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Transforming Livestock Production through Systems Thinking Approach: The Case of West Pokot and Narok Counties

Leonard Kirui and Nancy Laibuni

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Abstract

There have been a good number of livestock production studies in Kenya at micro level. However, most of these micro level analyses have not been able to show the feedback between the livestock sector and the rest of the economy. System dynamics is one of the powerful tools in the field of system thinking which can be used to show this interaction. To accomplish this, a series of interviews and workshops were undertaken to identify the problematic situation of smallholder beef farming in West Pokot and Narok counties. To describe its linkages, this problematic situation was then translated into a causal loop diagram from which the systems archetypes were identified. The nature of each archetype is described, and the implications for identification of the possible system leverage points are discussed. This paper provides a preliminary insight into the application of system thinking in analyzing the smallholder beef production in Kenya.

Abbreviations and Acronyms

ASALs	Arid and Semi-Arid Lands
ADF	Augmented Dickey-Fuller
AfDB	African Development Bank
APS	Average Propensity to Save
CBK	Central Bank of Kenya
EAC	East African Community
FDI	Foreign Direct Investment
GBP	Government Budget Position
GDP	Gross Domestic Product
GDS	Gross Domestic Saving
GoK	Government of Kenya
GTR	Government Tax Revenue
IMF	International Monetary Fund
LCH	Life-Cycle Hypothesis
MPS	Marginal Propensity to Save
OD	Overseas Development Assistance
PIH	Permanent Income Hypothesis
RIH	Relative Income Hypothesis
TOT	Terms of Trade
WB	World Bank
WDI	World Development Indicators

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1. Introduction

The agriculture sector in Kenya has been of fundamental importance in both national and the local economy by generating over 21 per cent towards GDP and supporting over 75 per cent of the national population directly or indirectly (Odhiambo et al., 2004). Half of the agriculture sector in Kenya is comprised of livestock farming mostly in the Arid and Semi-Arid Lands (ASALs) (Aklilu and Catley, 2010). Livestock farming is growing faster compared to any other agricultural sub-sector in Kenya. Recent statistics show that the livestock sub-sector in Kenya accounts for approximately 10 per cent of the national Gross Domestic Product (GDP). This is 30 per cent of the agricultural GDP. It employs about 50 per cent of the national agricultural workforce and approximately 90 per cent of these are in the ASALs. These numbers added to several factors such as favourable climate and satisfactory productivity explain the economic potential of the sector.

According to the data from the Ministry of Agriculture, Livestock and Fisheries, livestock occupy approximately 24 million hectares out of the ASAL's 48 million hectares (MoALF, 2012). The Agricultural Census 2009 data indicated that the cattle herd in Kenya is approximately 10 million head, of which around 90 per cent are in the hands of small scale farmers and pastoralists.

Kenyans consume an average of 15-16 kg of red meat (meat and offal from cattle, sheep, goats and camels) per capita annually for a national total of approximately 600,000 MT of red meat per year (Behnke and Muthami, 2011). Cattle are the most important source of red meat, accounting for 77 per cent of Kenya's ruminant off-take for slaughter (Behnke and Muthami, 2011), (Table 1). Approximately 80 to 90 per cent of the red meat consumed in Kenya comes from livestock raised by pastoralists within Kenya and neighbouring countries (Nyariki et.al., 2005). Another 2 per cent comes from livestock raised on ranches, and the remainder comes from the highlands. Of the total red meat supply, it is estimated that 20-25 per cent comes from livestock that originates in neighbouring countries, with significant livestock populations (Ethiopia, Somalia, Tanzania and Uganda), making Kenya a meat deficit country. Small volumes of meat are also imported from European countries, Brazil and the United Arab Emirates (UAE), but these are limited to high-end hotels and supermarkets in Nairobi, and the volumes are extremely small.

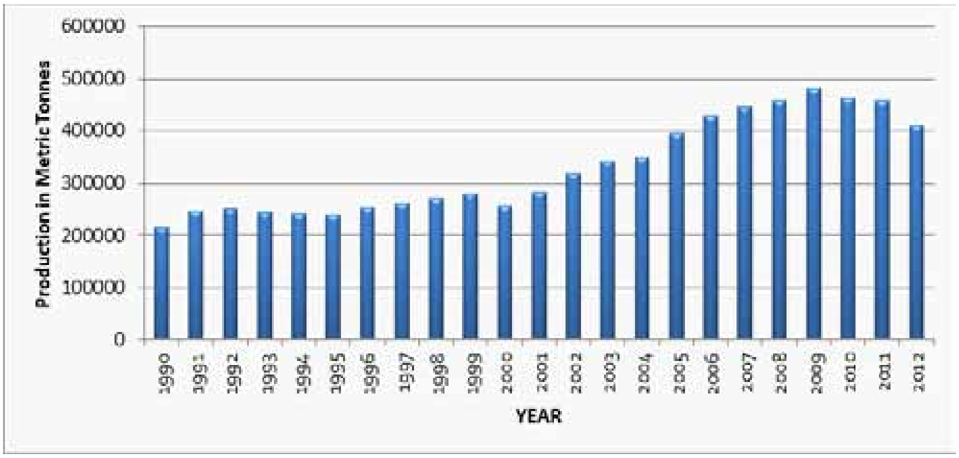
Table 1: Estimated contribution of beef supply to red meat consumption in 2011

Source	Total livestock head	Meat production (MT)	Offal production	Total contribution to red meat consumption (%)
Kenyan pastoralists	11,915,973	223,425	55,856	47
Neighbouring pastoralists	-	79,081	19,770	17
Dairy producers and other highlands	5,311,800	52,454	13,114	11
Commercial ranches	240,000	8,670	2,160	2
Totals	**17,467,773**	**363,630**	**90,900**	77

Source: Behnke and Muthami (2011)

Beef production in Kenya is estimated at 390,000 MT (Figure 1) with the bulk of the supply coming from ASALs. The rangeland in which the beef production sector thrives is prone to a myriad of risks, the consequences of which, if not managed, could affect both the national and local economy. At the national level, such risks affect beef supply and rural livelihoods (Aklilu and Catley, 2010). More specifically, the risks affecting beef markets affect the livelihood of beef producers (Fafchamps and Gavian, 1996). Other than the forces of demand and supply, beef production is influenced by many other factors such as livestock diseases, water availability, pasture condition and distance to the market (Barrett and Luseno, 2004). These factors can either be grouped as social, economic or environmental. The inability to predict the changes in these factors have contributed to low adoption of improved management of beef production despite the considerable knowledge on land and herd management. Understanding the internal mechanisms for the interactions between these major components is essential to the development of good management practices that ensure productivity (Mohtar et al., 2000).

Figure 1: Beef production (1990-2012)



Source: FAOSTAT (2014)

Despite the growth in livestock production in Kenya, research related to livestock production is less than desired, which has limited genetic progress in meat products, nutrition, and technology transfer (Sahlu et al., 2009). One underused but potentially valuable approach for research on livestock production is system thinking. System thinking can be used to assess many dimensions of livestock production, from herd dynamics to economic policies designed to support livestock production. System thinking provides a framework for the integration of scientific knowledge and allows for the creation of decision support systems (DSS) to make decisions regarding the improvement of livestock production systems at a variety of levels (Tedeschi et al., 2010). System thinking is a powerful approach to help the user understand the likely implications of diverse potential modifications to current production systems.

1.1 Problem Statement

The demand for food of animal origin in developing countries is expected to double by the year 2020 (Delgado, 2005). This is expected to be driven by increase in urbanization, population and income growth. Such demand will create markets for animal products and encourage commercialization of livestock production (Delgado, 2005). For the case of Kenya, the extent of this commercialization depends on the level of livestock production. To ensure the long-term success of livestock farming, management of the livestock production system has to be improved and the ability to deal with strategies integrating multiple choices over an extended planning horizon has to be taken into consideration. For example, the control of diseases, pasture availability, water availability and marketing of livestock become important to maintain production in the long run. However, the desired level of livestock production cannot be achieved if management strategies are taken without a holistic understanding of the whole system and the interactions between its components.

Despite the critical role the livestock sector plays in providing food of animal origin, the sector has not received the policy level priority it deserves. This is explained to a certain extent by a lack of in-depth analytical research and policy tool that will inform decision making and priority setting at sectoral, county or national levels. There have been substantial amounts of microeconomic analysis of livestock production in Kenya, particularly in the arid and semi-arid lands. However, the microeconomic analysis cannot show feedback mechanism between the livestock sector and the rest of the economy, since the rest of the economy is treated as exogenous. What seem to be missing are systematic studies using multi-sectoral and economy-wide techniques that will reveal interactions between the livestock sector and the rest of the economy. Therefore, a study which can describe the behaviour of smallholder livestock production system at the household level is required. Such a study would provide rich new information for understanding this key level of livestock production in Kenya.

1.2 Main Objective

The overall objective of this study is to develop strategies for transforming the smallholder livestock farming in Kenya in a system thinking approach.

Specific Objectives

The specific objective of this research is to:

(i) Identify the critical facets of the livestock production system in Kenya.

(ii) Formulate the most feasible strategies for enhancing livestock production in Kenya.

Research Questions

(i) What is the nature and complexity of the smallholder beef farming system in Kenya?

(ii) How can livestock productivity in Kenya be enhanced for profitability?

1.3 Justification

The importance of the livestock sub-sector particularly to the ASALs is well positioned in Kenya's ASALs' policy. One of the salient features of the ASALs' policy is commitment to increase income accruing to livestock keepers by a factor of four by the year 2015 through raising of livestock numbers and quality; improving access to forage and water resources through integrated resource management; control of livestock diseases; and improved access to functioning livestock markets. To foster this, it is important to have a good understanding on the effect of these factors on the livestock sub-sector.

Livestock production in Kenya comprises over 10 million heads of cattle, of which around 90 per cent are in the hands of small scale farmers and pastoralists (MoALF, 2012). For this reason, improvement of smallholder livestock production remains the key to development of the Kenyan livestock industry. However, it is important to note that livestock production at the smallholder level in Kenya is generally a sub-system of a mixed crop-livestock production system, rather than a production system in its own right. Efforts to improve livestock production may be ineffective if wider system implications are ignored.

In terms of productivity, livestock production tends to have poor performance (Patrick et al., 2010). However, from the point of view of the smallholder, livestock production is not merely an economic activity but also a "culture", a "way of life" that for most farmers extends over generations. It therefore has a multifaceted role that includes income generation, provision of social status, and contributes to household security. For smallholder families, cattle frequently represent their only buffer or insurance (Huyen et al., 2010). When farmers are faced with a sudden need for cash, for schooling or medical treatment for instance, they can sell some of their cattle. Thus, improving smallholders' livestock productivity becomes an essential step in alleviating farmers' household welfare concerns.

The importance of this research rests on the contribution it can make to formulating feasible strategies which holistically address the real problems of smallholder livestock production in Kenya. This can be achieved by using system thinking approach, which is able to represent the systemic behaviour of livestock production.

2. Literature Review

2.1 Theoretical Literature

From the theoretical point of view, three major phases can be acknowledged as the wave of system thinking development. The first phase is from the 1920s to the 1960s when system thinkers mainly focused on fundamental development of system thinking concepts among disciplines. The second phase is from the 1970s to the 1990s when many specific tools and applied methodologies were developed, and the more recent era that has been marked by the development of chaos and complexity theory (Mingers and White, 2010).

Ludwig Von Bertalanffy's General System Theory

Early significant developments in systems thinking occurred in the 1950s through the work of an Austrian biologist, Ludwig von Bertalanffy on General Systems Theory–GST (Haines, 2010). GST emerged from dissatisfaction with the fact that the modern era of scientific endeavour is characterized by specialization in all fields. Science is split into disciplines which will be further fragmented into numerous sub-disciplines. This 'reductionist' approach resulted in the generation of many specialities who rarely communicate with each other. They each seem to build their own universe, independent from others (von Bertalanffy, 2003). GST attempts to counter the 'reductionist' paradigm in belief that the unity of the science will produce more realistic outcomes.

Although GST is widely cited and acknowledged, it also has many critics. Its generalization was regarded as too universal to be attainable (Checkland, 1999; Mulej et al., 2004), and does not provide readily available formal methods and tools (Drack and Wolkenhauer, 2011). However, GST continues to be applied in various fields as a basic approach, such as in supply chain management (Caddy and Helou, 2007), and also in the fields of information systems, medicine and public health, and environment (Mingers and White, 2010).

Peter Checkland's Soft System Theory

Another important system thinker is Peter B. Checkland from Lancaster University in the United Kingdom. He introduce Soft System theory as an inquiring process which provides a step-by-step method for individuals and organizations in bringing the context of system thinking into real action (Flood, 2000; Mingers, 2000; Maani and Cavana, 2007). Hard systems thinking in the 1950s and 1960s focused mainly on goal seeking, while soft systems thinking in the 1980s and 1990s focused on the learning process (Jackson, 2002).

Checkland (1985; 1999) used the term “hard system thinking” to refer to approaches or methodologies in the areas of operational research (OR), system analysis (SA) and system engineering (SE). These methodologies have similar assumptions. They apply the scientific method to real problem situations and assume that the problems and objectives of the system can be clearly defined. The hard systems thinking approach tries to develop the most efficient strategy to achieve those objectives (Jackson, 2003). Therefore, it was also called a “means-ends approach”. It was mostly undertaken to serve decision-makers or managers (Flood, 2000).

On the other hand, soft systems thinking argues that capturing those ‘softer’ problems in a logic systems model simply did not work when applied to real-world problems because it has a basic problem relating to the determination of “the problem” and “the solution” (Checkland, 1985; Hardman and Paucar-Caceres, 2011). Checkland (1985; 1999) questioned who should determine that the problem defined is “the real problem” and that the objective stated is “the desired one” because many problems and objectives in real situations are both vague and unstructured. Instead, building the richest possible picture of the situation by disregarding the agreed goals and objectives is more suitable. Rich pictures are typically a hand drawn cartoon-like picture ‘visualizing the key elements in a problem situation, including issues of structure and process but without expressing these in terms of systems’ (Ramage and Shipp, 2009).

The strengths of soft system theory rest on its ability to acknowledge multiple stakeholders’ perspectives. Soft system theory reasonably regards the fact that different stakeholders have different interests (Rodríguez-Ulloa et al., 2011). However, it also has its limitations. Soft system theory is considered to be a “non-problem solving” methodology. It has been found to limit the intervention because it is not equipped with tools to observe the impact of the intervention (Rodríguez-Ulloa et al., 2011).

Ulrich’s Critical Systems Heuristics (CSH) Theory

Another important landmark in systems thinking development is Critical Systems Heuristics (CSH) theory which was introduced by Werner Ulrich in 1983 through his book Critical Heuristics of Social Planning (Ulrich, 1983; Ulrich and Reynolds, 2010). CSH is valued not only because it is the first systems approach that has a major concern in dealing with unfairness in the societal system, but also because it is practically oriented and can be complemented with other approaches in the body of system thinking (Jackson, 2003).

CSH has the ability to counter inequalities in the system. Inequalities occur when one group is benefiting at the expense of other groups which are suffering domination or discrimination (Jackson, 2002; 2003). Therefore, this inequality should be minimized by acknowledging multiple perspectives; not only of those involved in the system, but also of those parties affected but not involved (Flood and Jackson, 1991; Ulrich and Reynolds, 2010).

Similar to many other approaches, CSH was also debated for its strengths and limitations. CSH was considered to be the best approach to deal with coercion (Flood and Jackson, 1991), although Midgley (1997) disagreed and preferred to use the term "method of value clarification" because it contrasts "the involved planner" with "the affected but not involved" viewpoints (Jackson, 2003). Another contribution of CSH to critical systems thinking has been its efforts to build "systems boundaries" (Midgley, 1997). However, CSH was also considered as "methodologically immature" because it lacked practical guidelines (Flood and Jackson, 1991). Therefore, CSH should be viewed as complementary to other systems methods rather than a replacement for them (Midgley, 1997).

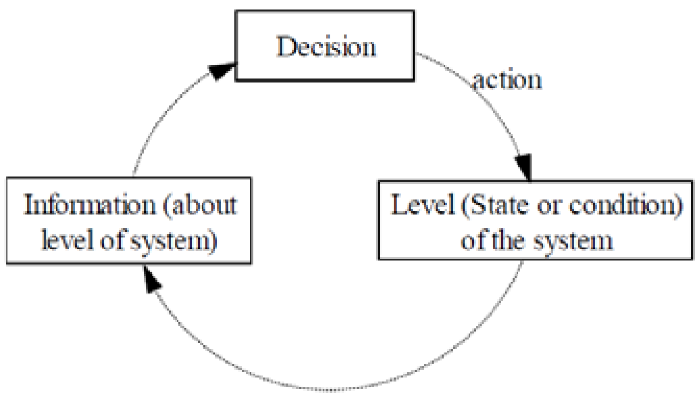
Forrester's System Dynamics Theory

In 1968, Jay W. Forrester, a Professor in management at Massachusetts Institute of Technology, published a book entitled "Principles of Systems" which is considered as marking the beginning of system dynamics, another important contribution to the development of systems thinking (Ramage and Shipp, 2001; Skyttner, 2001; Lane, 2007). He used system dynamics modelling to forecast the growth of an urban area (Forrester, 1969), the rise of western industry (Forrester, 1961), and the dynamics of global resource utilization (Forrester, 1971).

In his book, Forrester (1968) classified systems into two types: "open systems" and "feedback systems" which are also sometimes called "closed system". Open systems are characterized by having no relationship of output to input, whereas feedback systems the output influences input because of a closed loop structure that brings results from the current action back to control future action. Forrester (1968) also introduced "the feedback loop", 'a closed path connecting in sequence a decision that controls action, the level of the system, and information about the level of the system, with the latter being returned to the decision-making point' (Figure 2). The behaviour of this feedback loop over time shows the dynamics of the system.

Forrester (2003) warned that we will continue to make mistakes in developing corrective programmes until we develop a better understanding of the characteristics and behaviour of social systems, which fortunately can be obtained from a computer model. He pointed out that "the proper use of models of social systems can lead into far better systems, laws, and programs" so far as the model is not developed statistically from time series data but based on statement of system structure and assumptions being made about the system. A good model should be able to capture more of 'the essence of the social system that it presumes to represent' and taking into account any possible 'multiple-feedback loop and nonlinear nature of real system'.

Figure 2: Feedback loop



Source: Forrester (1968)

In summary, these four cornerstones of systems thinking development outlined above explain the importance of a systems approach. Without a systems approach, it will be difficult to fully understand why some phenomena occurred.

Livestock production in Kenya is a complex system, containing biophysical, economical, and social elements. This study takes Forester's approach because of its ability to incorporate complex non-linear relationships and the feedback loops that create holistic system evaluation (Forrester, 1994).

2.2 Empirical Literature

The supply and demand of livestock products relates to the uncertainties faced by the factors of production in a livestock production system. It is highly driven by the external and internal factors. Livestock producers are susceptible to risks and uncertainties facing livestock which occur through diseases, droughts, conflicts and market variability, among others (Little et al., 2001). A widely researched area is the drought component found to limit availability of water and pasture and sometimes exacerbate losses arising from disease and predation (Mizutani et al., 2005).

Smallholder Livestock Production and System Thinking

System thinking emerged to deal with complexity (Maani and Cavana, 2007). In the developing world, it has been applied to explain systemic complexity encountered, for example in the tourism industry in Vietnam (Mai and Bosch 2010) and forest management in Indonesia (Purnomo and Mendoza, 2011). Mai and Bosch (2010) points out that systems thinking is a powerful tool because it is able to describe the interrelations among economic, environmental, and socio-demographic sub-systems, to identify the root cause of a complex problem and to determine the intervention leverage point.

Smallholder livestock production is a complex system with multifaceted roles. Farmers have to simultaneously make many decisions as part of the strategy by which they sustain their farming. The strategy has to go beyond the technical agricultural aspects of farming, frequently involving social, economic, and even sometimes political elements. This makes it difficult to study smallholder livestock production using conventional linear-partial approaches (Snapp and Pound, 2008) or reductionist approach. Further, Snap and Pound (2008) argued that in some way, smallholder farmers are systems thinkers because farmers have to balance many different aspects. From a technical point of view, farmers need to consider what crop to grow or what animal to keep, where and how. From an economic point of view, farmers need to balance between the immediate household needs, and long-term objectives such as education for their children. Farmers also have to think of possible combinations of mixed farming and opportunities for off-farm income-generating activities, and their time allocation for farming activity and for performing social roles and responsibilities in the community. To handle all of this complexity, smallholder livestock farmers rely mainly on their experience, natural indicators, and some information from other sources such as extension officers, other farmers, and TV, radio or other media.

One key characteristic of smallholder livestock production is the interconnectedness among activities on the farm, in the household, and in the wider community or economy (MacLeod et al., 2011). External factors such as market price, consumer preferences, and the political situation can have a significant influence on smallholder livestock producers (Pound, 2008). Thus, smallholder farmers are involved with a wide variety of actors having a range of different interests and objectives as demonstrated by Hounkonou et al. (2012) in their study to develop smallholder farming in West Africa. Acknowledging smallholder farming as a social system consisting of different stakeholders with a wide variety of interest makes an important contribution to the success of a development strategy (Kaufmann, 2007; Binam et al., 2011).

It becomes clear that if we are to understand smallholder livestock production it will be essential to adopt an approach that can logically and systematically take into account the different short and long-term perspectives that smallholder livestock producers have to deal with. It is also important to account for the different and simultaneous decision-making and other roles that smallholders must undertake.

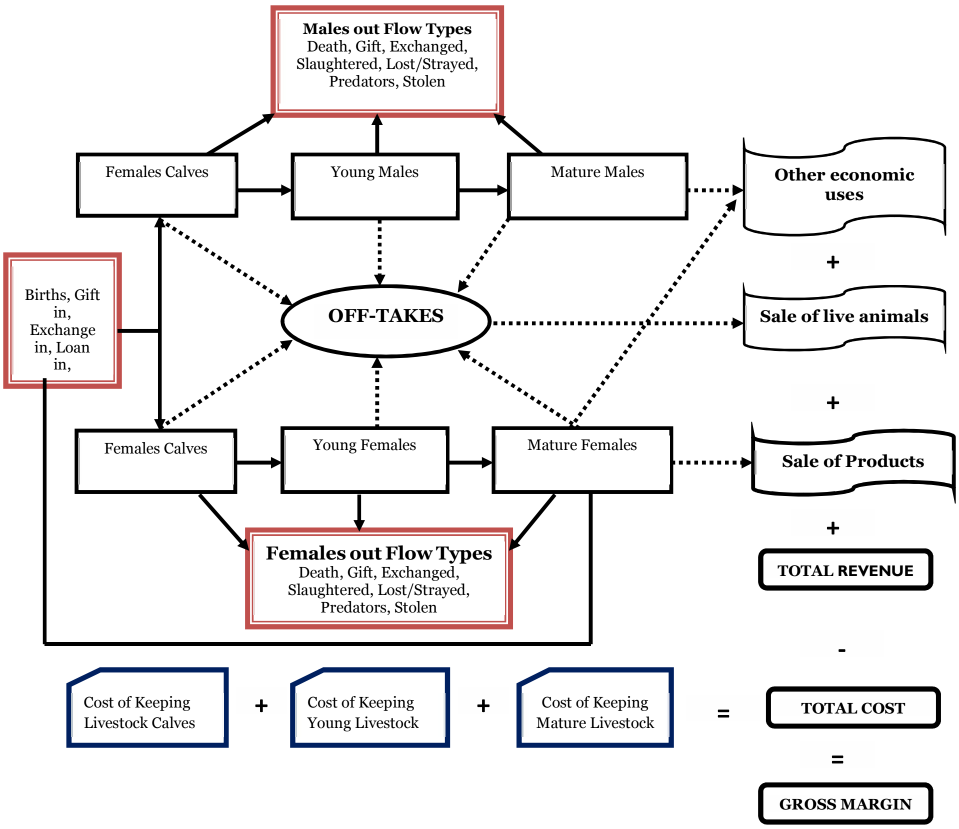
It is only by acknowledging and accounting for the complexity arising from these characteristics of the smallholder livestock producers that it will be possible to obtain the level of comprehensive understanding of the system necessary for the formulation and implementation of effective development interventions.

2.3 Conceptual Framework

Most livestock production systems can be represented in a stock-flow diagram. The dynamics of the stocks are represented by the solid lines related to adjustment to stocks, and changes in the number of livestock in different stages and ages. For instance, mature females give birth to young ones, which are then categorized into male and female counterparts. Each sex category will pass through different stages—calves, young, and then mature. The proportion that passes to the next stage depends on survival rates, which in turn are determined by out flows in form of deaths, exchanges, slaughters and off-take rates. (Figure 3).

Off-takes represent economic flows which in this case is sales of live animals from different stages of growth. There are other economic flows depicted in the right hand side of Figure 3: sale of livestock products (e.g. milk and meat) and other economic services from the livestock (e.g. oxen draft power). The quantity of live animals and livestock products multiplied by their corresponding prices give total revenue from livestock activities. The lower part of the figure shows costs of keeping livestock in different stages of development. Like other sectors, livestock production requires labour, land, and standard capital stock categories such as buildings, machinery, and equipment. The sum of these gives total costs of livestock production activity. The difference between total revenues and total costs yields gross margin of keeping livestock.

Figure 3: Conceptual framework



Source: Adapted from Sterman (2000)

3. Methodology

3.1 Study Area and Sampling

The data used for this study was obtained from a household survey of farmers during the 2015 production year in Kenya's arid and semi-arid land counties of Narok and West Pokot. The Kenya Institute for Public Policy Research and Analysis (KIPPRA) in collaboration with the African Capacity Building Foundation (ACBF) conducted the household survey. The two sampled counties were purposefully selected to include different attributes of the arid and semi-arid lands in Kenya including nomadic pastoral communities in the country, degree of livestock activities (percentage of households involved in livestock production), average annual rainfall and variability. The main livelihood in the two counties comes from livestock sources and like scores of pastoral communities around arid areas, few households have access to significant income diversification (Desta and Coppock, 2002)

The households which were interviewed from each sub-location in the sub-counties were purposefully selected from the arid and semi-arid areas. This led to the selection of two arid sub-counties in Narok County and four arid sub-counties in West Pokot County so that there were 17 administrative sub-locations in Narok County and 19 administrative sub locations in West Pokot County. The households were selected randomly using random numbers from a list of households in each sub-location. This led to random selection of 295 farmers from Narok County and 259 farmers from West Pokot County, resulting in a total of 554 interviewed households.

The collected data included household socio-economic characteristics, farm characteristics, livestock dynamics, water, pasture, diseases, sources of incomes and climate shocks experienced in the last five years.

3.2 Analytical Framework

The steps involved in conducting system thinking methodology vary among practitioners. However, they tend to adopt a similar process that can be generally described as: (1) structuring the problem; (2) discovering the causal structure; (Maani and Cavana, 2007).

Figure 4: Methodological steps

System thinking	Operational	Purpose
Expressing the flux of everyday farming	Workshop	Identify the actors, their activities and linkages
Investigating the problematic situation	Semi structured interview	Explore system's *ideal* and *current* situation
Structuring the problematic situation	Workshop	Structure the three-dimensional problematic situation: Forage, Markets, and Diseases
Translating the problematic situation into a Causal Loop	Developed by the researcher	• Visualize the causal linkages within the system • Identify the reinforcing and balancing loops • Identify the leverage points and possible strategy
Identify archetypes within the CLD		

Source: Adapted from Checkland (1999)

3.3 Structuring the Problem

This step answers the question of what problem needs to be addressed. In regard to this, a roundtable meeting was held in March 2014 where different actors along the value chain participated. The meeting discussed the critical issues affecting the livestock production system that affects beef production. This is an important step to justify and clarify the purpose of the whole system thinking approach, referred to as problem articulating (Sterman, 2000). From a system thinking point of view, structuring establishes the reference modes and explicitly sets the time horizon. Reference modes are a set of graphs, or other descriptive presentation showing the development of the problem over time. Setting the time horizon determines the appropriate time frame to obtain a richer and better understanding of the problem. These two processes facilitated the characterization of the problem dynamically, showing a pattern of behaviour over time (Sterman, 2000).

The next step in systems thinking requires us to move from thinking at the event level to understanding reality at the deeper pattern level and dentifying patterns, trends or changes in events over time (Anderson and Johnson, 1997). During the consultations, the meeting sort to ensure the challenges identified met the following conditions, namely: (i) able to elaborate several alternative perspectives and their relationship; (ii) easy and simple enough so that it enables participation from all actors with different backgrounds and knowledge; (iii) operates iteratively, so that the problem representation adjusts to reflect the state and stage of discussion among the actors, and vice versa; (iv) allows the identification of local or partial problems (Mingers and Rosenhead, 2004).

The consultations were expected to harness their perspectives and interest in the problem, and to generate commitment and collaboration from the start. The second step was to collect secondary data which indicates and clarifies the importance of the problem identified (Visser, 2007) aimed at encouraging new ideas and thoughts from a 'large pool of raw ideas' (Maani and Cavana, 2007).

3.4 Discovering the Causal Structure using Causal Loop Diagrams

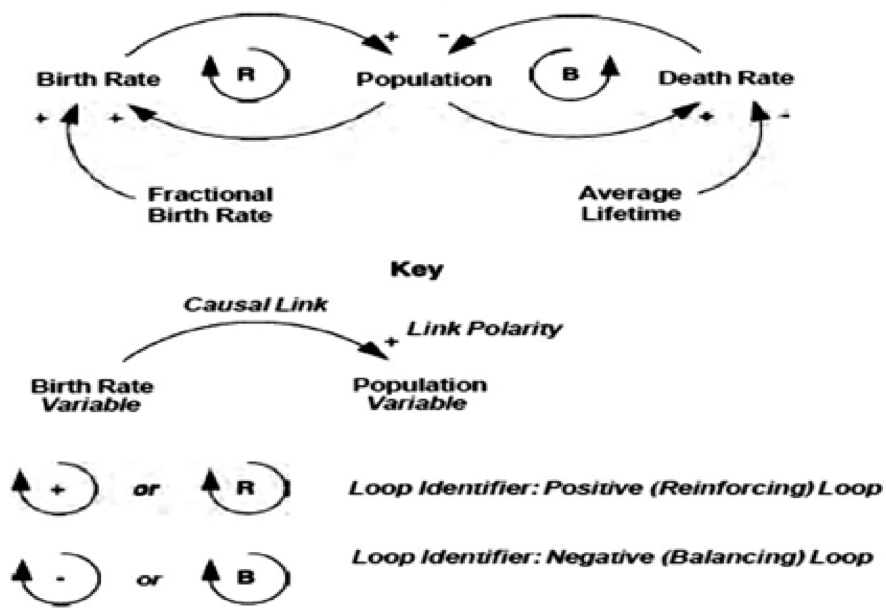
Developing Causal Loop Diagrams (CLD) was the next step, and this was carried out after the problem was identified (Maani and Cavana, 2002; 2007). CLDs are useful tools for mapping the feedback loop structures of a complex system (Sterman, 2000). Feedback loops are the most essential 'building blocks' of a system because they show the dynamic behaviour of systems describing how actions can reinforce or balance each other (Forrester, 1969).

Feedback loops provide a systematic picture of any patterns of interrelationships that can help us to 'see the deeper patterns lying behind the events', thus help visualize the interrelationships in circles, explaining that every influence is both cause and effect, contrary to the way we typically see straight lines and generally assume that influence goes only in one direction (Senge, 1992).

A feedback loop is built from two elements; variables and their causal links (Schaffernicht, 2006). The causal influence between two variables is generally shown by an arrow. Each of these causal links has polarity, and this explains how these variables are related (Sterman, 2000; Schaffernicht 2006). It can move in the same or opposite direction. Some literature uses different notations to show this polarity; Morecroft (2007) and Sterman (2000) use a positive sign (+) near the head of the arrow to show a causal link which goes in the same direction, and a negative sign (-) to show a causal link in opposite directions whereas Maani and Cavana (2002; 2007) use 's' as an abbreviation of same direction and 'o' for opposite directions.

There are two types of feedback processes: reinforcing and balancing loops. Reinforcing loops, also known as positive loops, are self-reinforcing, representing growing or declining actions in the systems while balancing, also known as negative loops, are self-correcting mechanisms which counteract and oppose change (Maani and Cavana, 2007).

Figure 5: Example of causal loop diagram



Source: Sterman (2000)

The example of a CLD in Figure 5 shows two loop identifiers, reinforcing, denoted as ‘R’ and balancing denoted as ‘B’. The reinforcing loop relating birth rate to population circulates clockwise. In this example, an increase in the birth rate will increase the population, and vice versa (same directions). On the contrary, the balancing loop presented in the loop relates death rate to population and it circulates counter-clockwise. An increase in the death rate will decrease the population, and vice versa (Sterman, 2000).

Other elements in CLD are delay and leverage (Maani and Cavana, 2002; 2007) and dangles (Sherwood, 2002). Delay refers to a time lag between a cause and its effect (Morecroft, 2007), whereas leverage refers to those interventions that can have the most influence on system behaviour (Maani and Cavana, 2007). Leverage is defined as “decisions and actions for change and intervention which have the highest likelihood of lasting and sustainable outcomes” (Maani, 2011). Finding the leverage point can be best reached by conducting open discussion with the group after all parties were aware of and have understood the implication of the interventions for the feedback structure within the embedded system.

This awareness and understanding can be achieved if the researcher learns about the dynamics of the causal loop (Sterman, 2000).

To sum up, a Causal Loop Diagram (CLD) which describes system variables and their causal links, polarity, feedback processes, delay and leverage points, will describe the system behaviour and will partly show the dynamics of the systems. However, CLDs are only well-suited to capturing mental models as an initial step in identifying system dynamics (Sterman, 2000). Having CLDs as a result of thinking indicates that we are already involved in a systems thinking approach. However, systems thinking is not enough. To provide better understanding of a system, the CLDs need to be converted into a dynamic model (Forrester, 2007). This will however be done in the second part of this study.

4. Results and Discussion

The results are presented in two sections; the first section describes the descriptive results from the primary data that was collected and which will be used to calibrate the model. These provide various numbers that will be used when building the model, such as mortality rate, birth rate, feed rate per animal, among others. This will be expounded further in the subsequent paper. The second section of the results presents the visualization of the causal linkages by identifying the reinforcing and balancing loops. Then the leverage points and possible strategies are presented.

4.1 Selected Socio-Economic and Livestock Dynamics in the Study Counties

Descriptive statistics were used to discern general characteristics of the data.

4.1.1 Land ownership

There are a similarities in the two counties in terms of land accessibility except that in Narok, most households have access to one parcel of land compared to West Pokot where most household have an access to mainly two parcels of land. However, the total average size of land owned in Narok (33 acres) is higher compared to that for West Pokot (11 acres) as shown in Table 2. The difference could be attributed to a large percentage of households who hold formal titles in Narok compared to West Pokot (33% against 15%) as shown in Table 2.

Table 2: Land ownership

County	Ownership	Mean	Maximum	Minimum	Standard Deviation
Narok	Parcels of land owned and/or accessed by the household	1	5	0	1
	Total size of all the land owned (in acres)	33	265	0	40
West Pokot	Parcels of land owned and/or accessed by the household	2	11	1	1
	Total size of all the land owned (in acres)	11	173	0	17

Source: Authors' computation

Land tenure in Narok is mainly based on formal title (49%) while in West Pokot it is mainly based on communal ownership (44%). The high number of households having title deeds in Narok County as compared to West Pokot County could explain the reason why there were no squatters in Narok while a few could be identified in West Pokot County (0.8%) as shown in Table 3.

Table 3: Land tenure

Type of land Tenure	Overall	Narok	West Pokot
Holds a formal title or allotment letter	33.45	49.66	15.10
Owns but has no formal title/document (e.g. inherited)	42.55	45.55	39.10
Lease/Rented	0.36	0.00	0.80
Has communal rights to use land (e.g. pastoral land, trust land)	23.27	4.79	44.20
Squatters	0.36	0.00	0.80

Source: Authors computation

There was slight variation in the area of land allocated to different uses in the two counties. The area of land allocated to natural pasture constituted the main land use in the two counties, with the highest average acreage being recorded in Narok County (22 acres) compared to West Pokot County (5 acres), Table 4.

Table 4: Land allocation to different uses

		Mean	Max.	Min.	Standard Deviation	%
Narok	Total household and livestock sheds land	2.00	15.00	0	2.00	53%
	Total land allocated to subsistence crop production	3.37	52.00	0	5.51	53%
	Total commercial production land	3.89	80.00	0	9.14	53%
	Total improved pastures land	0.72	105.00	0	6.57	53%
	Total natural pastures land	22.37	313.00	0	39.79	53%
	Total woodlot land	0.47	45.00	0	3.70	53%
	Total fisheries land	0.02	7.00	0	0.41	53%
	Total unusable land	0.44	39.00	0	3.18	53%
	Total idle land	1.33	196.00	0	12.21	53%

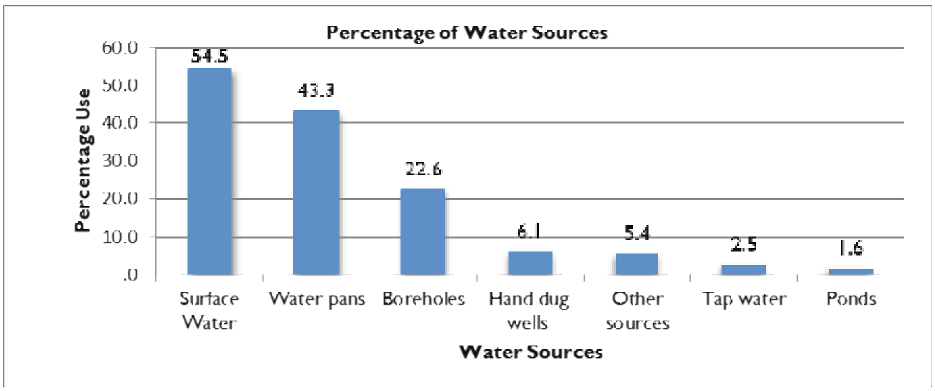
West Pokot	Total household and livestock sheds land	1.00	9.00	0	1.00	47%
	Total land allocated to subsistence crop production	2.44	17.00	0	2.47	47%
	Total land commercial production	0.43	38.00	0	2.96	47%
	Total improved pastures land	0.30	20.00	0	1.82	47%
	Total natural pastures land	5.55	163.00	0	13.33	47%
	Total woodlot land	0.06	10.00	0	0.66	47%
	Total fisheries land	0.00	0.00	0	0.00	47%
	Total unusable land	0.09	5.00	0	0.58	47%
	Total idle land	0.21	21.00	0	1.66	47%

Source: Authors computation

4.1.2 Water sources

Out of the 554 respondents who were interviewed, 54 per cent of them use surface water as the main source. The second most dominant sources are water pans. Only 2.5 per cent use tap water while the least utilized source of water is from the ponds at 1.6 per cent.

Figure 5: Water sources



Source: Authors computation

The long distance to the water sources is an indication of the enormous amount of time spent fetching water. Therefore, the time spent in fetching water is a function of distance to the water source. The longest distance to water source during the wet season is 3.96 km for the ponds while during the dry season the longest distance to a water sources is 5.32 km for the borehole.

Table 5: Distance to water sources

		Mean	Maximum	Minimum	Standard Deviation
Wet Season	Hand dug wells	1.57	12.00	0.00	2.30
	Surface water sources	3.67	50.00	0.00	5.24
	Pond	3.96	15.00	1.00	4.95
	Borehole	3.14	28.00	0.00	4.16
	Tap	3.37	35.00	0.00	9.65
	Water pan	2.86	30.00	0.00	4.01
Dry Season	Hand dug wells	1.68	7.00	0.00	1.58
	Surface water sources	4.93	50.00	0.00	6.44
	Pond	2.21	7.00	1.00	2.20
	Borehole	5.32	35.00	0.05	5.77
	Tap	3.37	35.00	0.00	9.65
	Water pan	3.89	53.00	0.00	5.59

Source: Authors computation

4.1.3 Livestock numbers

The average number of livestock kept per household in Narok and West Pokot counties varies substantially. Table 6 shows the total stock for each livestock type. Animal numbers indicate wealth and social status, and a buffer against uncertain events (Sintayehu et al., 2013). The most dominant livestock type in Narok County is sheep, with each household owning an average of 67 followed by goat and then cattle at an average of 26 and 30, respectively. The households in the county did not report presence of camel rearing. However, in West Pokot County, the most common livestock type was goats with each household owning an average of 23 followed by cattle and then goat at an average of 15 and 14, respectively, with a few farmers rearing camels (an average of 1 per household). Overall, the study found out that households own more small stock (average of 42 for sheep and 24 for goats) compared to cattle stock (average of 23). Household's camel ownership was generally minimal.

Table 6: Stock of livestock kept

		Mean	Max.	Min.	Standard Deviation	N
Narok	Camel stock total	0	0	0	0	277
	Cattle stock total	30	320	0	47.42	295
	Sheep stock total	67	900	0	103.81	295
	Goat stock total	26	500	0	55.66	295

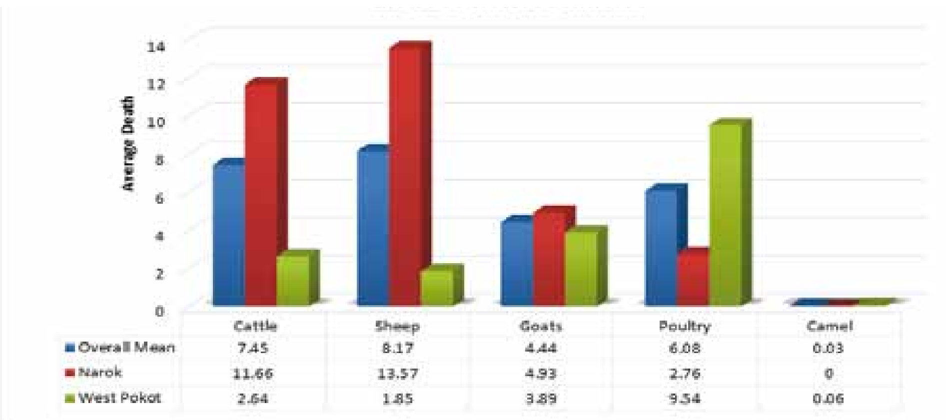
West Pokot	Camel stock total	1	70	0	5.32	258
	Cattle stock total	15	223	0	21.38	258
	Sheep stock total	14	465	0	32.23	259
	Goat stock total	23	120	0	23.59	259
Overall	Camel stock total	0.31	70	0	3.71	535
	Cattle stock total	23.32	320	0	38.27	553
	Sheep stock total	42.18	900	0	83.25	554
	Goat stock total	24.37	500	0	43.70	534

Source: Authors computation

4.1.4 Livestock losses

This study examined losses due to death among various livestock types across the two priority counties summarized in Figure 6. Notably, there is a high average loss of cattle and sheep in Narok County (Average of 12 per year for cattle and 14 for sheep per household) compared to West Pokot County where the losses in the two species are minimal.

Figure 6: Livestock mortalities



Source: Authors computation

4.1.5 Cost of inputs and services

The predominant sources of animal feeds in Narok County are grazing on own pasture (78%) while in West Pokot County the common source is public or communal land (74%). One of the sources which has been cited as means of responding to pasture shortages among the pastoral communities includes commercial feeds commonly used in established commercial ranches (Bebe et al., 2003). Among the two counties, this type of feed is mainly used in Narok (35%) compared to West Pokot (12%).

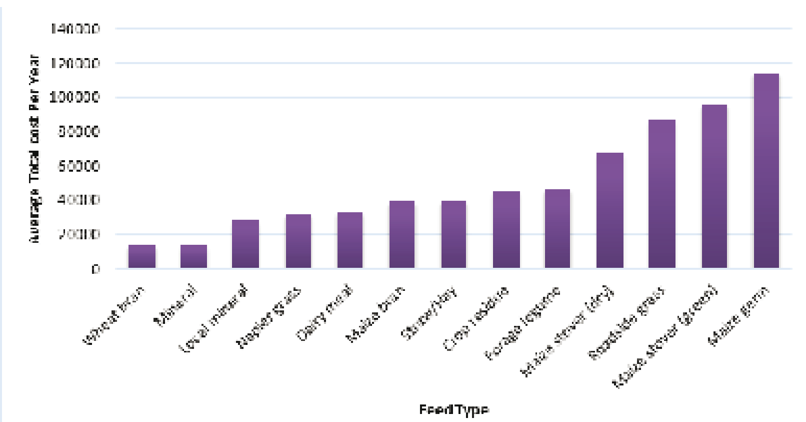
Table 7: Sources of feeds

Source of feeds	Narok %	West Pokot %	Overall %
Grazing on own pasture	77.60	45.90	62.80
Grazing on public/communal land	39.30	74.10	55.60
Grazing on crop residues	10.50	43.60	26.00
Cut and carry fodder	5.10	5.00	5.10
Cut and carry fodder from rented land	5.40	3.90	4.70
Cut and carry fodder from purchased land	60.90	0.40	32.30
Cut and carry fodder from public/communal land	5.10	1.20	3.20
Commercial feeds	34.60	12.40	24.20
Agro-industrial by-products	3.10	1.20	2.20
Other feeds	0.70	2.30	1.40

Source: Authors computation

Livestock production in the ASALs is largely constrained by year-long availability of feeds. This, therefore, necessitates the purchase of supplementary feeds from commercial means to reduce dependence on rangelands. The households interviewed in this study reported that they spend less amount of money on wheat bran, proprietary minerals, local minerals, nappier grass and dairy meal compared to the cost of maize germ, green maize stovers and road side grass.

Figure 7: Annual cost of livestock feeds

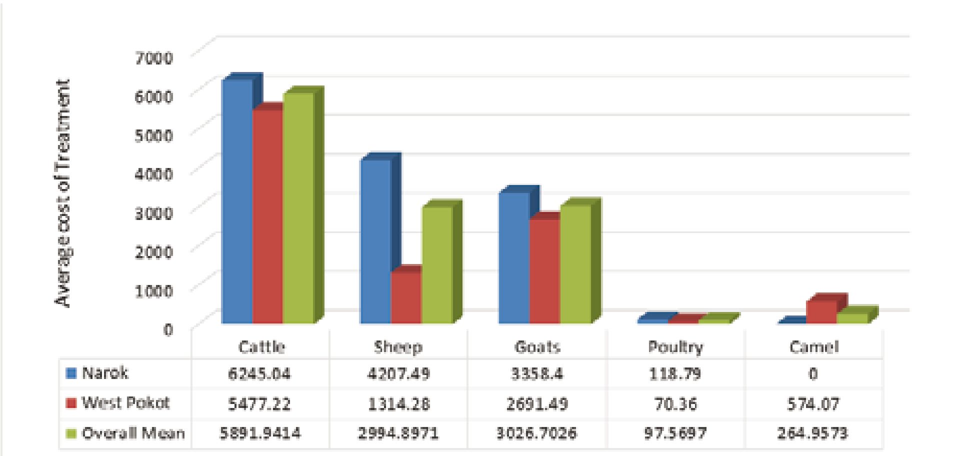


Source: Authors computation

4.1.6 Annual cost of livestock treatment

The annual cost associated with livestock treatment is presented in Figure 8. This study found that expenses vary with livestock species. On the total cost of treatment, more money is spent on treating cattle than all the other species with an annual average expenditure of Ksh 5,891 in both counties. However, more average expenditure is incurred on cattle in Narok County (Ksh 6,245) as compared to West Pokot County (Ksh 5,477).

Figure 8: Annual cost of livestock treatment



Sources: Authors computation

4.1.7 Sources of farm income

Substantial amount of household farm income is derived from livestock activities, which contribute an average of Ksh 151,143 annually. However, a big disparity in the two counties was noted where the average annual income from livestock activities in Narok County is Ksh 196,037 compared to West Pokot County where the annual income is Ksh 27,840. The second most important source of farm income was from crop activities, which earned households a total average of Ksh 114,207 but the same kind of disparity between the two counties was realized in livestock activities.

Table 8: Farm income

		N	Min.	Max.	Mean	Standard Deviation
Crop Activities	Overall	144	300	3,000,000	114,207.64	272,149.06
	Narok	122	3000	3,000,000	12,7912.30	293,146.82
	West Pokot	22	300	200,000	38,209.09	45,349.45
Livestock Activities	Overall	266	10	2,400,000	151,142.71	274,540.19
	Narok	195	10	2,400,000	196,037.49	308,228.08
	West Pokot	71	300	132,000	27,840.14	31,690.58
Woodlot Activities	Overall	6	1,000	595,000	139,900.00	229,352.23
	Narok	3	1,000	595,000	200,400.00	341,740.08
	West Pokot	3	43,200	150,000	79,400.00	61,148.02
Pastures sales	Overall	19	2,000	240,000	43,052.63	62,768.73
	Narok	17	2,000	240,000	35,764.71	56,508.05
	West Pokot	2	30,000	180,000	105,000.00	106,066.02
Other Income	Overall	3	500	84,000	48,166.67	42,989.34
	Narok	1	84,000	84,000	84,000.00	.
	West Pokot	2	500	60000	30,250.00	42,072.85

Source: Authors computation

4.1.8 Cattle trading practices

One of the methods used to capture the livestock entry into the herds is purchases. The general herd structure of livestock purchases is presented in Table 9. Entries in terms of purchases were higher for adult female goats at 47.22 per cent, followed by adult female cattle at 45 per cent and then adult female sheep at 38.52 per cent. However, between the two counties, Narok County registered the highest entry of adult female goats while West Pokot County recorded the highest entry of adult female cattle. The main reason which could be linked to the high number of females (breeding age) entries is because they are at a prime age for reproduction. A low entry for males than females in cattle, sheep and goats seems rational in a system of subsistence livelihoods depending on milk as an important food and sale of males as a cash source.

Table 9: Percentage type of livestock purchased

	Narok			West Pokot			Overall		
Livestock type	Cattle	Sheep	Goats	Cattle	Sheep	Goats	Cattle	Sheep	Goats
calf (<1 year)	14.41	5.68	3.70	2.27	35.29	8.89	10.00	4.10	6.94
Young female (pre-breeding)	28.95	29.55	25.93	36.36	38.24	20.00	31.67	31.15	22.22
Adult female (breeding age)	42.11	38.64	51.85	50.00	23.53	44.44	45.00	38.52	47.22
Males (entire)	10.53	19.32	14.81	11.36	2.94	26.66	10.83	20.49	19.44
Males (castrated)	3.95	6.82	3.70			4.44	2.50	5.74	4.20

Source: Authors computation

Different livestock species are purchased to serve different purposes within the farm enterprise. The main reason why the households purchased different types of livestock was mainly to increase their stock as cited by 73 per cent for those who made cattle purchases and 82 per cent and 84 per cent for sheep and goats purchases, respectively.

Table 10: Reason for purchasing livestock

	Narok			West Pokot			Overall		
	Cattle	Sheep	Goats	Cattle	Sheep	Goats	Cattle	Sheep	Goats
Increase stock	74.3	82.8	85.2	75.0	82.4	84.1	73.7	82.6	84.5
Breed Improvement	14.9	6.9	7.4	13.6	11.8	9.1	14.4	8.3	8.5
Other reasons	10.8	10.3	7.4	11.4	5.9	6.8	11.8	9.1	7.0

Source: Authors computation

According to the survey data, most the livestock were purchased at the village market, which can be described here as the primary market because livestock are bought directly from the producer. About 62 per cent of the cattle purchases were done at the village market while 73 per cent and 59 per cent were done at the same point for sheep and goats, respectively. Few purchases were however done at the auction market, which in this case can be referred to as the terminal market. These minimal cases were only evident in West Pokot County.

Table 11: Livestock purchase points

	Narok			West Pokot			Overall		
	Cattle	Sheep	Goats	Cattle	Sheep	Goats	Cattle	Sheep	Goats
Another farmer	6.76	5.75	3.70	38.64	17.65	25.00	18.64	9.09	16.90
Trader	4.05	4.60	3.70	9.09	17.65	11.36	5.93	8.26	8.45
Village market	74.32	79.31	77.78	40.91	55.88	47.73	61.86	72.73	59.15
Regional market	10.81	9.20	11.11	11.36	5.88	9.09	11.02	8.26	9.86
Auction Market	0.00	0.00	0.00	0.00	2.94	4.50	0.00	0.00	1.41
Others	4.10	1.15	3.70	0.00	0.00	2.27	2.50	1.70	4.20

Source: Authors computation

4.1.9 Livestock sales and prices

According to the Focus Group Discussion which was done at the two counties, livestock keepers categorize their livestock based on the size of their animals. However, traders/brokers categorize the livestock to purchase based on the weight of the various animal types. Castrated males fetch higher prices because during transportation these animals loose less weight compared to other animals. Besides, traders and brokers are much concerned about the weight of the various livestock since they are interested in making profits. Table 12 presents the general price range and weights of the three main livestock types.

Table 12: Average livestock prices

	Calves/kids <1 yr-cattle <5 months-shoats		Young female Pre-breeding		Adult female Breeding		Mature female	
	Price (ksh)	Weight (kg)	Price (ksh)	Weight (kg)	Price (ksh)	Weight (kg)	Price (ksh)	Weight (kg)
Cattle	4000	50-70	15000	120-150	18000-30000	150-200	30000-50000	250-300
Goats	300-500	7-13	1200-2500	20-30	1200-3500	30-40	2500-4500	40-65
Sheep	200-400	7-13	800-2500	25-30	1200-3000	30-40	2000-2500	30-64

Source: Authors computation

4.1.10 Livestock price seasonality

The price seasonality was informed by the discussions in the FGD. The participants mentioned that prices are low between the months of January to April because livestock farmers make distress sales to meet emergencies such as school fees, purchase food, seeds, and plough, land among others. Similarly, during these periods, a large number of pastoralists sell their livestock, therefore dampening the prices. However, between August and December, livestock fetch higher prices. During these periods, the farmers who practice mixed farming have adequate food and therefore sell few livestock, thus creating the high demand among the traders/brokers.

Table 13: Livestock price seasonality

Period	Prices
January - May	Prices are low especially when schools are opening in January and February. There are many animals in the market
June - July	The season is higher and there are options for animal feeds, such as crop residues from beans and maize stover and green maize cobs
August - December	Prices increase steadily until they reach the highest peak at Christmas

4.1.11 Livestock marketing costs

Transport costs from production areas to terminal markets and slaughter facilities are thought to be the major costs of marketing for live animals.

Table 14: Livestock marketing costs

County	Livestock Type	N	Min	Max	Mean	Standard Deviation
Narok	Cattle	70	0	17000	1651.43	3352.08
	Sheep	85	0	4500	545.29	880.06
	Goats	27	0	10000	981.74	2052.13
West Pokot	Cattle	43	0	10000	534.88	2019.77
	Sheep	32	0	600	100.75	169.88
	Goats	44	0	4900	227.27	748.76
Overall	Cattle	113	0	17000	1226.55	2957.83
	Sheep	117	0	4500	423.71	779.85
	Goats	71	0	10000	514.18	1429.90

Source: Authors computation

4.1.12 Natural shocks experienced by households

Most of the households who were interviewed mentioned that they had experienced some natural shocks in the last five years. Table 15 shows that over 84 per cent of households acknowledge to have experienced drought shocks while 74 per cent admitted to have experienced shocks related to livestock parasites and diseases. Drought shocks were highly experienced in Narok County (87%) compared to West Pokot County (84%). However, this was contrary with respect to livestock parasites and diseases as West Pokot County experienced highly at 74 per cent compared to Narok County at 70 per cent. The least natural shock which was acknowledged was hailstorms at 0.20 per cent. The household further indicated their potential to respond to the shocks as highlighted in Annex 7.

Table 15: Natural shocks experienced by households

	Narok		West Pokot		Overall	
Type of shock/risks	Yes	No	Yes	No	Yes	No
Crop pest and diseases	55.60	44.40	25.90	74.10	41.70	58.30
Livestock parasites and disease	70.20	29.80	79.20	20.80	74.40	25.60
Floods	8.10	91.90	6.60	93.40	7.40	92.60
Droughts	87.10	12.90	80.70	19.30	84.10	15.90
Poor distribution of rain	62.70	37.30	66.80	33.20	48.90	51.10
Human parasites and diseases	19.10	80.90	30.90	69.10	24.60	75.40
Landslides	0.70	99.30	3.10	96.90	1.80	98.20
Hailstorms	0.30	99.70	0.00	100.00	0.20	99.80
Frost	3.40	96.60	3.90	96.10	3.60	96.40
Strong Winds	14.60	85.40	17.40	82.60	15.90	84.10

Source: Authors computation

4.1.13 Emerging coping strategies

Despite the presence of these shocks, most households mentioned during the FGD meeting that they respond towards droughts and other shocks by utilizing the available resources. One of the forms of handling drought which was mentioned by households is introduction of grazing patterns and feed conservation. This is being practiced by a group in West Pokot County called Mosol Peace Development

Initiative. Other ways involve migration to other areas in search of water and pasture. Most farmers in Narok County move their livestock to Njoro in Nakuru County and into Tanzania while in West Pokot County they migrate to Uganda. However, most of them do not sell the livestock as it is cultural to keep the animals and if they sell them, they do so at low prices.

To handle livestock pests and disease shocks, county governments have been able to intervene by providing vaccination for preventable diseases. They announce through radio when vaccination will be carried out in an area. Other measures include use of indigenous technical knowledge to prevent diseases, such as the use of *Aloe Vera* for preventing worms, local quarantine especially in times of disease outbreaks, people washing their legs before crossing rivers, establishment of cattle dips for tick and fly control, and establishment of cattle crushes for vaccination.

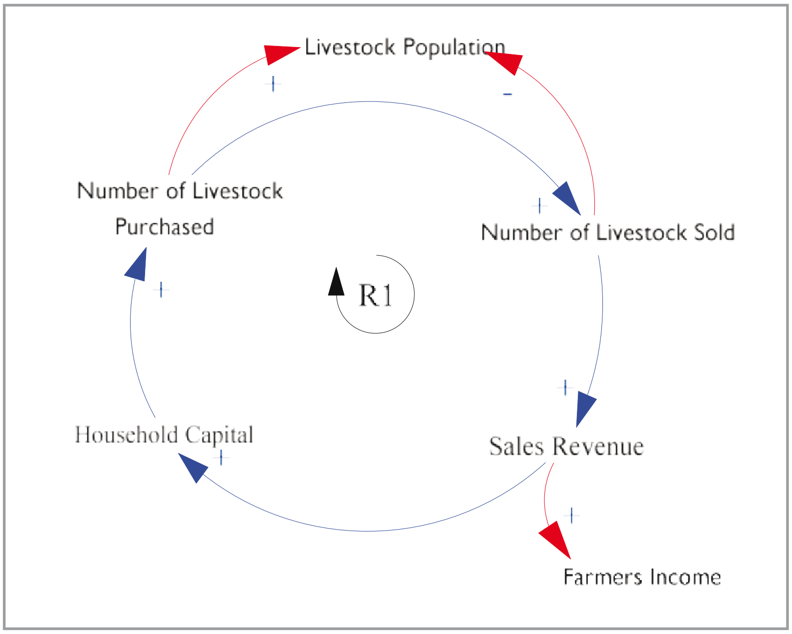
4.2 The Critical Facets of the Livestock Production System

As indicated in the justification for this study, the smallholder livestock production system received commitment from government through the ASAL policy to increase income accruing to livestock keepers by a factor of four by the year 2015. The essence of this commitment is to increase the welfare of farmers' households by generating additional net revenue. However, some critical facets are identified through literature review which may have potentially obstructed the commitment. These are feed availability, water availability, disease prevalence and lack of access to functioning markets.

4.3 Identification of the Causal Loop Diagram

The main tool of a CLD is feedback loops, which visualize interrelationships in circles, explaining that every influence is both cause and effect (Senge, 1992). Therefore, the next step was to identify the cause and effect of each variable. These causal links have polarity which explain how the variables are related (Schaffernicht, 2006); a positive (+) or negative (-) sign near the head of the arrow shows whether the variables move in the same or opposite direction (Sterman, 2000). The feedback loops may occur either in a reinforcing (R) or balancing (B) loop type. Reinforcing loops represent growing or declining actions in the systems, while balancing loops represent self-correcting mechanisms which counteract and oppose change (Maani and Cavana, 2007). Vensim PLE® software version 5.10 was used to translate the conceptual models into the CLD of the smallholder livestock production system. The basic diagram for smallholder livestock production system is presented in Figure 9.

Figure 9: Basic diagram for smallholder livestock production system



Source: Authors

Livestock production has two objectives: increasing the population and generating income. A reinforcing loop (R1) represents the basic operation of livestock production. It involves four variables: household capital; number of livestock purchased; number of livestock sold; and sales revenue (Figure 5). The diagram also has two dangles, variables included in the diagram, but lying outside the loop, which is livestock population and farmer's income as two main goals of the system.

The R1 loop describes the situation where more household capital enhances farmers' ability to purchase more livestock. Increasing the number of livestock purchased enables the farmers to increase the number of livestock sold and gain more sales revenue. Increasing sales revenue will further increase household capital and the reinforcing loop continues. Also, increasing sales revenue has a positive linkage to farmer's income. Additionally, number of livestock purchased increases the population. Contrarily, number of livestock sold reduces the livestock population.

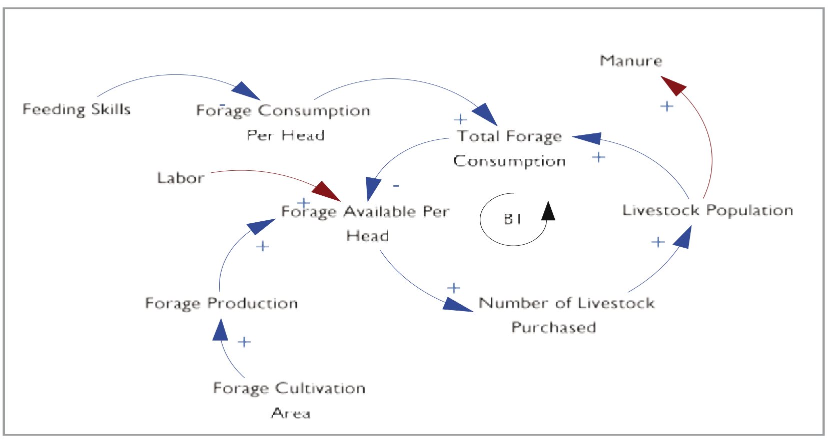
However, in the real world, the situation is not that simple. Many variables affect the behaviour of the livestock production system. This study aimed to explore those variables in three dimensions: forage, disease, and markets.

4.3.1 Forage module

As ruminants, cattle for example require forage for their diet. Generally, growing cattle require a minimum daily dry matter intake of 1.8 – 2 per cent of body weight (Hersom, 2013). Therefore, a 300 kg animal will need 5.4 – 6 kg of dry matter intake per day. If fed on nappier grass from a cultivation area, with a dry matter content of 20-25 per cent (Yunus et al., 2000), this equates to 21-30 kg of fresh grass per head per day. Smallholder livestock producers who are mainly in ASALs are often not able to provide that amount of grass despite the wide grazing area due to aridity. Therefore, they commonly rely on one source of feed which is local native grass. Interviews with farmers revealed that with the current land area and livestock population of 11 animals per farmer, they did not have any problem of forage availability during the rainy season, but during the dry season forage becomes their main problem. Figure 10 portrays the situation where forage becomes one of the constraints to increasing livestock population.

Figure 10 described in one balancing loop (B1) shows that increasing livestock population means more livestock need to be fed, thereby increasing the total forage consumption which diminishes forage available per head. Consequently, the carrying capacity decreases and suppresses the number of livestock purchased and reduces livestock population.

Figure 10: Forage module

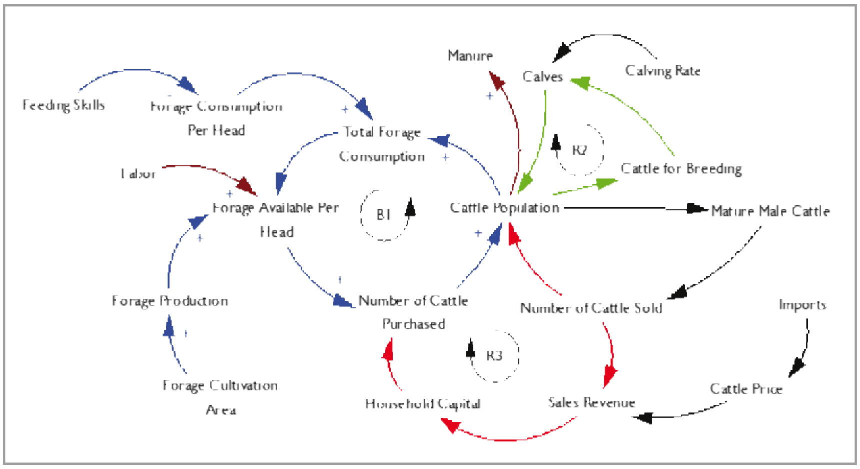


Source: Authors

4.3.2 Marketing module

To encourage international trade in livestock, the government has waived import and export taxes on livestock. Figure 11 describes how imports have effects on the system. On one side, good prices increase farmers' preferences to keep livestock. On the other side, imports decrease market prices, thus lessening sales revenue. These effects impact on the official system purposes, which are to increase both the livestock population and farmers' incomes. Moreover, as livestock price decreases, so does sales revenue.

Figure 11: Marketing module



Source: Authors

This also negatively affects the B1 loop which results in less cattle population. If the price is significantly reduced, it might decrease farmers' actual income thus decelerating the B1 loop, which ends up decreasing livestock population and farmers' income.

4.3.3 Disease module

Livestock diseases expose households to some level of welfare uncertainty. Although mortalities arising from common diseases are at a lower risk, their persistent occurrence is worrying for pastoral communities. Campbell et al. (2000) in their study on examining economic stocking rates among Zimbabwean pastoral communities highlighted the role played by subsidized government veterinary services. Substantial reduction in disease-related mortalities or a complete wipe-out of livestock diseases would therefore help herders to accumulate more stock, which then would mean more wealth and food for them (Lusigi, 1984). However, pastoral communities incur minimum expenditure in prevention of livestock diseases (Scoones, 1995; Solomon et al., 2007). Survey data analysis in this study showed that households spent less than a dollar to treat livestock, suggesting the reported losses arising from diseases. Aklilu and Wekesa (2002) noted in the report on intervention for 1999-2001 drought years that households which participated in general vaccination of livestock against common diseases reduced drought related mortality by 20 per cent.

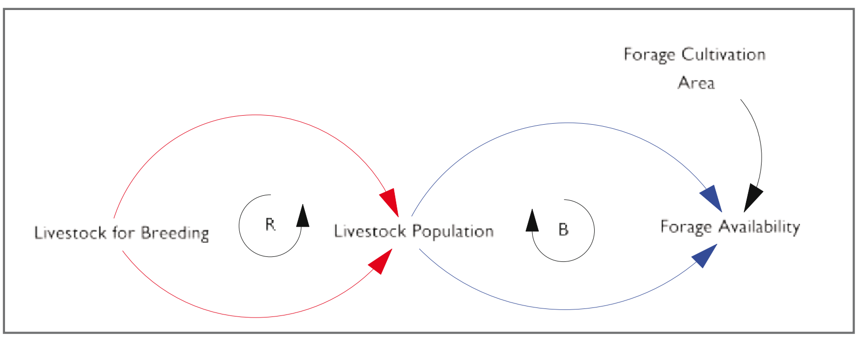
4.4 Strategies for Enhancing Livestock Production in Kenya

Analyzing system archetypes can assist in the identification of system leverage points (Senge, 2006) as a reference to generate strategies to improve the system.

4.4.1 Feed Availability

Increased livestock population should mean that more animals are allocated for breeding purposes, thus more calves are produced. Increased livestock population provides opportunities for farmers to allocate more animals to breeding purposes. This breeding operation is the engine of growth of the livestock population. However, this loop has an opposite balancing loop. As the population increases, so does their forage consumption. In most arid and semi-arid grazing situations, without any supporting intervention to increase feed availability, breeding success will be jeopardized (Figure 12).

Figure 12: Feed availability



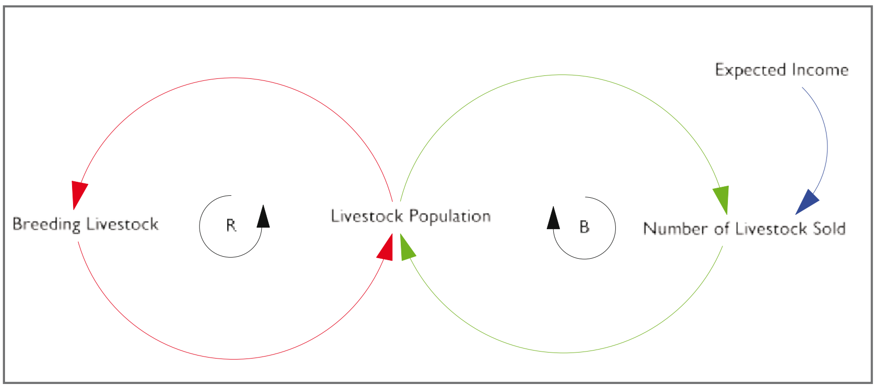
Source: Authors

The key leverage point to this archetype is to find an intervention which relaxes or removes the constraint. Therefore, strategies to increase the availability of feed become one alternative issue to be discussed with the farmers to increase beef production.

4.4.2 Number of sales

As indicated in the previous archetype, breeding produces calves which increase the livestock population. This reinforcing loop is the engine of livestock population growth. However, it has a balancing loop which limits growth; the number of livestock sold (Figure 13). Most often due to household pressing needs, most farmers need to sell their livestock to earn income. As a result, sales rate exceeds the calving rate, with the unintended and perverse outcome of a reduced rather than increasing livestock population.

Figure 13: Number of sales



Source: Authors

The proposed strategy for this situation is to provide education about herd replacement strategies. This includes improving farmers' awareness that with the current practices, their farming will not be sustainable.

4.5 Current Economic Situation of Livestock Production

The purpose of this gross margin analysis is to provide a preview of the importance of each type of livestock to households in terms of its financial contribution. Therefore, gross margin analysis was chosen to highlight the inflow of cash from each livestock type to the households. The results indicate that goats are a major source of cash flow to the households. The analysis should not be used as a reference of a yearly condition of the household as it was generated only from one year data.

Table 16: Gross margin analysis

Component	Cattle	Goats	Sheep	Total
Cost				
Livestock purchases	69,204.27	16,816.28	48,452.07	134,472.62
Marketing	1,226.00	423.00	514.00	2,163.00
Treatment	5,891.00	3,026.00	2,994.00	11,911.00
Total cost	76,321.27	20,265.28	51,960.07	148,546.62
Total revenue	81,499.86	28,199.76	57,791.00	167,490.62
Gross margin (GM)	5,178.59	7,934.48	5,830.93	18,944.00
Proportional to total GM	0.27	0.42	0.31	1

Source: Authors computation

5. Conclusion and Recommendations

5.1 Conclusion

One thing that should be clearly defined when studying a system is its boundary. This is essential in order to identify the elements within the system of interest, so their interactions can be studied, and also to define what is beyond this system, as any system is part of a hierarchy, and essentially a sub-system of a larger system. Therefore, it is difficult to grasp the system "wholeness" without clearly defining its boundary. This study focused on an agricultural system. However, agricultural systems have many levels from sectoral systems at regional or national level to individual systems. This study focused on the specific household level system of livestock production system.

According to the system archetypes analyzed in this study, one of the leverage points is to increase feed availability. Planting high quality grass and reseeding in the arid areas and applying feed preservation technologies are some of the strategies which could be explored.

There is need to control trading because reducing the number of cattle sold will lead to decreased farmers' actual income, increase the desired sales rate and encourage a farmer to sell more cattle (B1 loop), thus providing education about herd replacement strategies to maintain the desired sales rate in a sustainable level is preferred.

Educating the farmers on animal assessment to select a good breeding cow is one strategy to improve the ability to select quality cows, thus reinforcing the R2 loop as the engine of growth of the cattle population. Currently, selecting the breeding cow is merely based on its appearance as it was indicated in the Focus Group Discussion.

5.2 Recommendations

Since breeding is the key to increasing cattle population, more comprehensive policy on breeding herd development is required, such as establishing breeding farms or breeding stations where farmers could buy reliable locally adapted breeding cows suitable for intensive animal husbandry.

With regard to import policy, the government should carefully consider the balance between securing the national beef supply and maintaining the national beef population growth. The marketing module showed the sensitivity of market to imports. The import decreases the market price, thus lessening sales revenue.

5.3 Further research

Based on the information presented in this paper, the study can now proceed to build the livestock sector model.

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Annex

Annex 1: Annual sources of off-farm income

	N	Minimum	Maximum	Mean	Std. Deviation
Salary (Household head)	68	1	960,000	197,760.31	205,745.49
Salary (spouse)	23	12,000	600,000	188,478.26	167,674.97
Pension	11	2,400	168,000	38,036.36	47,448.99
Social Protection	11	1,800	600,000	62,596.36	178,413.10
Farm Wage	25	1,500	120,000	29,788.00	30,135.90
Non Farm Wage	16	5,000	480,000	113,100.00	130,495.98
Business	154	240	1,200,000	110,674.16	185,842.70
Amount received from Children	22	2,000	288,000	50,454.55	70,316.51
Remittances	10	3,000	240,000	54,200.00	68,385.83
Renting out Land	22	10,000	180,000	47,027.27	50,458.91
Renting out Oxen	2	16,000	60,000	38,000.00	31,112.70
Renting out Equipment	1	360,000	360,000	360,000.00	.
Valid N (listwise)	0				

Annex 2: Narok off-farm income

	N	Minimum	Maximum	Mean	Standard Deviation
Salary (Household Head)	22	24,000	600,000	191,163.64	162,090.48
Salary (Spouse)	12	12,000	600,000	178,000.00	172,902.50
Pension	9	2,400	168,000	37,155.56	52,919.35
Social Protection	8	1,800	9,600	5,070.00	2,830.10
Farm Wage	23	2,400	120,000	31,686.96	30,656.61
Non Farm Wage	12	15,000	480,000	134,883.33	142,933.11
Business	82	2,400	924,000	117,068.05	160,653.18
Amount Received from Children	9	5,000	288,000	65,200.00	87,447.87
Remittances	7	16,000	240,000	67,571.43	78,845.54
Renting out Land	20	10,000	180,000	38,730.00	41,878.46
Renting out Oxen	2	16,000	60,000	38,000.00	31,112.70
Renting out Equipment	1	360,000	360,000	360,000.00	.

Annex 3: West Pokot off-farm income

	N	Minimum	Maximum	Mean	Std. Deviation
Salary (Household Head)	46	1	960,000	200,915.24	225,242.38
Salary (Spouse)	11	21,000	480,000	199,909.09	169,388.58
Pension	2	36,000	48,000	42,000.00	8,485.28
Social Protection	3	24,000	600,000	216,000.00	332,553.76
Farm Wage	2	1,500	14,400	7,950.00	9,121.68
Non-Farm Wage	4	5,000	120,000	47,750.00	51,422.27
Business	72	240	1,200,000	103,392.22	211,849.79
Amount Received from Children	13	2,000	180,000	40,246.15	57,259.65
Remittances	3	3,000	36,000	23,000.00	17,578.40
Renting out Land	2	80,000	180,000	130,000.00	70,710.68
Renting out Oxen	0				
Renting out Equipment	0				

Annex 4: Average number of livestock purchased

County		N	Minimum	Maximum	Mean	Standard deviation
Narok	Cattle	156	1	80	9.07	12.41
	Sheep	169	1	480	23.53	44.58
	Camel	0	-	-	-	-
	Goats	94	1	100	10.72	14.85
West Pokot	Cattle	209	1	19	3.24	2.93
	Sheep	148	1	30	4.99	4.91
	Camel	2	1	2	1.50	0.71
	Goats	180	1	30	5.93	5.01
Overall	Cattle	365	1	80	5.73	8.88
	Sheep	317	1	480	14.87	33.97
	Camel	2	1	2	1.50	.71
	Goats	274	1	100	7.57	9.84

Annex 5: Other types of livestock inflows

Other % types of livestock inflows	Narok			West Pokot			Overall		
	Cattle	Sheep	Goats	Cattle	Sheep	Goats	Cattle	Sheep	Goats
Birth	92.95	0.59	92.55	96.65	97.97	96.67	95.07	94.03	95.26
Gift in	5.77	90.59	5.32	0.96	0.68	2.22	3.01	3.46	3.28
Exchange in	0.64	5.88		0.48	0.00		0.55	0.31	
Loan in	0.00	0.59	2.13	0.00	0.00			0.63	0.73
Keep on behalf of others	0.64	1.18	0.00	0.00	0.68	1.11	0.27	0.63	0.73
Others e.g. Dowry	0.00	1.20		1.91	0.68		1.10	0.90	

Annex 6: Medical cost

		Mean	Maximum	Minimum	Standard Deviation
Narok	Cost of medicine	2,963.89	30,000.00	0.00	7,268.62
	Cost of travel	968.42	7,000.00	0.00	1,821.42
	Days kept from work	7.78	8.00	4.00	0.85
	Days kept from school	6.79	8.00	1.00	2.13
West Pokot	Cost of medicine	1,603.57	7,500.00	0.00	2,786.95
	Cost of travel	185.71	800.00	0.00	244.50
	Days kept from work	7.85	8.00	6.00	0.55
	Days kept from school	7.46	8.00	3.00	1.45

Annex 7: Capacities of households to respond to shocks

	Narok					West Pokot					Overall				
Type of shock/risks	Very High	High	Neutral	Low	Very Low	Very High	High	Neutral	Low	Very Low	Very High	High	Neutral	Low	Very Low
Crop pest and diseases	30.12	12.05	5.42	35.54	16.87	18.37	12.24	14.29	36.73	18.37	27.44	12.09	7.44	35.81	17.21
Livestock parasites and disease	38.46	20.67	10.58	26.44	3.85	30.00	13.50	23.00	24.00	9.50	27.27	33.33	6.06	15.15	19.15
Floods	25.00	45.00	15.00	10.00	5.00	30.77	15.38	15.38	15.38	23.08	27.27	33.33	6.06	15.15	18.45
Droughts	20.08	20.47	8.66	43.31	7.48	28.86	13.93	18.91	29.85	8.96	23.96	17.58	13.19	37.36	7.97
Poor distribution of rain	24.44	10.56	6.11	45.56	13.37	11.48	8.20	21.31	34.43	24.59	21.16	9.96	9.96	42.74	15.87
Human parasites and diseases	14.29	30.36	12.50	39.29	3.57	17.33	28.00	36.00	14.67	4.00	16.03	29.01	25.95	25.19	3.82
Landslides	50.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	50.00	50.00	25.00	0.00	25.00	25.00	25.00
Hailstorms	0.00	0.00	0.00	100.00	0.00						0.00	0.00	0.00	100.00	0.00
Frost	20.00	20.00	60.00	0.00	0.00	0.00	28.60	57.10	14.30	0.00	11.76	23.53	58.82	5.88	0.00
Strong winds	4.76	11.90	19.05	52.38	11.90	9.10	0.00	0.00	27.30	63.60	5.66	9.43	15.09	47.17	22.64

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