654.0	4000	100	394.5	586.2	4000

Table 21. Proportion of manure applied to crop fields from own production.

	Season 1 (March – June)			Season 2 (September – November)		
District	Obs	Mean	Std. Dev.	Obs	Mean	Std. Dev.
Bungoma	66	0.94	0.21	28	0.95	0.19
Siaya	88	0.95	0.20	83	0.96	0.17
Embu	69	0.89	0.31	63	0.93	0.25
Meru South	63	0.96	0.18	57	0.97	0.16
Imenti South	86	0.98	0.15	83	0.97	0.15

Note: Minimum is zero and maximum is 1 in all Districts.

5.3. Draft power use

As discussed in section 4.2.1 (Table 11), sample households in the western part (Bungoma and Siaya) owned a number of trained oxen. However, except in Embu, where the number is still limited, sample households in the Eastern Province did not keep trained oxen. They relied either on renting draft power or have adopted a Hoe-culture in land preparation. Under such circumstances where land preparation is expected to be laborious or expensive, the introduction and promotion of zero tillage practices as a component of CA could y more likely be adopted and faster.

The descriptive results presented in Table 22 show the existence of a variation in the average number of oxen-days used by district and season. A relatively larger use of oxen-days per household was observed in Meru South followed by Bungoma during both cropping seasons. On the other hand, average use of oxen-days per household in Embu was found to be low.

The intensity of oxen-days per acre was high in Meru South during both seasons, with 4.3 oxen-days per acre used in season one and 4.7 oxen-days per acre used in season two. In contrast, the intensity of oxen-days per acre was low in Embu (0.9 oxen-days per acre) during both the rainy seasons. This variation by district could be a result of different factors such as differences in the nature of plots operated, cultivation practices employed, and the availability of oxen power. In the districts with higher intensity of oxen power use per acre, the crop-livestock interaction was also high. Details related with the intensity of use of oxen power by district and season are presented in Table 23.

The sample households in the western districts of Bungoma and Siaya spent higher amounts of money for hiring oxen days both in season 1 and 2 (Table 24). In Bungoma, on average, each household spent Ksh. 2902 and Ksh. 1084 to hire draft animals for land preparation in season one and two respectively.

Table 22. Oxen-days used in crop production by season and District (oxen-days/household).

	Season 1 (March – June)				Season 2 (September – November)			
District	Obs	Mean	Std Dev	Max	Obs	Mean	Std Dev	Max
Bungoma	148	5.0	5.1	28	97	2.9	3.5	16
Siaya	148	2.9	8.7	99	139	2.0	3.3	15
Embu	105	1.1	4.5	42	100	1.2	4.7	42
Meru South	102	8.6	6.9	26	101	8.8	6.9	28
Imenti South	102	2.3	4.3	22	102	2.6	5.2	30

Note: Minimum value in both seasons and all Districts is zero.

Table 23. Intensity of use of oxen power (oxen-days/operated acre/season).

	Season 1 (March – June)				Season 2 (September – November)			
District	Obs	Mean	Std Dev	Max	Obs	Mean	Std Dev	Max
Bungoma	129	3.9	4.2	24	147	1.5	3.5	27
Siaya	145	1.8	5.8	66	145	1.2	2.1	12
Embu	109	0.9	2.8	16	108	0.9	2.8	16
Meru South	101	4.3	3.5	16	101	4.7	4.9	32
Imenti South	102	1.6	3.4	18	101	1.7	3.6	20

Note: The minimum value for both the seasons and all districts is zero.

Though subject to further economic analysis, the introduction of zero tillage and use of chemicals (Roundup®) to control weeds could potentially decrease the amount of money spent to hire draft animals for land preparation. The minimum average cash outlay for oxen rent was reported in Embu where the average amount of money spent per household to hire oxen for land preparation was Ksh. 55 in both seasons.

Table 24. Cash outlay to hire oxen power for land preparation (KSH/household/season).

	Season 1 (March – June)				Season 2 (September – November)			
District	Obs	Mean	Std Dev	Max	Obs	Mean	Std Dev	Max
Bungoma	148	2902.03	8633.90	92000	97	1084.02	1648.76	8000
Siaya	148	1398.35	2558.45	16800	139	1133.83	212385	9200
Embu	105	55.71	457.28	4500	100	54.00	458.02	4500
Meru South	102	599.02	1318.75	6300	101	557.03	1242.43	6300
Imenti South	102	97.06	486.14	3200	102	122.55	618.99	5000

Note: Minimum value in both seasons and all Districts is zero.

Summary and Conclusions

The use of manure and draft power in crop production in mixed crop-livestock farming systems, and that of crop residues as livestock feed constitute the major linkages between the two sub-systems. This study investigated the implications of these linkages to the adoption and expansion of conservation agricultural practices (minimum soil disturbance, retention of crop residue on plots, intercropping and crop rotation) in eastern and western Kenya.

The result shows that using crop residues as livestock feed and retaining crop residues on plots for soil mulching and nutrient management by smallholders represent two practices that compete against each other for access to a single resource. In systems where livestock production is minimal and population density is low, retaining crop residues in the field could be a realistic and viable option unless there are other equally important purposes that smallholders use the residue for. Experience from Bungoma shows the importance of increasing biomass production to reduce the trade-offs between the use of maize residue for livestock feed and soil mulch. Increased biomass production boosts the total amount of crop residue available and, even under the existing proportion of use, could increase the volume of residue allocated for each purpose. Thus, technologies and agricultural practices that potentially contribute towards enhancing crop-biomass production could have more likelihood to be adopted under mixed crop-livestock farming systems.

The study also shows that there is a tradition of using oxen power for land preparation both in the eastern and western parts of the country. Households using zero/minimum tillage in field crops' production were found to have/own no oxen. Still further study needs to be undertaken to determine as to whether the farmers adopted zero/minimum tillage due to a lack of oxen or because they have destocked their oxen due to the adoption of zero/minimum tillage. Nevertheless, the possible adoption of zero tillage practices mingled with herbicide use observed in western Kenya seems promising due to the high cost of renting oxen to be used for land preparation.

Though small in terms of quantity, there are cases where maize and legume crop residues are burnt on farm plots. On top of the severe trade-off between using crop residue as soil mulching and livestock feed, the experience of burning crop residue left on farm plots could indicate inefficient residue use anchored on traditional knowledge. Thus, enhancing the awareness of smallholder farmers on the importance of using crop residue for soil mulching, increasing soil organic matter, reducing run-offs, facilitating infiltration, among others, seems essential.

Generally, in areas where a strong linkage was established between crop and livestock production, the introduction and expansion of conservation agricultural practices could have some pros and cons that should be examined carefully. Introducing and strengthening maize-legume intercropping and/or crop rotation could enhance biodiversity and crop biomass, which, in turn, increases the availability and quantity of diverse crop residue types as livestock feed. The overall increase in crop biomass as a result of enhanced soil nutrient content through the adoption of CA-practices could also increase the level of crop residue left on plots after satisfying the residue required as livestock feed. However, at the initial adoption stages of CA practices, retaining crop residue on farm plots and its use as livestock feed could be a challenge. The introduction of forage shrubs and trees side by side with residue retention could, thus, help in reducing the demand for residue for livestock feed. But these forage trees and shrubs should not compete severely with other crops for land and labor. Unless this is the case the acceptability and adoption of these technologies by smallholders as pathways for a more sustainable and resilient agriculture is challenged.

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Annex

Table A1. Quantity of maize residue use in Western Kenya per season (kg/household).

	Bungoma				Siaya			
	Season 1 (N=142)		Season 2 (N=36)		Season 1 (N=146)		Season 2 (N=134)	
Purpose	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std Dev
Burnt on plot	97.0	523.6	27.2	95.1	104.2	520.2	99.5	535.0
Firewood	337.8	1000.3	58.1	121.8	19.3	208.4	20.7	217.1
Soil mulch	6577.3	29793.9	5782.6	30394.9	1769.6	3738.4	1479.6	3308.4
Livestock feed	3131.4	16374.2	4215.9	20238.0	916.8	2840.0	828.9	2709.8
Construction	1.4	16.8	0.0	0.0	0.0	0.0	0.0	0.0
Sold	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Survey 2011.

Table A2. Quantity of maize residue use in Eastern Kenya (kg/household).

	Embu				Meru South				Imenti South			
	Season 1 (N=105)		Season 2 (N=99)		Season 1 (N=87)		Season 2 (N=79)		Season 1 (N=100)		Season 2 (N=90)	
Purpose	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std Dev
Burnt on plot	6.1	62.5	13	103	29.3	203.1	3.2	28.1	8.0	56.3	5.6	52.7
Firewood	0.0	0.0	0	0	0.0	0.0	0.0	0.0	4.0	40.0	5.6	43.3
Soil mulch	112.0	424.7	120	450	124.0	367.1	76.1	180.8	122.6	366.6	119.4	300.9
Livestock feed	746.2	888.6	610	746	958.7	847.9	818.9	789.4	913.7	721.5	755.6	562.0
Construction	0.0	0.0	0	0	0.0	0.0	18.2	162.0	0.0	0.0	0.0	0.0
Sold	105.1	336.5	64	257	177.7	518.1	47.1	166.1	47.9	207.6	55.9	307.7

Source: Survey 2011.

Table A3. Quantity of manure applied to crop fields from own production (kg/household).

	Season 1 (March – June)				Season 2 (September – November)			
District	Obs	Mean	Std. Dev.	Max	Obs	Mean	Std. Dev.	Max
Bungoma	148	744.1	2525.3	22000	95	204.7	610.3	4200
Siaya	148	936.6	2526.8	20000	139	794.0	2402.9	20000
Embu	106	4950.3	46779.6	481960	104	4963.2	47230.9	481960
Meru South	102	1326.3	7230.5	72000	101	587.0	1487.3	14000
Imenti South	102	591.7	734.3	3840	101	538.3	651.6	3000

Source: Survey 2011.

Table A4.Quantity of manure purchased and applied to crop fields (kg/household).

District	Season 1 (March – June)				Season 2 (September – November)			
	Obs	Mean	Std. Dev.	Max	Obs	Mean	Std. Dev.	Max
Bungoma	148	13.2	107.4	1200	95	5.7	39.2	300
Siaya	148	22.4	136.5	1200	139	10.9	64.7	500
Embu	106	138.6	748.0	7000	104	92.6	712.5	7000
Meru South	102	93.2	640.0	6000	101	65.4	599.4	6000
Imenti South	102	12.3	101.8	1000	101	17.3	113.2	1000

Source: Survey 2011.

Table A5. Cash outlay for manure purchase (KSH/household/season).

District	Season 1 (March – June)				Season 1 (March – June)			
	Obs	Mean	Std. Dev.	Max	Obs	Mean	Std. Dev.	Max
Bungoma	148	7.4	64.0	600	95	0.0	0.0	0
Siaya	148	16.8	103.2	1000	139	12.2	81.2	700
Embu	106	178.3	1038.1	10000	104	47.1	299.8	2800
Meru South	102	98.0	667.6	6000	101	118.8	725.1	6000
Imenti South	102	31.4	214.3	2000	101	24.8	204.6	2000

Source: Survey 2011.

CIMMYT[MR]
International Maize and Wheat Improvement Center

P.O. Box 5689, Addis Ababa, Ethiopia
m.jaleta@cgiar.org
www.cimmyt.org