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*Full Length Research paper*

# Crop-livestock diversification patterns in relation to income and manure use: A case study from a Rift Valley Community, Kenya

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**Most rural households in the semi-arid regions of sub-Saharan Africa practise mixed crop-livestock farming. With population growth and the subsequent scarcity of land available for extensive farming, the only option available for these households is to intensify production. For this to be successful, one must understand the divergent patterns of intensification and their relation to the economic needs of households. In a Rift Valley community in Kenya, inter-household heterogeneities in adopting distinctive combinations of particular crop and livestock productions (they are defined as 'crop-livestock diversification' or CLD patterns) were observed. Principal component analysis was used to identify the dominant CLD patterns which reflect complementarities between crop and livestock types. This was followed by an assessment of the association between the CLD patterns and the economic returns and manure use of the households. Among the five dominant CLD patterns identified, households that kept improved cattle and grew fruits were found to earn higher incomes and apply more organic manure. Conversely, households that grew staple crops with or without indigenous animals were found to apply less manure. Education, participation in farmers' groups, access to the training centre, and family size were key factors affecting the adoption of CLD patterns.**

**Key words:** Crop-livestock integration, sustainable intensification, income, manure application, rural Kenya

## INTRODUCTION

Mixed crop-livestock systems are the most important mechanisms for producing food across sub-Saharan Africa, where 166 million poor agro-pastoralists live (Kristjanson and Thornton, 2004; Herrero et al., 2007). Recently these systems have experienced tremendous socio-economic changes and faced environmental challenges. As livelihoods transform from subsistence to a more monetary economy due to infrastructure and educational development, the need to earn cash has increased. Such development is often accompanied by an increasing scarcity of land for extensive farming and by continuous use of farmland without fallow and is exacerbated by population growth (Shepherd and Soule, 1998; Tittonell et al., 2005). The rise in population has increased pressure on soils; Place et al. (2003) estimated that two-thirds of agricultural land in Africa has been degraded. Mixed crop-livestock farming systems in Kenya are no exception. Smallholders have diversified their farming activities to include various food crops and local animals, and some have introduced exotic cash crops and improved animal breeds.

There should be diverse interactions between various crop and livestock components of mixed systems during the intensification process (Kristjanson and Thornton, 2004). Ensuring sustainable intensification and economically profitable integration of crop-livestock farming to meet the welfare and environmental goals of people is paramount (Williams et al., 1999; Place et al., 2003; Makinde et al., 2007). Better utilisation of organic manure from livestock has the potential to ensure sustainable crop-livestock intensification for poor agro-pastoralists, especially as they often cannot afford to buy expensive inorganic fertilisers (Bationo et al., 2004; Makinde et al., 2007). Efficiently applied, crop and livestock activities would not only contribute to income generation but also to higher crop productivity and better environmental hea-

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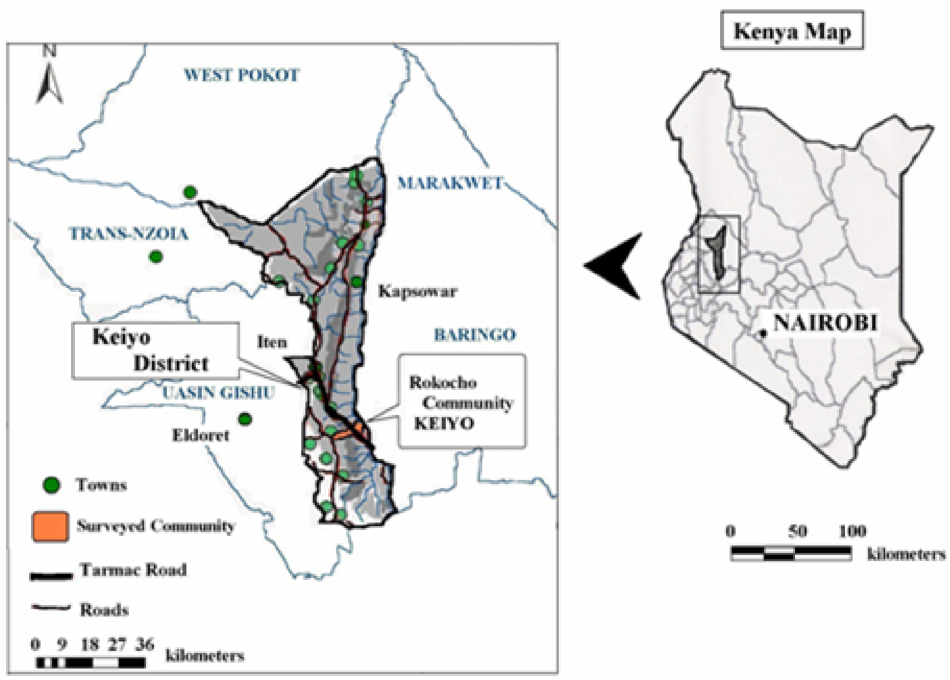


**Figure 1.** Keiyo District (source) Iiyama (2006).

lth through supplying nutrients to soils without relying on external resources. A better understanding of diverse interaction of crop and livestock components and which of them are more associated with welfare and manure application should be a first step toward developing more effective extension services.

Many studies have tried to determine how households decide to integrate manure into their farming activities, that is., household characteristics (family composition, education, land and livestock) and physical characteristics of farms (soil type, slopes and distance to homesteads) (Clay et al., 2002; Freeman and Coe, 2002; Place et al., 2002; Place et al., 2003). However, there have been few empirical studies to look at the relationship between manure use and distinctive crop-livestock activities. Even within a small area, one can observe inter-household heterogeneities in the adoption of different sets of crop-livestock types, that is., indigenous or exotic, subsistence or commercial, which have different levels of economic returns and input use (Tittonell et al., 2005). If there are some complementarities between particular types of crop and livestock production, they must be understood as a set. To formulate an effective extension service, it is more practical to identify portfolios of varieties that improve welfare and ensure sustainable soil management rather than to identify household/farm characteristics to influence better soil management. Some patterns may serve to increase income and ensure food security and to counter risks for households by diversification. However, without intensified use of inputs, such patterns might be environmentally unsustainable in the long term. In such cases, we need some interventions to encourage households to better manage and utilise their resources.

In this study we define 'crop-livestock diversification (CLD)' patterns as particular combinations of crops and animals. Some CLD patterns have more complementarities between components than others do. Diversification occurs where components co-exist rather independently on the farm. Their combination serves to reduce risks, but their interactions are minimal. Conversely, integration occurs where the components are interdependent (van Keulen and Schiere, 2004). Application of organic manure from animals to crops can be one indicator of better integration.

This paper presents ongoing inter-household heterogeneities in CLD patterns from an agro-pastoral community in the Kenyan Rift Valley. The main purposes of this study are to:

- Identify the dominant CLD patterns in the study area.
- Investigate which CLD patterns are associated with higher income and with more intensive manure use.
- Examine which factors affect a households' decision to adopt better CLD patterns.

## MATERIALS AND METHODS

### Study area

Keiyo District is located along the basin of the Kerio River in the Rift Valley Province of Kenya (see Figure 1). The district can be divided into three agro-ecological zones: highlands in the west, escarpment in the central parts, and the valley floor. For this study, we focus on the valley floor community.

There are 16 sub-locations in Keiyo District, from which Rokocho Sub-location (Soy Division, Kibargoi location) was randomly selected. Rokocho community consists of 177 households, all of which were included in the study. The household survey was conducted between July and September 2006 by the project leader and two local enumerators. The project team collected data from the households using a structured questionnaire. The questionnaire was designed to collect variables to capture aspects of livelihood activities from which households derive income (crop, livestock and off-farm income activities), adoption of measures by households to maintain soil fertility (manure input), and household characteristics (family composition, skills and education).

There is a major tarmac road traversing Rokocho Sub-location in a North-South direction and there is other infrastructure such as a primary school and a church mission with a training centre. It is warm for most of the year and temperatures range between 22 and 31˚C. Average annual rainfall is between 700 and1000 mm. Altitude ranges between 1000 and 1600 m above sea level (Muchemi et al., 2002; SARDEP, 2002). Before independence in the early 1960s, the authorities considered farming in the Kerio basin unviable due to lack of permanent sources of water. After the 1970s, and especially since 1985, the construction of the tarmac road greatly transformed the livelihoods of people living in the valley floor. Institutions, such as churches and non-governmental organisations, have also stimulated development initiatives by providing villagers with training in management skills and capital to practise horticulture and buy exotic animals. Furthermore, water projects have allowed more people to settle in the valley (Mizutani et al., 2005; Iiyama, 2006). As population increases, the land available to individual households is becoming smaller. The demand for CLD patterns both to ensure high economic returns and sustainable land use for households in the study area is therefore high.

**Crop-livestock categories**

Households in the study area plant various kinds of crops and keep various types of animals.

Crops were categorised into:

- Drought-resistant crops: including indigenous varieties such as sorghum, millet and cassava.
- Staple crops: including maize, beans, cowpeas, green grams and groundnuts.
- Fruits: including mangoes, pawpaw, citrus, bananas and avocadoes.
- Commercial crops: including wheat, potatoes and carrots.

Animals were classified as:

- Improved breeds of cattle: exotic and crossbred cattle.
- Dairy goats.
- Indigenous cattle.
- Sheep and goats.

**Analytical methods**

Four methods were used to analyse the data. First, descriptive statistics of crop-livestock activities were summarized. They were presented in terms of the acreage of land planted by particular crop types and the average number of livestock by animal types owned. CLD patterns are treated not as diversities of crop-livestock varieties at individual plot-level but as portfolios of household choices. To calculate the area planted with a particular crop is not as straightforward as counting the number of livestock, since households often have access to more than one plot and plant different crop types on the same plot, as is the practice in other parts of rural Africa. Where this was the case, households were asked to approximate the percentage of the plot devoted to a particular crop type (see Shepherd and Soule, 1998; Benin et al., 2004).

Secondly, principal component analysis was used to derive a new set of variables (scores) to represent CLD patterns from the variables representing crop and livelihood activities. Other studies which investigate determinants and/or implications of adopting soil conservation measures rarely differentiate distinctive crop and animal types but aggregated them as ‘total land size’ and ‘total livestock holdings’ (Clay et al., 2002; Freeman and Coe, 2002; Place et al., 2002; Morera and Gladwin, 2006). However, when there is diversity in crop and animal types (i.e. there are many variables) and complementarities between particular types (that is., there are high correlations between variables), these aspects should be reflected in analysis. Principal component analysis is an appropriate multivariate analytical tool to deal with this kind of variables. The analysis is a tool to describe the variation of a set of multivariate data in terms of a set of uncorrelated variables, each of which is a particular linear combination of the original variables. The object of this analysis is to see whether the first few components account for most of the variation in the original data. If so, they can be used to summarise the data with little loss of information. The principal components may be useful when:

- There are too many explanatory variables relative to the number of observations.
- The explanatory variables are highly correlated (Everitt and Dunn, 2001).

For example, when particular crop and livestock activities are complementary (positively correlated) or substitute (negatively correlated), a new set of variables, or principal components, can reflect such aspects. If a principal component is highly associated positively with factor weights for crop type [A] and animal type [B] but negatively associated with crop type [C], this principal component represents a CLD pattern with crop type [A] and animal type [B] with less of crop type [C]. The analysis also yields scores for households with each principal component. Households allocating more land to planting crop type [A] but less to crop type [C] with more of animal [B] are given high scores for that crop type [A] and animal type [B] component.

Thirdly, ordinary least squares (OLS) analysis was used to estimate which CLD patterns were associated with a higher level of household income (KSh per year)[1] and increased use of organic manure (kg/total land area in acres used by household). The quantity of manure was estimated for each crop type and aggregated for the total number of acres a household uses. For explanatory variables, the principal component factor scores were used to indicate the degree of engagement by households in a particular CLD pattern. While other studies investigate a causal relation between ‘whether households apply manure or not’ and aggregate land and livestock holding by binary logistic/probit analyses (Clay et al., 2002; Freeman and Coe, 2002; Place et al., 2002), our analysis used continuous variables to quantitatively reveal associations between manure use and CLD patterns.

Fourthly, the households were ranked with the principal component factor score for the CLD pattern found to be associated with higher household income and manure use, in the previous section, and grouped into three groups (tertile). Then mean values of socio-economic variables representing household characteristics (such as age, gender and education years of the head) were compared among the groups, to identify which of these factors influence households to adopt better CLD patterns while keeping others from doing so.

[1] US$ 1 was equivalent to KSh 70 in 2006.

**Table 1**. Descriptive Statistics of Variables on Crop-Livestock Activities

| | N | Mean | Std.D | Min | Max | Share |
|---|---|---|---|---|---|---|
| **Variables of Crop-Livestock Activities** | | | | | | |
| Land with drought- resistant crop (acres) | 177 | 0.14 | 0.40 | 0 | 2 | 0.06 |
| Land with Staple crop (acres) | 177 | 1.27 | 2.59 | 0 | 21 | 0.55 |
| Land with fruits (acres) | 177 | 0.80 | 1.29 | 0 | 10 | 0.35 |
| Land with commercial crop (acres) | 177 | 0.07 | 0.39 | 0 | 4 | 0.03 |
| Total land used (acres) | 177 | 2.28 | 2.99 | 0 | 24 | |
| No. of improved cattle (TLU) | 177 | 0.79 | 1.88 | 0 | 10 | 0.15 |
| No. of dairy goats (TLU) | 177 | 0.03 | 0.11 | 0 | 1 | 0.01 |
| No. of indigenous cattle (TLU) | 177 | 2.69 | 5.31 | 0 | 38 | 0.52 |
| No. of sheep/goats (TLU) | 177 | 1.64 | 4.36 | 0 | 44 | 0.32 |
| No. of total animals owned (TLU) | 177 | 5.14 | 7.45 | 0 | 44 | |
| **Variables for Income/Manure Application** | | | | | | |
| Total gross income | 177 | 83,989 | 95,235 | 4,150 | 666,200 | |
| % of households applying manure (yes=1, no=0) | 177 | 0.49 | 0.50 | 0 | 1 | |
| Amount of manure applied per acre (kg/acre) | 177 | 152 | 473 | 0 | 3,800 | |

## RESULTS

### Crop-livestock activities

The summary of statistics of the variables representing crop-livestock activities in the study area are presented in Table 1. Of the total amount of land used, most (55%) was planted to staple crops followed by fruits (35%) with much less allocated to drought-resistant and commercial crops. The number of livestock owned was calculated as total livestock units (TLU).[2] Of these, indigenous cattle took up the highest average proportion (52%) of the total average number of animals owned by a household (5.14). This was followed by sheep and goats (32%) and improved cattle (15%); dairy goats on average accounted for 1% of the total livestock holding. These averages, however, tend to mask the heterogeneities in adopting certain crop/livestock types among households and particular complementarities between crops/livestock.

A correlation matrix of standardised scores[3] of the variables representing crop and livestock activities is shown in Table 2. The ratio of land with staple crop was negatively correlated with fruits (-.61), positive with total land used (.25), % of indigenous cattle in total TLU (.21), and total TLU (.24). On the other hand, the ratio of land with fruits was positively correlated with % of improved cattle in total TLU (.25). The ratio of improved cattle in total TLU was negatively correlated with those of indigenous cattle (-.33) and sheep / goats (-.21). The ratio of indigenous cattle in total TLU was negatively correlated with that of sheep / goats (-.31), but positively with total TLU (.35). The ratios of land with commercial crop and of dairy goats did not have any correlation with the other variables.

The finding shows that there should be some ‘patterns’ of crop-livestock combinations. Households that grow fruits tend to keep improved breeds of livestock intensively, while those devoting bigger portions of land to staple crops tend to use larger areas for crops and to own more indigenous cattle. Therefore, rather than independently dealing with variables representing engagement in each crop/livestock type, it is better to look at them in an integrated manner.

### Identification of dominant CLD patterns

Principal component analysis was used to derive a new set of components representing CLD patterns from the original variables representing the crop-livestock portfolios (see Table 2). In choosing the number of components, two criteria were used:

- Retain just enough components to explain a large percentage (between 70% and 90%) of the total variation in the original variables and
- Exclude those principal components whose eigenvalues are less than the average, or 1 for this case, as the components are extracted from the correlation matrix (Everitt and Dunn, 2001).
- The results of the principal components analysis are summarised in Table 3. Five principal components, which explain 71.52% of the total variances in the data, were extracted from the original crop-livestock portfolio variables.

[2]A TLU is calculated as follows: a bull is equivalent to 1.29 TLU; cow 1 TLU; calf 0.7 TLU; sheep and goat 0.11TLU (Kristjanson et al. 2002).

[3]Standardised (z) score for x is calculated from the following formula: z = {(x – mean)/(standard deviation)}. Even variables have different units in measurement (ex. %, acres, TLU), all standardised variables have the same mean (0) and the variance (1).

**Table 2**. Correlation Ratios between Crop-Livestock Activities.

| Z scores | drought-resistant | staple | Fruits | commercial | total acres | improved cattle | dairy goats | indigenous cattle | sheep / goats | total TLU |
|---|---|---|---|---|---|---|---|---|---|---|
| **Land allocated to** | | | | | | | | | | |
| Drought-resistant (%) | 1 | | | | | | | | | |
| Staple (%) | -.20(**) | 1 | | | | | | | | |
| Fruits (%) | -.32(**) | -.61(**) | 1 | | | | | | | |
| Commercial (%) | -0.09 | -0.10 | -0.03 | 1 | | | | | | |
| Total land used (acres) | -0.14 | .25(**) | 0.00 | 0.08 | 1 | | | | | |
| **Animal held in** | | | | | | | | | | |
| Improved cattle (%) | -.16(*) | -0.07 | .25(**) | 0.12 | .26(**) | 1 | | | | |
| Dairy goats (%) | -0.06 | 0.03 | 0.05 | -0.04 | -0.01 | 0.00 | 1 | | | |
| Indigenous cattle (%) | -0.12 | .21(**) | -0.08 | -0.04 | -0.05 | -.33(**) | -0.10 | 1 | | |
| Sheep & goats (%) | 0.01 | -0.10 | -0.03 | -0.08 | 0.00 | -.21(**) | -0.09 | -.31(**) | 1 | |
| Total TLU | -.16(*) | .24(**) | -0.15 | -0.08 | 0.13 | 0.04 | -0.08 | .35(**) | 0.00 | 1 |

**. Correlation is significant at the 0.01 level, *. At 0.05 level (2-tailed).

**Table 3**. Dominant CLD Patterns (Principal Component Analysis).

| | component | | | | |
|---|---|---|---|---|---|
| | **CLD 1** | **CLD II** | **CLD III** | **CLD IV** | **CLD V** |
| | **Maize + ind cattle** | **Ex cattle + fruits** | **Extensive crop** | **Sheep/goats** | **Dairy goats** |
| | + staple crop +indigenous cattle - fruits | +improved cattle + fruits + land use -drought resistant | -indigenous cattle - fruits + land use | +sheep &goats | + dairy goats - commercial crop |
| **Z scores** | | | | | |
| **Land allocated to** | | | | | |
| Drought-resistant crop | -0.04 | -0.66 | 0.22 | -0.34 | -0.21 |
| Staple crop (%) | 0.80 | 0.18 | 0.35 | -0.06 | 0.20 |
| Fruits (%) | -0.70 | 0.35 | -0.48 | 0.24 | 0.08 |
| Commercial crop (%) | -0.14 | 0.24 | 0.11 | -0.40 | -0.50 |
| Total land used (acres) | 0.15 | 0.57 | 0.46 | 0.11 | -0.06 |
| **Animals held in** | | | | | |
| Improved cattle (%) | -0.35 | 0.66 | 0.28 | -0.14 | -0.10 |
| Dairy goats (%) | -0.10 | 0.07 | 0.04 | -0.30 | 0.83 |
| Indigenous cattle (%) | 0.60 | 0.07 | -0.67 | -0.06 | -0.12 |
| Sheep & goats (%) | -0.16 | -0.34 | 0.38 | 0.74 | 0.00 |
| Total livestock unit (TLU) | 0.54 | 0.30 | -0.17 | 0.37 | -0.11 |
| **Initial Eigenvalues** | | | | | |
| Total | 1.98 | 1.64 | 1.32 | 1.14 | 1.08 |
| % of variance | 19.76 | 16.39 | 13.20 | 11.42 | 10.76 |
| Cumulative (%) | 19.76 | 36.15 | 49.34 | 60.76 | 71.56 |

### CLD I: Maize and indigenous cattle

Staple crop (mainly maize) and indigenous cattle were positively associated with this component, while fruits were negative. Households with a higher score for this component are specialised in extensive production of staple crops and grazing of indigenous cattle.

### CLD II: Improved (exotic) cattle and fruits

Ratios of improved cattle and total land used were highly positive, while those for drought-resistant crops were negative. Although it was less than 0.5, the weight for fruits was higher than that for the other components. Households with a higher score for this component are specialised in keeping improved cattle breeds, integrated with the production of fruits.

### CLD III: Extensive crop production

Indigenous cattle and fruits were negatively associated with this component while total land used was positive. Households with a higher score for this component are engaged in cultivation of large areas of relatively more drought-resistant and staple crops, without owning animals.

### CLD IV: Sheep and goats

The sheep/goat ratio in total TLU was highly positive. Households with a higher score for this component keep more of these small indigenous animals than other households do.

### CLD V: Dairy goats

Ratio of dairy goats in total TLU was highly positive, while area with commercial crop was negative. Households with a higher score for this component are more likely to adopt dairy goats.

### Implications of CLD patterns on income and intensified manure use

The average total household income in Rokocho Sub-location was KSh 83,989 per year, with 49% of the households using manure (Table 1). However, it is likely that there are substantial differences in income levels and in the intensity of manure application among households, as they pursue different CLD patterns. The principal component scores derived from the analysis (see the previous Section) can be used as explanatory variables to define the engagement of households in the particular CLD patterns. The dependent variables are total house hold income level and the quantity of manure input per

**Table 4.** Implications of CLD Patterns on Total Income and Manure Input (OLS Results).

| | Total gross income coefficient | t | Manure per acre coefficient | t |
|---|---|---|---|---|
| (constant) | 83,988.79 | 14.09 *** | 152.13 | 4.52 *** |
| **CLD I: maize + indigenous cattle**<br>+ staple crop, + ind cattle, - fruits | -71.96 | -0.01 | -122.78 | -3.64 *** |
| **CLD II: exotic cattle + fruits**<br>+improved cattle, +fruits + land use | 48,054.37 | 8.04 *** | 103.34 | 3.06 *** |
| **CLD III: extensive crop production**<br>-indigenous cattle, -fruits, + land use | 21,430.82 | 3.59 *** | -48.61 | -1.44 |
| **CLD IV: sheep/goats**<br>+ sheep & goats | 11,687.90 | 1.96 * | 27.70 | 0.82 |
| **CLD V: dairy goats**<br>+ dairy goats, -commercial crop | -7,632.36 | -1.28 | 2.84 | 0.08 |
| R Square | 0.33 | | 0.13 | |
| Adjusted R Square | 0.31 | | 0.10 | |
| F | 16.60 *** | | 5.08 *** | |

(Note) 177 households. ***:significant at <.01, **:<.05, *:<.1..

acre. The results of OLS regressions are presented in Table 4.

CLD patterns II, III and IV were significant and positive for income. However, CLD pattern II was positive for manure input per acre, while CLD pattern I was negative. CLD pattern II (improved cattle and fruits) is not only associated with better income but also with more intensified manure use through better crop-livestock integration. Fruits are more likely to be planted on fenced homestead plots. Exotic animals are managed with more intensive grazing within an owner's plots, because they have a higher economic value than indigenous cattle do, therefore their dung is more easily available for applying to fruits. In contrast, CLD pattern I (maize and indigenous cattle) had a negative sign for income, and was significantly associated with lower manure input per acre. Despite being associated with more indigenous cattle, it appears that manure is rarely utilised for staple crops. CLD pattern III (extensive crop production) was significantly associated with higher household income but had a negative sign for manure application.

## Household characteristics

In the previous section, CLD pattern II of improved cattle and fruits was found to be more associated with higher household income and application of manure. To examine household characteristics with higher engagement in CLD pattern II, the 177 households were ranked by factor score II and grouped into three or tertile. The means for income components, application of manure, and variables representing household characteristics, such as age, gender, education years of the head, family labour (in adult equivalent[4]), number of years in farmers' group and distance in minutes to local training centre are summarised in Table 5.

On average, the top tertile group earns about KSh 143,129 a year, nearly double the earning of the middle tertile group (KSh 71,149) and four times the low tertile group (KSh 35,870). Of the high tertile group, 72% apply organic manure on their plots (on average 267 kg/acre), but only 21% of low tertile households do so (on average 39 kg/acre). If we turn to household characteristics, the high tertile group relative to the other two groups is on average characterised by larger households headed by more educated males, who have participated in a farmers' group for a longer time and with homesteads located nearer to local training centre. Conversely, smaller households, headed by older, less educated people with little experience in participating in a farmers' group, and whose homesteads are located far from local training centre, are less likely to adopt the CLD pattern of improved cattle and fruits, therefore to earn less income and rarely apply manure.

## DISCUSSION

In this study, five dominant CLD patterns were identified. Among them, a pattern of improved cattle and fruits was found to be associated with higher household income and more intensive manure use. This combination may have an inherent incentive for mutual intensification, and can be interpreted as an integrative crop-livestock intensification pathway, not only welfare enhancing but also

[4] A person over 15 years old is equivalent to 1 adult equivalent (AE), 0.65 AE for over 5 to 14 years, and 0.24 for less than 4 years old.

**Table 5.** Groups of Households Ranked According to Principal Component Factor II.

| | CLD II Tertile 1 | CLD II Tertile 2 | CLD II Tertile 3 | Total average | F |
|---|---|---|---|---|---|
| No. of households | 58 | 59 | 60 | | |
| **Income Component** | | | | | |
| Total gross income(ksh/year) | 35,870 | 71,149 | 143,129 | 83,989 | 24.78 *** |
| Off-farm income(ksh/year) | 25,039 | 37,983 | 66,470 | 43,398 | 6.62 *** |
| Crop income(ksh/year) | 5,420 | 21,813 | 42,092 | 23,324 | 16.99 *** |
| Livestock income(ksh/year) | 5,190 | 11,468 | 33,642 | 16,927 | 19.79 *** |
| **Application of Manure** | | | | | |
| Ratio of households applying manure | 0.21 | 0.54 | 0.72 | 0.49 | 18.89 *** |
| Manure use per acre(ksh/year) | 39.07 | 145.97 | 267.48 | 152.13 | 3.55 ** |
| **Households Characteristics** | | | | | |
| Age | 52.36 | 43.25 | 45.05 | 46.85 | 4.55 ** |
| Gender (male1, femaleO) | 0.60 | 0.83 | 0.90 | 0.78 | 8.90 ** |
| Education years of the head | 4.33 | 6.31 | 8.05 | 6.25 | 10.49 *** |
| Family labour (Adult Equivalent) | 2.62 | 3.40 | 3.85 | 3.30 | 7.88 *** |
| Participation years in farmers group | 0.90 | 2.47 | 4.08 | 2.50 | 6.29 *** |
| Minute distance to training centre | 35.66 | 24.80 | 23.93 | 28.06 | 4.48 ** |

environmentally sustainable. In contrast to horticulture, the CLD pattern of staple crops with or without indigenous cattle has few incentives to apply manure. Especially for CLD pattern I, the staple crop serves to satisfy the food security needs of households, but the potential for using manure from indigenous animals has not been sufficiently tapped. It is probable that indigenous cattle are rather extensively grazed in open commonages and their dung is difficult to collect. Unlike the combination of improved cattle and fruits, this combination is a mere diversification without integration.

Fruits require some years to produce income flows and it may take more time and expertise for households to successfully introduce large improved animals (Conelly, 1998). Education and access to knowledge and skills through participation in farmers' groups and close access to the training centre appear to be crucial factors for households to adopt CLD pattern II. In the short term, it may not be practical to recommend households without capital to immediately undertake this pathway. CLD pattern V with dairy goats was neither significantly associated with higher income nor more manure use. It is possible that it is easier for lower income households to incurporate dairy goats in their farming practices than it is for them to incorporate improved cattle. The selection of crop and livestock activities may need to be compatible with household needs for food security/income and their initial management capacity. A recommendation is to integrate crop-livestock activities through sensitisation. Sustainable crop-livestock livelihood evolution can be successful only if it comes with appropriate support for technology transfer and with environmental education.

Other studies suggest that intensified manure use is strongly affected by larger livestock holdings and agro-ecological and physical conditions of farms, while size of land holding is ambiguous (Clay et al., 2002; Freeman and Coe, 2002; Place et al., 2002). They conclude that this result is not surprising because households with large numbers of animals should use more manure. While our analysis did not include physical characteristics of farms, our results indicated that it is not the number of animal holdings but rather the degree of integration between distinctive crop types that determines intensified manure use. At the same time, the quantity of manure applied in the study area is much lower than that in other studies, while few inorganic fertilisers are used. For example, animal manure production by zero-grazing cattle in Kenya has been estimated at 1–1.5 t/animal (Strobel, 1987 cited in Bationo et al., 2004). Manure use should be more encouraged for sustainable horticulture and crop production.

For extension services, it is more practical to understand which crop/livestock varieties contribute to development for agro-pastoral smallholders in mixed farming systems than it is to search for independent factors affectting adoption of soil conservation measures. As a conclusion, the methodology of this study should contribute to a better understanding of diverse interactions of crop-livestock components and their implications for income and manure management.

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## REFERENCES

Bationo A, Nandwa SM, Kimetu JM, Kinyangi JM, Bado BV, Lompo F, Kimani S, Kihanda F, Koala S (2004). Sustainable Interaction of Crop-Livestock Systems through Manure Management in Eastern and Western Africa: Lessons Learned and Emerging Research Opportunities', in Williams (eds.), Sustainable Crop-Livestock Production for Improved Livelihoods and Natural Resource Management in West Africa. Nairobi: International Livestock Research Institute. pp. 173-198.

Benin S, Smale M, Pender J, Gebremedhin B, Ehui S (2004). The Economic Determinants of Cereal Crop Diversity on Farms in the Ethiopian Highlands, Agric. Econ. 31: 197-208.

Clay DC, Kelly V, Mpyisi E, Reardon T (2002). Input Use and conservation Investments among Farm Households in Rwanda: Patterns and Determinants', in Barrett et al. (eds.), Natural Resources Management in African Agriculture: Understanding and Improving Current Practices. Oxon and New York: CABI publishing. pp. 103-114.

Conelly WT (1998). Colonial Era Livestock Development Policy: introduction of Improved Dairy Cattle in High-Potential Farming Areas of Kenya. World Develop. 26(9): 1733-1748.

Everitt BS, Dunn G (2001). Applied Multivariate Data Analysis: Second Edition. London: Arnold. pp. 48-73.

Freeman AH, Coe R (2002). Smallholder Farmers Use of Integrated Nutrient-Management Strategies: Patterns and Possibilities in Machakos District of Eastern Kenya, In: Barrett et al. (eds.), Natural Resources Management in African Agriculture: Understanding and Improving Current Practices. Oxon and New York: CABI publishing. pp. 143-154.

Herrero M, González-Estrada E, Thornton PK, Quirós C, Waithaka MM, Ruiz R, Hoogenboom G (2007). IMPACT: Generic Household-Level Databases and Diagnostics Tool for Integrated Crop-Livestoc System Analysis. Agric. Syst. 92: 240-265.

Iiyama M (2006). Livelihoods Diversification Patterns among Households and their Implications on Poverty and Resource Use: A Case Study from Kerio River Basin Community. LUCID Project Working Paper 51; Nairobi, Kenya: International Livestock Research Institute.

Kristjanson P, Radney M, Nkedianye D, Kruska R, Reid R, Gichohi H, Atieno F, Sanford R (2002). Valuing Alternative Land-Use Options in the Kitengela Wildlife Dispersal Area of Kenya. A Joint International Livestock Research Institute (ILRI) and the African Conservation Center (ACC) report undertaken for the Kitengela community. Nairobi: International Livestock Research Institute.

Kristjanson PM, Thorton PK (2004). Methodological Challenges in Evaluating Impact of Crop-Livestock Interventions', in Williams (eds.), Sustainable Crop-Livestock Production for Improved Livelihoods and Natural Resource Management in West Africa. Nairobi: International Livestock Research Institute. pp. 160-172.

van Kuelen H, Schiere H (2004). Crop-Livestock Systems: Old Wine in New Bottles?' Proceedings of the 4th International Crop Science Congress. 26 Sep-1 Oct 2004, Brisbane, Australia.

Makinde EA, Saka JO, Makinde JO (2007). Economic Evaluation of Soil Fertility Management Options on Cassava-Based Cropping Systems in the Rain Forest Ecological Zone of South Western Nigeria. Afr. J. of Agric. Res. 2(1): 007-013.

Mizutani F, Kariuki PC, Iiyama M, Matsumoto K, Kariuki PN, Kiprono M, Cherwon K, Kristjanson P (2005). Kerio Valley Baseline Survey: Advancing Capacity of the Community through the Baseline Survey for Sustainable Rural Development in Marakwet and Keiyo Districts. Nairobi: International Livestock Research Institute in collaboration with Japan International Cooperation Agency.

Morera MC, Gladwin CH (2006). Does Off-Farm Work Discourage Soil Conservation? Incentives and Disincentives throughout Two Honduran Hillside Communities. Hum. Ecol. 34(3): 355-378.

Muchemi J, Mwangi W, Greijn H (2002). Participatory Land Use Planning towards Community- based Natural Resource management in the Districts of Keiyo & Marakwet, Kenya: A GIS and Remote Sensing Approach, mimeo. http://www.ermisafrica.org/doc/kmplup.pdf.

Place F, Franzel S, DeWolf J, Rommelse R, Kwesiga F, Niang A, Jama B (2002). Agroforestry for Soil-Fertility Replenishment: Evidence on Adoption Processes in Kenya and Zambia, In: Barrett et al. (eds.), Natural Resources Management in African Agriculture: Understanding and Improving Current Practices. Oxon and New York: CABI publishing. pp. 155-168.

Place F, Barrett CB, Freeman HA, Ramisch JJ, Vanlauwe B (2003). Prospects for Integrated Soil Fertility Management Using Organic and Inorganic Inputs: Evidence from Smallholder Afr. Agric. Syst. Food Policy 28: 365-378.

SARDEP (2002). SARDEP Keiyo/Marakwet, Participatory Land Use Plans for Community-based Natural Resource Management, Transect E. Iten: The Semi-Arid Development Programme. pp. 17-19

Shepherd KD, Soule MJ (1998). Soil Fertility Management in West Kenya: Dynamic Simulation of Productivity, Profitability and Sustainability at Different Resource Endowment Levels. Agric. Ecosyst. Environ. 71: 131-145.

Tittonell P, Vanlauwe B, Leffelaar PA, Rowe EC, Giller KE (2005). Exploring Diversity in Soil Fertility Management of Smallholder Farms in Western Kenya I. Heterogeneity at Region and Farm Scale. Agric. Ecosyst. Environ. 110: 149-165.

Williams TO, Hiernaux P, Fernández-Rivera S (1999). Crop-Livestock Systems in Sub-Saharan Africa: Determinants and Intensification Pathways', in McCarthy, N., Swallow B., Kirk, M., and Hazell, P. (eds.), Property Rights, Risk and Livestock Development in Africa. Washington D.C.:IFPRI , Nairobi: ILRI. pp. 132-151.