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Assessing Crop-Livestock Interaction in Mixed Farming Systems of North Western Kenya

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Abstract

A study was conducted in the four counties the maize- wheat-tea-potato and sugarcane-based farming system in North western Kenya to explore the variability among household characteristics and farm productivity. The aim of this work was to establish homogenous groups of crop-livestock mixed farming systems of Kenya. A two step approach was adopted for the study. The first was a rapid rural appraisal followed by a formal survey aimed at establishing farm types to facilitate detailed analysis of synergistic crop-livestock interaction systems. A random sample of 423 farmers was interviewed using a semi structured questionnaire. Descriptive and multinomial techniques were used in the analysis. Two classifications were utilized, the first step was establishing the criteria for classification and the second based on resource accessibility by farmers. The criteria used were the proportions of various crop and livestock enterprises and resource endowment. The process came up with eight farm types based mainly on the farm enterprise orientation, farm size, land productivity, cattle breeding, and farm by-products. Based on the formal survey three farm types were identified as intensive, semi intensive and extensive systems. The resource groups in all the counties were identified by: crop-livestock management, soil fertility management, food security and farm and off-farm income as important indicators of variability.

However, all households were net food buyers, implying food insecurity. In addition, off-farm activities and off farm income were important livelihood survival strategies. Development planners and policy makers need to develop unique interventions targeting each specific group, since blanket policies are not appropriate in such a situation. Options such as optimizing livestock numbers to match available feed resources and improving feed availability through breeding and adoption of dual-purpose crop varieties with better digestibility coefficient, improving the cost-effectiveness of existing nutrition technologies (e.g. crop-by-products'), and bringing more land under fodder crops need to be explored. Since the farm sizes within the region had continued to decline, limiting the availability of on-farm livestock feed, there is need for policy instruments that can discourage land fragmentation

Key words: *Household characterization, crop-livestock interaction, farm typologies analysis, Kenya*

Introduction

Most parts of Kenya and other sub-Saharan African (SSA) countries have experienced rapid land use and forest cover changes in the past three decades. This is attributed to increased pressure on land, caused by the ever-increasing human population leading to land sub-division with significant changes in per capita income and consumption patterns (Iiyama 2007; FA0 2011). These demographic and economic changes have led to higher demand for high-value livestock and crop products (Riddell et al, 2006). This demand creates opportunities and challenges for farmers and other stakeholders along the agricultural product value chain (APVC) to expand and add value to agricultural products (Devereux et al 2004). The farmers' response has taken different forms including intensification of livestock-crop production systems to produce more food and incomes (Rota and Sperandini 2005). The changes have created both positive and negative on crop-livestock-environmental interactions. For example, these changes have exerted pressure on the environment including rapid climatic changes resulting into progressive land degradation. The negative effects have become the concern for development agents, policy makers and other actors along the APVC to reverse these negative effects (Mwongera 2008). Most people in Kenya and other SSA countries practice mixed farming systems (crop-livestock) production and both crops and livestock it account for a significant proportion to the Kenyan economy (Republic of Kenya. 2004). Crop-livestock (C_L) interaction systems have the potential of increasing contribution to farmers' welfare. The combination of livestock with crop production is an effective way of not only managing risk aversion mechanism, but also sustaining land productivity. The C-L system is good for recycling of all the products of the farming operations, local crop and livestock material including household waste. These crop residues and other products would otherwise pose a major waste disposal problem. The crop residues that can be fed to livestock include; maize stovers, straw, haulms, damaged fruits, grains and household wastes. These practice leads to effective and efficient nutrients recycling on farms where manure from livestock a valuable source of soil nutrients (like nitrogen, phosphorus and potassium) including trace elements at varying levels but also improved soil structures and water holding capacity. Draught animal power is widely used for farm operations. Despite the recognized role that crop-livestock interaction plays in determining the state of the ecosystems and sustaining livelihoods within the farming systems, the spatial extent and intensity of crop-livestock interaction practices is yet to be assessed and fully explored. This study was aimed at bridging this gap. It is recognized that all stakeholders along the APVC including policy makers need to be informed, through generation of information regarding the crop-livestock interaction and probably spatial distribution of livestock-crop production systems, factors determining this interaction and the possible effect of suggested alternative interventions. The overall objective of this study was to analyze the crop-livestock interaction production systems in Northwest Kenya. The specific were; 1). Characterize crop-livestock production systems in North western Kenya; 2) to determine the factors that influence crop-livestock production systems and 3) suggest alternative interventions and assess their impacts on crop-livestock production systems. Modelling crop-livestock farming systems can help identify and quantify significant interactions that occur between the various components of mixed farming systems through simulation exercises of existing land use patterns or interventions.

Methodology

Study site

Crop and livestock production are the main sources of household livelihoods in rural Kenya. Majority of farmers practice mixed farming, integrating crops and livestock. The farm sizes range from 0.5 ha to about 500 ha. The most important crops grown in the four the region are wheat, tea, maize, potatoes, beans, wheat, floriculture, carrots, and other vegetable crops such as kales, cabbage and local vegetables. A significant proportion of farms are under arable land with limited available for pasture. Livestock production is another important activity in the study area. Previous studies have shown that the most prominent livestock activity is the dairy production mainly on subsistence basis. Farmers also keep some sheep, goats, poultry and donkeys. Additional household economic activities include salaried employment, small and micro enterprises, firewood gathering and selling, charcoal burning and selling, quarrying and sand harvesting. The scales of agricultural practices are relatively varied depending on the agro-ecological systems under review.

Sampling Design and Techniques

In order to achieve the set objectives both secondary and primary data were utilized. Primary data was generated through surveys. The sampling frame for the study was all crop-livestock farmers in the study counties, with a household as the sampling unit. The study was undertaken in two stages starting with rural rapid appraisal followed by personal interviews at household level. The surveys were carried in between June and July 2011. Multistage sampling approach was used where counties, locations and households were randomly selected using simple random sampling technique. Four counties (Bungoma, Uasin Gishu, West Pokot and Trans Nzoia) were purposively selected based on farming systems while 10 locations and 423 households were randomly selected farmers based on 2009 human census data (KNBS. 2009). A semi-structured questionnaire and check lists were utilized in formal and RRA surveys respectively. The questionnaire was field tested in one county that exhibited large differences in farming system. In each sub-location a sample frame was generated by listing farmers. The sample size of 423 was computed based on 2009 population census figures (KNBS. 2009) was arrived at using a formula adapted from Kothari (1995)

Sample size:

$n = P*Q / (SE)^2$

$n = 423 = (0.5*0.5) / (0.0456)^2$

Where:

n = sample size

P = proportion of the population containing the major attribute

Q = 1-p

SE = standard error of the proportion

The Analytical Framework and Specification of the model

In order to analyze crop-livestock systems the requirements are to; describe and quantify the interactions between the system's components; represent the farmer's management practices; determine the impacts of management strategies on use of land and other resources; and allow the possibility of studying both the medium-and the long-term effects of the C-L strategies. The first step is to characterize the farming system and understand the importance of the crop-livestock integration in the study area. This can be followed by testing of associations between variables in the farming systems. A number of priority variables for describing C-L interactions are grouped. This was achieved through descriptive, principal component analysis, and multinomial regression analysis.

Descriptive statistics

Descriptive statistics were computed on key personal (age, education, gender, marital status of head of household,), farm (farm size, farm enterprises-crops and livestock, soil fertility and management), institutional (markets, credits, group membership) characteristics of the sampled households. The statistics included frequencies, means, variances and standard deviations/errors to describe the data. The results were cross-tabulated and where necessary, charts, graphs, and other diagrams were used to summarize and interpret the data.

Inferential statistics

Inferential analyses were utilized in the regression models. Three distinct analyses were carried out, namely a correlation analysis, the multiple linear regression (step-wise) and the logistic regression. The broad reasons for the multilayered analysis have been given in the introduction above but will be revisited in the subsections below within which they are elaborated and specified.

Model Specification and Data Analysis Techniques

To achieve the set objectives of this study, several statistical techniques were employed. They included descriptive and regression analyses. These specifically included Principal Component analysis (PCA) and multinomial logit models.

Principle component analysis

There are a wide range of factors that can be used to describe the farming systems which included farmer, farm and institutional factors. Because of this multitude factors, principle component analysis was used to reduce these factors. Principle component analysis is a statistical method that assists in identifying and weighing the most important indicators in order to calculate an aggregate index of farming systems description for a specific sample household.

Basically, the principal component (PC) technique slices information contained in the set of indicators into several components. Each component is constructed as a unique index based on the values of all the indicators. The main idea is to formulate a new variable, X*, which is the linear combination of the original indicators such that it accounts for the maximum of the total variance in the original indicators. That is, X* is computed as

$$X^* = w_1 X_1 + w_2 X_2 + w_3 X_3$$

Where the weights (the ws) are specified such that X* accounts for the maximum variances in X_1, X_2, and X_3. This index has a zero mean and a standard deviation equal to one (Basilevsky 1994; Sharma 1996).

The PC analysis therefore extracts underlying components from a set of information provided by summary indicators. In the case of this farming systems description method, information collected from the questionnaires make up the .indicators and the underlying component that is isolated and measured is farming systems. The first principal component accounts for the largest proportion of the total variability in the set of indicators used. The second component accounts for the next largest amount of variability not accounted by the first component, and so on for the higher order components. As the collection of indicators towards those describing poverty, the poverty component is expected to account for most of the movements in the indicators and will be the strongest of all the components. The farming systems component can be easily identified by analyzing the signs and size of the indicators in relation to the new component variable. For example, according to theory, education should contribute positively not negatively to wealth. PC analysis, hence, can be used to compute a series of weights that mark each indicators relative contribution to the overall wealthy component. Using these weights, a household-specific wealth index/score can be computed based on each household's indicator values.

Multinomial logit model

To assess the determinants of the household's preference for a particular crop-livestock production system, multinomial logitistic regression analysis was used. From the cluster analysis done in objective one, three livestock production systems were identified: Intensive, Semi-Intensive and Extensive. The dependent variable was therefore discrete in nature hence the use of the Logistic a choice regression model. In the analysis, marginal effects were estimated and reported. A farmer may choose a livestock management option (LMO) on the farm depending on socio-economic, business and biophysical characteristics environment. The options include: intensive, semi-intensive and extensive management systems. The choice can be explained in household consumer behaviour as the decision to be engaged in a given a livestock system activity, which is influenced, by a number of factors. The choice can be modelled within frameworks that explain individual choice behaviour. The decision to choose a given LMO is a behavioural response arising from a set of alternatives and constraints facing the decision maker. Livestock systems choice necessitated the use of discrete choice theory in analyzing the livestock system choices. In analyzing the determinants of income diversification portfolios, a multinomial Logit model were used (Maddala 1983; Greene 2003).

Multinomial Logit

In analyzing factors affecting the choice of LMOs, a multinomial logit (MNL) model was used. The MNL model is based on the random utility theory. The utility to a household who selects an income portfolio (U) is specified as a linear function of the individual and farm specific characteristics, the attributes of the alternative LMOs and other institutional factors as well as stochastic component. In this study individual specific and institutional characteristics (X) were used as shown in equations 1 to 3.

$$U(LMO\_\ Intensive\_0) = \beta_j X_0 + e_j \quad \text{Equation 1}$$

$$U(LMO\_SEMI\_Intensive\_1) = \beta_j X_0 + e_j \quad \text{Equation 2}$$

$$U(LMO\_extensin\sin comeportfolioj) = \beta_j X_0 + e_k > \quad \text{Equation 3}$$

If the observed outcome (dependant variable) = LMOs j and if U

$$U(LMO\_j) > U(LMO\_k) \quad \forall j \neq \text{k then} \quad \text{equation 4}$$

$$\beta_j X + e_j > \beta_k X_k + e_k \quad \text{equation 5}$$

The MNLM defines probabilities as function of X_i of unknown disturbance term e

$$P_i = (P_s(X_i, e)$$

The standard MNM the probability function defined as by Maddala (1983). The reference LMO was intensive LMO and this was compared to other two LMOs. Hence, for each LMO there was 3-1=2 predicted log of odds, one for each LMO relative to intensive LMO. When M=1 you get ln(1) = 0 = Z_{11} and exponential (0) = 1.

The probability of choosing the LMO is equal to the probability that the utility of that particular LMO is greater than or equal to the utilities of other alternatives in the choice set. The farmer maximizes utility from LMO in the sense that, that particular choice best minimizes the cost of production, maximizes profits or ensures achievement of a threshold level of LMO of any other objectives.

The dependent variable was discrete variable taking values 0, 1, and 2 for cases where LMO was LMO semi-intensive=1, LMO extensive=2 = f(age, education, sex, relation of Household member to the HHH., family size, time on-farm, employment type, farm size, credit access, extension access, distance to markets, acreage).The independent variables (X_{0s}).

Identification and Characterization of crop-Livestock Production Systems

First rural rapid appraisal was used to characterize the crop-livestock production systems. A team that consisted of socio-economist, livestock nutritionist, forage agronomists, and livestock extension officer were involved in the activity. This was followed by Principal components analysis (PCA) and two step cluster analysis were used to characterize livestock production systems using the formal survey data. The Cluster analysis procedure was used to identify relatively homogeneous groups of cases based on selected characteristics, using an algorithm that starts with each case in a separate cluster and combines clusters until only one is left. The variables used for Principal Components and cluster analyses were selected a priori. These variables were grouped into four categories: Herd structure, socioeconomic factors, management practice strategies, and soil management practices. The farmer's management behaviour is reflected in his /her decisions on livestock production. Crucial decisions include feeding strategies (e.g. whether to feed wholly on forages or to mix with some concentrates), the livestock health management and breed selection. Depending on the farmers' skills and resource endowment, the management behaviour may differ between farmers. Depending on how much the farmers orient their production towards the market; their commercialization index may reveal their livestock management behaviour. Farmers are normally exposed to several uninsured risks such as natural disasters, demographic changes, price volatility and policy changes. To manage the exposure to these risks, risk averse farmers may forgo activities which could yield high expected outcomes. However some farmers may adopt strategies which help them to spread risks. Such strategies include farm enterprise diversification, and hiring additional parcels of land away from their homes. Due to lack of proper methods to quantify the fodder fed to livestock within the year, the current rental value of the land dedicated to livestock production was used to compute the expenditure on fodder. The proportion of marketed milk output was used as a proxy for commercialization index. The number of enterprises and farms a farmer had was taken as an indicator of the farmers risk management and diversification behaviour. However, it was recognized that this could also be an indicator of farmers' wealth status. The more risk averse farmers are expected to have more enterprises which help to spread their risk. They are also expected to have more farms spread in different parts of the watershed for the same reasons. PCA was based on the variables include: Herd structure (average number of cattle per household, average number of goats per household, average number of sheep per household, average number of poultry per household, livestock intensity and main cattle breeds.); Socioeconomic factors (age of household head and average education level for the household); Management practice strategies (Mode of feeding, proportion of land under pastures, proportion of milk output sold per household, average milk production per cow, and expenditure on concentrates) and Farmers' risk behaviour factors (Number of farms, number of enterprises, access to credit and distance to the market). Variables used in Principal components and subsequently selected were as shown in Table 1.

Table.1 Livelihood factors used in classifying production system

Social	networks, membership in organizations and community support Family size, membership in associations, .
Financial	stocks and regular inflow of money which includes incomes, savings assets and credit . per capita expenditure and value of assets
Hunan capital	the ability to supply labour, skills, knowledge, education and good health that influence achievement of set objectives
Physical	basic infrastructure and producer goods like tools, machinery and equipment used for efficient functioning. (includes roads, irrigation, electricity, equipments, housing)
Natural assets	Natural capital are stocks such as soils, land, water, air, forests, grazing employed in developing livelihood strategies

Results and Discussions

Rapid rural survey

Farm description

Farms varied widely in size and other characteristics, ranging from very small-scale farmers who sold their labour and were net buyers of food to fully commercial oriented farms that generate annual million shillings. Based on land area covered by various farm types, eight farm types were identified as shown in Table 2. The major criteria used were proportion of area under farm enterprises, agricultural potential and access to resources.

Table 2: Description of farm types in selected counties of North western region

Farm typology	County	Characteristics
1. Dairy-Wheat-Maize farm types (large, medium and small)-Lower Humid (LH) Zone	Uasin Gishu, Trans Nzoia	Wheat 50%, Maize 20%, Dairy30%. These consist of large, medium and small scale farmers. Wheat production is more favourable, however maize also does equally well. These farm types are highly mechanized. They also use more chemicals for weed and pest control. Dairy in this region is dependent on natural ley grasses and wheat and maize by-products. Some farmers process the farm by-products for feed. Poor dairy breeds and low quality feeds is the constraint to efficient livestock production
2. Tea-Maize-Dairy (large, medium and small) Upper Midland	Nandi, Trans-Nzoia, Elgeyo Marakwet, West Pokot	Tea (30%), Maize (30%), dairy/pasture (40%). These consist of large, medium and small scale farmers. Tea performs best in this zone and is the main source of income. Casual employment is also high in tea picking. Maize is grown for both green and dry-grain market
3. Maize-Dairy Upper Midland zone-4	Trans Nzoia	Maize (75%), dairy/pasture (20%) Other crops (5%). These consist of large, medium and small scale farmers.

Farm typology		County	Characteristics
4.	Sugarcane-maize-dairy(large, medium and small) Lower midland Upper Midland	Nandi, Bungoma	Sugarcane (70%), Maize (28%), dairy/pasture (2%). These consist of large, medium and small scale farmers. These farm types are mostly contracted by sugar companies (Nzoia, Chemilil), though some are privately engaged. A high number of casual labour is utilized in cane production. Households in these region import food crops from other regions because delayed harvesting/payment for cane delivered in factories.
5.	Potato-Dairy-maize- (large, medium and small) Upper Humid zone	Uasin Gishu Trans Nzoia and West Pokot	Potato (40%), Dairy 40%, Maize (20%). These consist of large, medium and small scale farmers. Potato does well in these zones unlike maize which take over 9 months to mature. Farmers are also engaged in sheep and goats rearing because of the favourable alpine environment
6.	Cattle-Shoats-Acacia woodland Inner Lowlands	West Pokot and Uasin Gishu	Cattle (45%), Shoats (55%) Mostly pastoralists with very limited crop production because of the harsh weather. Some pastoralists plant sorghums, finger-millet and maize in river-Rhine areas and in upper zones when rainfall is reliable. Camel production is slowly being introduced in these farm types. Depend on acacia woodlands as feed source
7.	Irrigation-Acacia woodland Inner Lowlands	West-Pokot, Keiyo/Marakwet	Irrigation (5%), Livestock (70%) others (25%). These are government supported projects growing fruits, maize, and other food horticultural crops and also contracted by seed companies to multiply basic seed for various crops

Farm typology	County	Characteristics
8. Horticulture-Dairy-Maize UM/LH	Uasin Gishu, Trans Nzoia	Horticulture (70%); Dairy (15%) Maize 15%. Mostly Large Scale Commercial farms. They specialize in horticulture for export but in addition incorporate dairy and maize farming.

Dairy-Wheat-Maize farm types (large, medium and small)-Lower Humid (LH) Zone: Wheat 60%, Maize20%, Dairy20%. These consist of large, medium and small scale farmers under varying management practices. Wheat production is more favourable, however maize also does equally well. These farm types are highly mechanized. They also use more chemicals for weed and pest control. Dairy in this region is dependent on natural ley grasses and wheat and maize by-products. Wheat by-products mainly straw is fed baled into hay and also fed insitu. Farmers often burn their farms before they plough in order to make ploughing using mainly disc-plough easy and efficient. Some farmers process the farm by-products for feed. Poor dairy breeds and low quality feeds is the constraint to efficient livestock production. Natural pasture is reserved in many farms but the productivity is so low that it cannot be sustained. Farms with zero and semi-zero grazing system are few.

Tea-Maize- Dairy (large, medium and small) Upper Midland: Tea is the predominant crop in these categories occupying about 40-75% of the farms depending on the scale of operation, Maize occupies about 20-40% and often sold as green, The region occasionally imports maize from other regions. Dairy/pasture is a key enterprise in the region occupying about 20-40%. However, this category of farm are faced with pasture feed constraints because a larger acreage is occupies by tea and maize. These consist of large (25 acres), medium (5-24acres) and small scale (<5 acres), farmers. Tea performs best in this zone and is the main source of income. Casual employment is also high in tea picking. Maize is grown for both green and dry-grain market

Maize-Dairy Upper Midland zone-4: Maize (80%), dairy/pasture (5%). These consist of large, medium and small scale farms. This is mainly found in Trans Nzoia, upper parts of Bungoma, Uasin Gishu and some parts West Pokot (Kapenguria division). Dairy is equally important in these regions with crosses and improved dairy cattle breeds reared. The milk production is relatively low. Area under pastures is low though some farm had improved pastures mainly Napier grass and Rhodes grass.

Some farms are producing hay for sale and for own use. One bale of hay ranges from 150-250 shillings. Road side grazing is practiced by small-scale farmers. Farms with zero and semi-zero-grazing system are there particularly in small and medium scale farms

Sugarcane-maize-dairy (large, medium and small) Lower midland Upper Midland: Sugarcane (60%). Maize (35%), dairy/pasture (2%). These consist of large, medium and small scale farmers. These farm types are mostly contracted by sugar companies (Nzoia, Chemilil), though some are privately engaged. A high number of casual labours are utilized in cane production. Households in these region import food crops from other regions because delayed harvesting/payment for cane delivered in factories. These types of farm types started emerging in western Kenya in 1970s after the establishment of sugar factories in the region. Large quantities of sugar cane by-products namely sugarcane tops, molasses and mud filter from factories are produce but very limited recycling of these products was observed.

Potato-Dairy-maize- (large, medium and small) Upper Humid zone: Potato (50%), Dairy 40%, Maize (10%). These consist of large, medium and small scale farmers. Potato does well in these zones unlike maize which take over 9 months to mature. Farmers are also engaged in sheep and goats rearing because of the favourable alpine environment. Zero grazing is very important in this zone. Farms under zero-grazing systems have relatively high milk production than those under free-range.

Cattle-Shoats-Acacia woodland Inner Lowlands: Cattle (50%), Shoats (45%) Mostly pastoralists with very limited crop production because of the harsh weather. Some pastoralists plant sorghums, finger-millet and maize along the river basins and in upper zones when rainfall is reliable. Camel production is slowly being introduced in these farm types. Depend on acacia woodlands as feed source. Nutrient recycling through manure is limited

Irrigation Acacia woodland Inner Lowlands: Irrigation (50%), Livestock (15%) others (25%). Crop farming is an emerging system. These are government supported projects growing fruits, maize, and other horticultural food crops and also contracted by seed companies to multiply basic seed for various crops. The types of livestock breeds are mainly local with very low milk production.

Horticulture-Dairy-Maize UM/LH: Floriculture (70%); Dairy (15%) Maize 15%. Mostly Large Scale Commercial farms. They specialize in floriculture for export but in addition incorporate dairy and maize farming. Some farms in this farm type are purely floricultural farms producing flowers under green house. The markets for these farms are mainly for export.

The results are reported starting with the principal components and followed by cluster analysis results. Due to the heterogeneity nature of the data set of the sampled farmers it was necessary to first characterize them into homogenous categories, called the crop-livestock production typologies. This was followed by the descriptive analysis which presents the descriptive results based on the crop and livestock production systems.

Principal Component and Cluster Analysis Results

Principal Components Analysis Results

Cluster analysis was preceded by factor analysis, through Principal components method which was used to identify underlying variables that explain the pattern of correlations within each of the sets of observed variables. The objective of using analysis was for data reduction to identify a small number of factors that explain most of the variance observed in a much larger number of manifest variables. Each of the 423 households was given a score along the new variables generated that consisted of the sum of the products of the weightings and their scores along the original variables. The components with the Eigen-values greater than one were selected and used in the subsequent cluster analysis (Table 2). The Eigen-value represented the amount of variance in the original variables accounted for by each component. All the rotated factor matrices were obtained through the varimax. The VARIMAX this method maximizes the sum of variances of required loadings of the matrix centres by simplifying the columns of the factor matrix

Using the new components is preferable to using the original variables, which are highly correlated with the components because the components are representative of all the original variables but are not linearly correlated with each other.

Table 2: Total variance explained

	Total Variance Explained								
	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.972	16.431	16.431	1.972	16.431	16.431	1.86	15.497	15.497
2	1.404	11.702	28.133	1.404	11.702	28.133	1.324	11.032	26.529
3	1.192	9.932	38.065	1.192	9.932	38.065	1.23	10.251	36.78
4	1.092	9.104	47.169	1.092	9.104	47.169	1.198	9.98	46.76
5	1.059	8.827	55.996	1.059	8.827	55.996	1.078	8.986	55.746
6	1.025	8.542	64.538	1.025	8.542	64.538	1.055	8.792	64.538

Principal Component Analysis by farm types

Six variables (principal components) were selected to represent the crop-livestock enterprise mix for each household. All the six had eigenvalue greater than one, hence were selected. Four principle components, each with eigenvalue greater than one, were considered. The first component explained 16.431% of the variance in the farming systems description. The second component explained 17.02% of the variance in the data set. The third explained 9.932%. The fourth, fifth and the sixth components accounted for 9.104%, 8.827%, and 8.542% of the variance, respectively (Table 2). These explained 64.538% of the variation in the original variables.

Principal Component Analysis by Household Socioeconomic Factors

In the study, 33 explanatory variables were considered for their potential role in accounting for the description of crop-livestock interaction farming systems. When the components were rotated using varimax rotation with Kaiser normalization (Wuensch, 2006), thirteen of the information sources loaded heavily (r coefficient $\geq|\pm 0.4|$) on the first and second principle components while the third and fourth components had only one information source loading heavily with each. (Table 3). To represent the household socioeconomic factors, 12 variables were selected and subjected to principal components analysis (Table 3). This yielded two factors with eigen-value greater than one. These factors contribute 57.02 % of the variation. These variables were named experience and labour availability. Six Principal components to represent the farmer's crop-livestock management practice were selected. These yielded six factors which contributed to 62.12 % of the total variation. These factors were farm size, number of exotic/cross-breed cattle, farm orientation, and membership in groups and cattle management.

Table 3: Rotated Component Matrix based on the responses of farmers

Variable	Component					
	1	2	3	4	5	6
1. Farm size	0.942882	-0.09790	0.061922	0.030847	0.01492	0.013847
2. Number of exotic dairy cattle kept	0.940442	-0.03182	0.001498	0.024772	-0.00337	0.035683
3. Number of local cattle kept	0.134937	0.274871	0.496262	-0.1759	-0.16159	-0.32847
4. Family size	0.133414	-0.05284	-0.11432	0.635303	0.3913	0.054455
5. Highest level of education of respondent	0.022462	-0.04983	0.044818	-0.09049	-0.12593	0.842039
6. Sex of HoH	-0.01198	0.026199	0.631147	0.391248	-0.07954	0.132366
7. Membership in group	-0.01317	0.301844	-0.66414	0.131331	-0.1859	-0.05941
8. Age of household head	-0.01463	0.057078	0.039447	-0.05058	0.858793	-0.06949
9. Farm group	-0.01884	0.710088	-0.32353	0.063175	-0.10454	0.003154
10. Number of off farm permanent employment	-0.02892	0.004431	0.070443	0.738924	-0.21378	-0.0924
11. Production system	-0.12481	-0.48628	-0.03367	-0.11533	-0.20187	-0.43635
12. Soil fertility for farm	-0.18005	0.62977	0.114688	-0.13092	0.085083	-0.09379
% of variance explained	2.781737	3.285611	3.32457	5.45238	5.273576	6.00163

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization

Cluster Analysis Results

The study identified three major livestock production systems through Principal components and cluster analysis. The three clusters yielded three livestock production systems: Intensive, Semi intensive and Extensive livestock production systems.

Intensive Livestock Production System

Cluster one was the intensive production system, which was characterized by highly diversified and commercial oriented farmers. Farmers in this livestock production system constituted the smallest number in the entire sample. These farmers were spread over the three zones in Northwest and West Kenya, Bungoma, Trans Nzoia, Uasin Gishu and West Pokot. Compared with the farmers in the Extensive livestock production system, farmers in intensive and semi-intensive systems had a relatively lower number of cattle and farm size. The mean land holding varied greatly across the clusters. They relied on grown fodder with some of them bought or rented pastures for grazing.

Semi Intensive Livestock Production System

The second cluster was the semi-intensive livestock production system. Farmers in this cluster were also dispersed in the region. They relied on own established pastures and had established pastures with some of them buying. Some of these farmers relied on roadside grazing or grazing on public land. A few were practicing tethering some categories/kinds of livestock. This type of livestock management practices implies livestock feeds are not commensurate with livestock numbers. Roadside grazing predisposes the livestock to diseases and parasites leading to extra costs of treatment. This type of livestock rearing is partially attributed to limited resource (e.g. land and working capital).

Extensive Livestock Production System

These farmers were relatively wealthy with large tracks of land. Because of rapid increases in population and land sub-division due to inheritance and selling the population of this system is rapidly declining. They are commercial oriented by virtue of their scale of operation. They had the largest number of pure and/or improved dairy cattle. Crop rotation is practiced but not fully integrated into their plans. Most of these farms were acquired from white settlers after independence (Syagga 2010).

Table 4: Descriptive statistics of general socio-economic variables

variable	n	Mean	SE
Sex of household head	362	.88	.034
Age of household head	340	55.06	5.627
Years in crop farming	414	19.73	.646
Years in Livestock rearing	385	19.29	.761
Total male and female age >55years	206	1.1602	.06226
Number of casual people	194	2.8505	.51800
Number of off farm permanent employment people	144	1.5972	.21621

The descriptive statistics presented in Table 4 reveal that the sex of the household head was 0.9 while the mean age of the household head was 55 years. The experience of the head of household was in crop farming was 20 years and that in livestock rearing was 19 years. The mean number of household members was 6 and those beyond 55 years. The average number casuals were 3 per household while the number of permanent

casual was two.

Multinomial Logistic Regression Results

The log likelihood of the fitted model was -201.31, and from this value we can reject the null hypothesis that all the regression coefficients are simultaneously equal to zero. The likelihood ratio on the other hand was

89.92 (degrees of freedom = 236 observations) and the p-value was 0.0000. These two statistics help us to reject the null hypothesis that all regression coefficients across both models are simultaneously equal to zero. Lastly the McFadden's pseudo R^2 was 0.1826. This was within the highly satisfactory range of 0.2 – 0.4. Table 3 presents the results obtained from the analysis on the multinomial logistic regression model. The factors that significantly influenced the likelihood of practicing semi-intensive system compared to intensive system (base) were marital status, years in crop and livestock farming use of hired labour and household food security status. The marginal effects are presented in Table 5.

Table 5: Logit model of factors influencing use of livestock grazing systems

					P>z	[95% Conf. Interval]
0 (base outcome=intensive system)	coef	se	z	p-value		
Sex of household head	0924607	..4909492	0.19	0.851	-.869782	1.054703
Farm size	.0839726	.1717646	0.49	0.625	-.2526797	0.420625
Marital status	-.3166685	.5247329	-0.6	0.546	-1.345126	0.711789
Years in livestock rearing	-.0203716	.0181441	-1.12	0.262	-.0559334	0.01519
Years in crop rearing	.0116984	.0211146	0.55	0.580	-.0296854	0.053082
family size	-.0403166	.0357787	-1.13	0.260	-.1104416	0.029809
Off farm employment	-.0281474	.083925	-0.34	0.737	-.1926375	0.136343
Hired labour	.2349618	.3788898	0.62	0.535	-.5076485	0.977572
hhsfcfr	.0905614	.1539434	0.59	0.556	-.2111622	0.392285
q3hhlvst	.0111075	.0663796	0.17	0.867	-.1189942	0.141209
Trans-Nzoia county dummy	1.362472	1.15481	1.18	0.238	-.9009142	3.625859
Uasin-Gishu county dummy	6798424	.1.146318	0.59	0.553	-1.5669	2.926585
West Pokot county dummy	-16.68384	1162.813	-0.01	0.989	-2295.756	2262.389
Constant	-.8748506	1.7768	-0.49	0.622	-4.357315	2.607614
2=Semi-intensive						
sexhhh	-.8308767	.5668298	-1.47	0.143	-1.941843	0.280089

farmsize	-.169264	.2095097	-0.81	0.419	-.5798955	0.241368
marsthhh	**-1.966038**	**.617865**	**-3.18**	**0.001**	**-3.177031**	**-0.75505**
yrslvtfmng	**-.0802491**	**.0323077**	**-2.48**	**0.013**	**-.143571**	**-0.01693**
yrscrpfmng	**.0749128**	**.0335137**	**2.24**	**0.025**	**- .0092272**	**0.140598**
famsz	-.0739907	.0508116	-1.46	0.145	-.1735797	0.025598
offrmppl	.0017466	.1020795	0.02	0.986	-.1983255	0.201819
hrdlbr	**-.9864099**	**.4675659**	**-2.11**	**0.035**	**-1.902822**	**-0.07**
hhsfcfr	-.5001964	.2694134	-1.86	0.063	-1.028237	0.027844
q3hhlvst	.0578283	.086715	0.67	0.505	-.1121299	0.227787
TZdum*	.3140219	1.204074	0.26	0.794	-2.04592	2.673964
UGdum*	-.4305208	1.195373	-0.36	0.719	-2.773408	1.912367
WpoDum*	-1.144165	1.234998	-0.93	0.354	-3.564717	1.276386
_cons	**5.10955**	**1.698676**	**3.01**	**0.003**	**- 1.780206**	**8.438894**
Number of observation						278
LR chi2(26)						89.92
Prob > chi2						0.0000
Pseudo R2						0.1826
Log likelihood						-201.3079

Table 5: Marginal effects of multinomial model of factors influencing use of livestock grazing systems

variable	dy/dx	Std. Err.	z	P>z	[95% C.I.	]	X
sexhhh* .	0878119	.74753	0.12	0.906	-1.37733	1.55295	0.809353
farmsize .	0136919	.31765	0.04	0.966	-.608894	.636278	1.90288
marsthhh	.1735053	.21038	0.82	0.41	-.238833	.585844	2.04676
yrslvt~g	.0071655	.01213	0.59	0.555	-.016613	.030944	18.3561
yrscrp~g	-.006607	.00915	-0.72	0.47	-.024546	.011332	19.3489
famsz	.0068478	.06907	0.1	0.921	-.128519	.142215	8.1295
offrmppl	.0001643	.07732	0	0.998	-.151372	.151701	0.528777
hrdlbr*	.0986838	1.15783	0.09	0.932	-2.17063	2.36799	0.697842
hhsfcfr	.0422263	.51299	0.08	0.934	-.963222	1.04767	1.66187
q3hhlvst	-.0051235	.00769	-0.67	0.505	-.020203	.009956	3.41727
TZdum*	-.0497756	4.80703	-0.01	0.992	-9.47138	9.37183	0.280576
UGdum*	.0291572	2.13329	0.01	0.989	-4.15202	4.21034	0.478417
WpoDum*	.3427578	.08193	4.18	0	.182178	.503338	0.21223

(*) dy/dx is for discrete change of dummy variable from 0 to 1

Conclusions

The study characterized and classified livestock farmers within North western Kenya region into eight crop-livestock production systems using the RRA approach and three major production systems, intensive, semi intensive and extensive using the formal survey approach. Majority of the farmers were in the extensive and semi intensive livestock production systems, which are mainly land based systems. This study therefore ascertained that, land based systems are mainly used to produce a large share of livestock products within the study area. However, there is a moderate transition into the intensive systems, driven by policy, socioeconomic and biophysical factors. The spatial distribution of these livestock production systems was found to be influenced by size of land, sex of household head, and number of livestock.

Policy Implications

Livestock producers in North western Kenya and other similar agro-ecological zones are in three distinct production systems namely intensive, semi-intensive and extensive. The changes in resource use and demand patterns cause changes in the behaviour of livestock production systems. This implies that livestock is essential for the sustainability of farming system in one context and detrimental for the same or another system in a context elsewhere with other farm resource flows.

Household livestock numbers are not commensurate with available feed resources is an impediment to improving productivity. Options such as optimizing livestock numbers to match available feed resources and improving feed availability through breeding and adoption of dual-purpose crop varieties with better digestibility coefficient, improving the cost-effectiveness of existing nutrition technologies (e.g. crop by-products), and bringing more land under fodder crops need to be explored. Therefore, development planners and policy makers need to develop unique interventions targeting each specific group, since blanket policies are not appropriate in such a situation. Across the three systems, policy needs to encourage interventions that can enhance sustainability and productivity of livestock production systems. This can be addressed through reforms on institutions governing land tenure and fragmentation within the region. Intensive livestock production systems were associated with high productivity and can help to reduce the burden of livestock production on the environment. Since the farm sizes within the region had continued to decline, limiting the availability of on-farm livestock feed, there is need for policy instruments that can discourage land fragmentation.

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