Transforming Livestock Production through Systems Thinking Approach: the case of West Pokot and Narok Counties

N. Laibuni[1]; L. Kirui[2]

1: Kenya Institute for Public Policy Research and Analysis, Productive Sector, Kenya, 2: International Livestock Research Institute (ILRI), Regional Strategic Analysis and Knowledge Support System (ReSAKSS), Kenya

Corresponding author email: nancy.laibuni@gmail.com

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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. In order to accomplish these, a series of interviews and workshops was 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 small-holder beef production in Kenya.

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1. Introduction

Agriculture sector in Kenya has been of fundamental importance in both national and the local economy by generating over 30% towards GDP and supporting over 75% of the national population directly or indirectly (KNBS, 2017). Half of the agriculture sector in Kenya is comprised of livestock farming mostly found in the Arid and Semi-Arid Lands (ASAL) (Aklilu and Catley, 2010). Data on livestock farming is largely based on estimates made from the National Census report (2009) that included livestock numbers and an Intergovernmental Authority for Development (IGAD) commissioned study carried out in 2010. It is estimated that the cattle herd in Kenya is approximately 10 million head, of which around 90 percent are produced by 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 percent of Kenya's ruminant off-take for slaughter (Behnke and Muthami 2011), Table 1. Approximately 80 to 90 percent of the red meat consumed in Kenya comes from livestock that are raised by pastoralists within Kenya and neighboring countries (Nyariki, et.al. 2005). Another 2 percent 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 percent comes from livestock that originates in neighboring 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	223425	55856	47
Neighboring pastoralists	-	79081	19770	17
Dairy producers and other highlands	5,311,800	52454	13114	11
Commercial ranches	240,000	8670	2160	2
Totals	**17467773**	**363630**	**15274**	**77**

Source: Behnke and Muthami 2011

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 increases 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 like these 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 tools 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.

System thinking can be used to assess many dimensions of livestock production, from herd dynamics to economic policies designed to support livestock production 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. The overall objective of this study is to develop strategies for transforming the smallholder livestock farming in Kenya in a system thinking approach. Specifically identify the critical facets of the livestock production system in Kenya. And secondly, formulate the most feasible strategies for enhancing livestock production in Kenya.

2. Empirical literature Review

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). 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).

Small Holder Livestock Production and System Thinking

System thinking emerged to deal with complexity (Maani & Cavana, 2007). In the developing world, it has been applied to explain systemic complexity encountered, for example in the tourism industry in Vietnam (Mai & Bosch 2010) and forest management in Indonesia (Purnomo & Mendoza 2011). Mai (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 & 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, as well as 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.

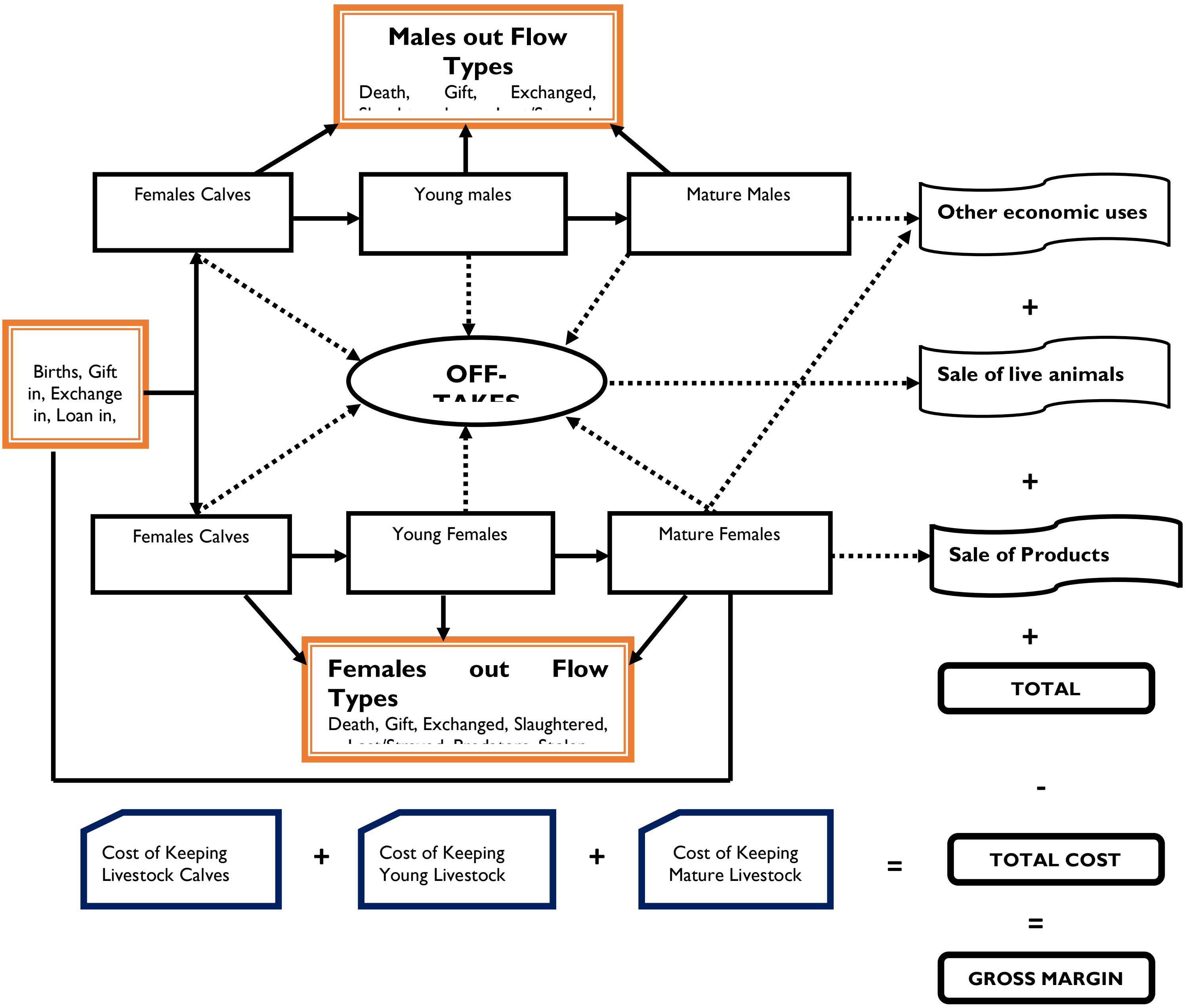
One key characteristics of smallholder livestock production, is the interconnectedness among activities on the farm, in the household, and in the wider community or economy (MacLeod et al. 2011). External factors such as market prices, consumer preferences, and the political situation can have a significant 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 producer 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 production 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.

3. Conceptual Framework

Most livestock production systems can be represented in the stock-flow diagram. The dynamics of the stocks are represented by the solid lines related to adjustment to stocks, 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 1: Conceptual Framework



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 1: 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 labor, 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.

4. Methodology

4.1. 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 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 come 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.

4.2. 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 & Cavana 2007)

Table 2: 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 a reinforcing and balancing loop • Identify the leverage points and possible strategy
↓ Identify archetypes within the CLD		

4.3. Structuring the Problem

This step answers the question of what problem needs to be addressed. This requires identification of the real problem, not just symptoms or events of difficulties. This is an important step to justify, and clarify the purpose of, the whole system thinking approach. This step is also known as problem articulating (Sterman 2000). From a system thinking point of view, structuring must establish reference modes and explicitly set the time horizon. Reference modes are set of graphs, or other descriptive presentation showing the development of the problem over time. Setting the time horizon determines the appropriate time frame in order to obtain a richer and better understanding of the problem. These two processes will help to characterize the problem dynamically, showing a pattern of behaviour over time (Sterman 2000).

Systems' thinking requires us to move from thinking at the event level to understanding reality at the deeper pattern level. Patterns are trends or changes in events over time (Anderson & Johnson 1997). Unstructured problems are characterized by the existence of multiple actors, multiple perspectives, conflicting interest, important intangibles, and key uncertainties (Mingers & Rosenhead 2004). Methods for structuring problems must, however, meet some ground conditions, such as: (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, as well as vice versa, (iv) allows the identification of local or partial problems, and thus can be improved (Mingers & Rosenhead 2004).

Consultation with relevant stakeholders needs to be one of the initial steps in problem structuring in order to harness their perspectives and interest in the problem, as well as to generate commitment and collaboration from the start. The second step is to collect secondary data which indicates and clarifies the importance of the problem identified. Ideally, this should be followed by group sessions (Visser 2007) aimed at encouraging new ideas and thoughts from a 'large pool of raw ideas' (Maani & Cavana 2007).

5. Results and Discussion

5.1. Selected Socio-economic characteristics

Descriptive statistics were used to give an overview of some of the data collected.

Land allocation to different Uses

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) as compared to West Pokot County (5 acres), Table 3

Table 3: Land Allocation to different uses

		Mean	Maximum	Minimum	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%

Livestock Numbers

The average number of livestock kept per household in Narok and West Pokot Counties varies substantially. Table 4 presents 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 stock 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 stock and then goat stock at an average of 15 and 14 respectively with a few farmers rearing camels (an average of 1 per household). In overall the study found out that household own more small stock (average of 42 for sheep and 24 for goats) as compared to cattle stock (average of 23). Household's camel ownership was generally minimal.

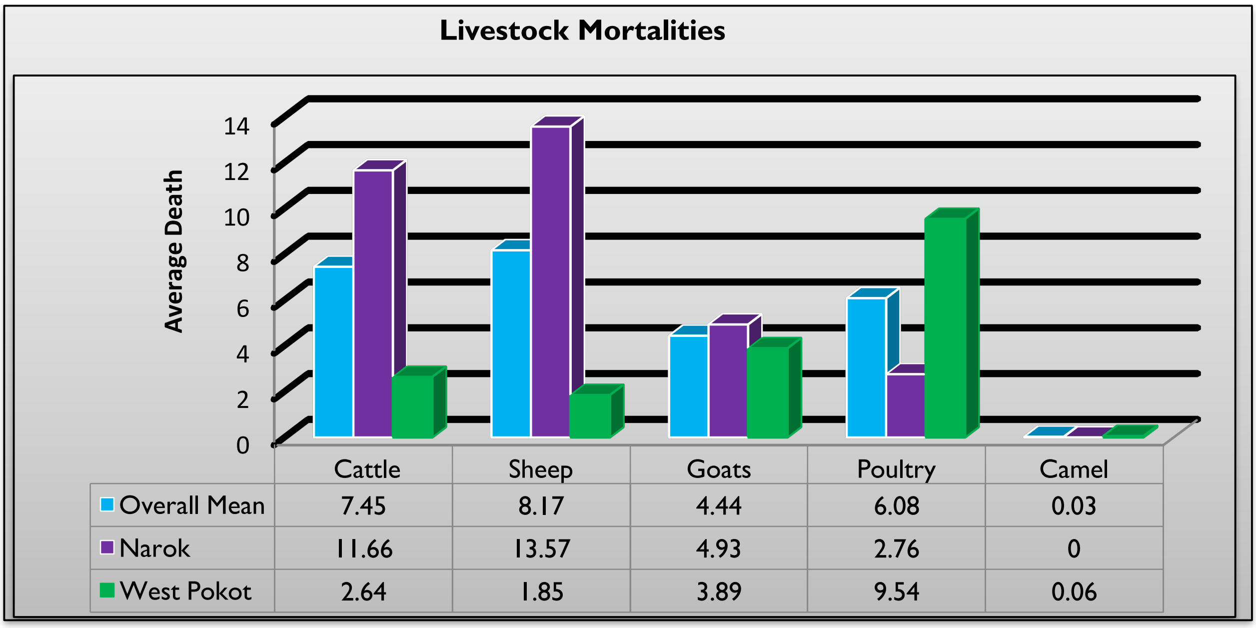
Table 4: Stock of livestock Kept

		Mean	Maximum	Minimum	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

Livestock Losses

This study examined losses due to death among various livestock types across the two priority Counties and this is summarized in Figure 2. Notably, there is a high average loss of cattle and sheep in Narok County (Average of 11 per year for cattle and 13 for sheep per household) as compared to West Pokot County where the losses in the two species are minimal.

Figure 2: Livestock Mortalities

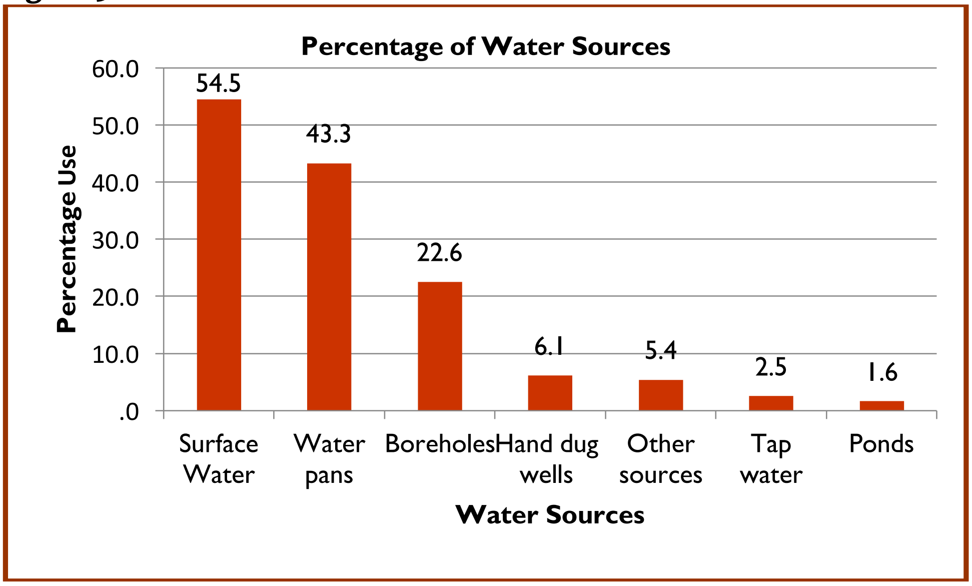


	Cattle	Sheep	Goats	Poultry	Camel
Overall Mean	7.45	8.17	4.44	6.08	0.03
Narok	11.66	13.57	4.93	2.76	0
West Pokot	2.64	1.85	3.89	9.54	0.06

Water sources

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

Figure 3: Water Sources



Cost of inputs and services

The predominant sources of animal feeds in Narok County grazing on own pasture (77%) 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 (34%) as compared to West Pokot (12%)

Table 6: Sources of feeds

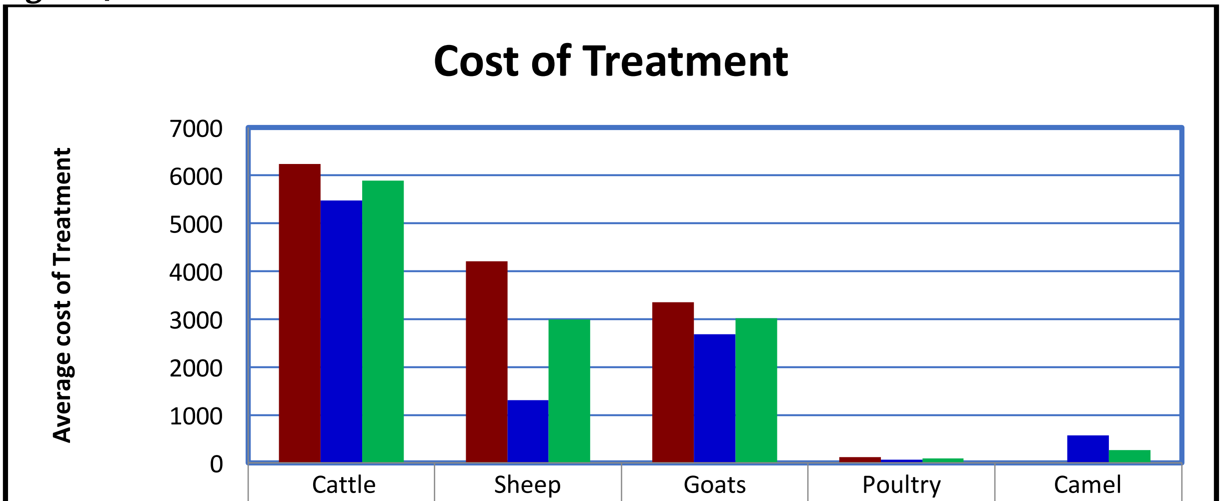
Source of feeds	Narok %	West Pokot	Overall
Grazing on own pasture	77.60%	45.90%	62.80%
Grazing on public/communal land	39.30%	74.10%	55.60%
Grazing on crop residues	10.50%	43.60%	26.00%
Cut and carry fodder	5.10%	5.00%	5.10%
Cut and carry fodder from rented land	5.40%	3.90%	4.70%
Cut and carry fodder 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%

Livestock production in the ASALs is largely constrained by year-long availability of feeds (Mnene et al 2004, Kibet et al 2006, Abusuwar and Ahmed 2010). This therefore necessitates the purchase of supplementary feeds from commercial means to reduce dependence on rangelands. The households who were interviewed in this study reported that they spend less amount of money on wheat bran, proprietary minerals, local minerals, nappier grass and dairy meal as compared to the cost of maize germ, green maize stovers and road side grass.

Annual Cost of livestock treatment

The annual cost associated with livestock treatment is presented in Figure 5. 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. 5891 in both counties. However, more average expenditure is incurred on cattle in Narok County (Ksh. 62445) as compared to West Pokot County (Ksh. 5477)

Figure 4: Annual Cost of Livestock Treatment



	Cattle	Sheep	Goats	Poultry	Camel
Narok	6245.04	4207.49	3358.4	118.79	0
West Pokot	5477.22	1314.28	2691.49	70.36	574.07
Overall Mean	5891.9414	2994.8971	3026.7026	97.5697	264.9573

6. 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 market.

6.1. 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 show 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 & 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 5

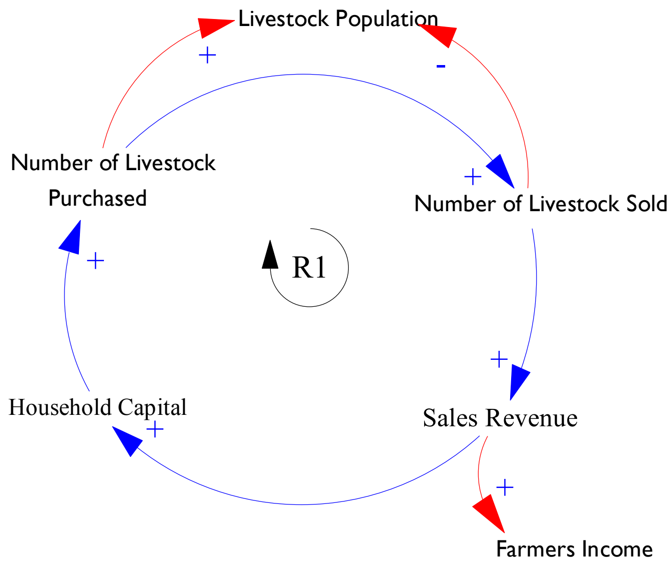


Figure 5: Basic diagram for Smallholder Livestock Production System

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 the 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 so 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.

6.2. 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% of body weight (Hersom 2013). Therefore, a 300kg 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% (Yunus et al. 2000), this equates to 21 – 30 kg of fresh grass per head per day. Smallholder livestock producers who are mainly in ASALSs 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 rainy season, but during the dry season forage become their main problem. Figure 6 portrays the situation where forage becomes one of the constraints to increasing the livestock population.

Figure 6 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 the livestock population.

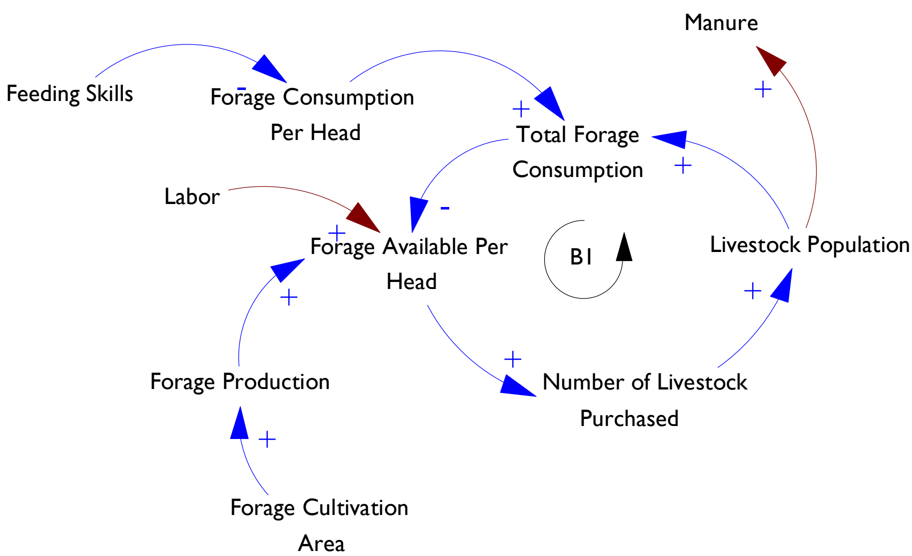


Figure 6: Basic diagram for forage module

6.3. Marketing Module

To encourage international trade in livestock, the government has waived import and export taxes on livestock. Figure 7 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. 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.

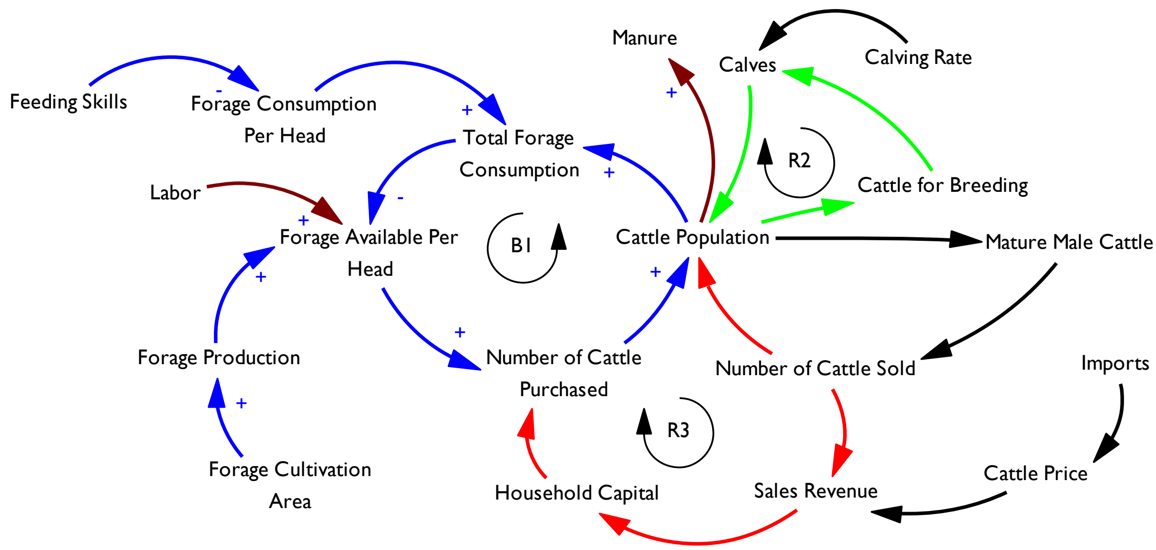


Figure 6: Basic diagram for marketing module

6.4. 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. (2000a) in their study on examining economic stocking rates among the 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%.

7. 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.

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 situation, without any supporting intervention to increase feed availability, breeding success will be jeopardized, Figure 7.

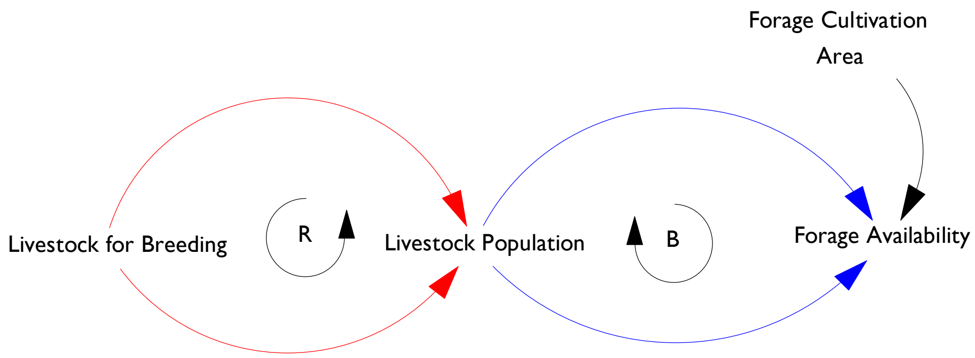


Figure 7: Feed Availability

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 in order to increase beef production.

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 8). Most often due to household pressing needs, most farmers need to sell their livestock in order 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.

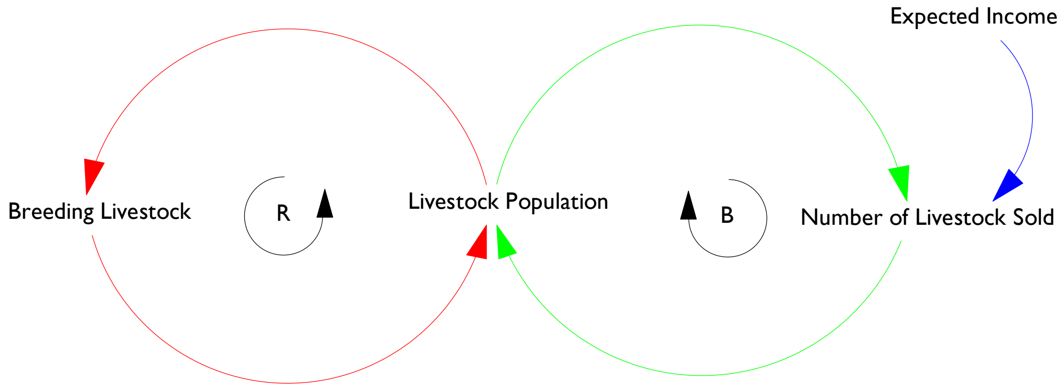


Figure 8: Number of Sales

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.

8. 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 type to the households in terms of its financial contribution. Therefore, the 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 7: Gross Margin Analysis in Kenya Shillings

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**

9. 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 in a livestock production system. According to the system archetypes which were 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 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.

The next step for this study is to develop the dynamic model and add an extension to the economy wide model Kenya Threshold 21 model so as to develop indicators on the implications on and/or for the economy.

References

Bebe, B., Udo, H., Rowlands, G. & Thorpe, W. 2003. Smallholder dairy systems in the Kenya highlands: cattle population dynamics under increasing intensification. Livestock Production Science, 82, 211-221.

Behnke, R. & Muthami, D. (2011). The Contribution of Livestock to the Kenyan Economy. IGAD LPI Working Paper No. 03-11.

Brooks, K., Ellison, B., (2014) Which Livestock Production Methods Matter Most to Consumers? Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2014 AAEA Annual Meeting, Minneapolis, MN, July 27-29, 2014

Campbell, B. M., Gordon, I. J., Luckert, M. K., Petheram, L. & Vetter, S. 2006. In search of optimal stocking regimes in semi-arid grazing lands: One size does not fit all. Ecological Economics, 60, 75-85.

Carter, M. & Barrett, C. 2006. The economics of poverty traps and persistent poverty: An asset-based approach. Journal of Development Studies, 42, 178-199.

Chantarat, S., Mude, A. & Barrett, C. 2009. Willingness to pay for index based livestock insurance: results from a field experiment in northern Kenya. Ithaca, NY (USA): Cornell University.

Delgado, C. 2005 Rising demand for meat and milk in developing countries: implications for grasslands-based livestock production. In Grassland: a global resource (ed.D. A. McGilloway), pp. 29–39. The Netherlands: Wageningen Academic Publishers.

DFID 1999. Sustainable livelihoods. Lessons from early experience. London: Department for International Development.

Ellis, F. & Mdoe, N. 2003, Livelihoods and rural poverty reduction in Tanzania: World Development, 31, 1367-1384.

Evans, J., D'Souza, G., Sperow,M., Rayburn, E.,(2004), An Economic Analysis of Pasture-Raised Beef Systems in Appalachia, Selected Paper prepared for presentation at the American Agricultural Economics Association Annual Meeting, Denver, Colorado, August 1-4, 2004

G. P. Juma, M. Ngigi, I. Baltenweck, and A. G. Drucker, "Consumer demand for sheep and goat meat in Kenya," Small Ruminant Research, vol. 90, no. 1–3, pp. 135–138, 2010.

Galvin, K., Thornton, P., Boone, R. & Sunderland, J. 2004. Climate variability and impacts on east African livestock herders: the Maasai of Ngorongoro Conservation Area, Tanzania. African Journal of Range and Forage Science, 21**,** 183-189.

Khan, M. M., Mock, N. B. & Bertrand, W. B. 1992. Composite Indicators for Famine Early Warning Systems. Disasters, 16**,** 195-206.

Leggett, K., Fennessy, J. & Schneider, S. 2003. Seasonal vegetation changes in the Hoanib River catchment, north-western Namibia: a study of a non-equilibrium system. Journal of Arid Environments, 53**,** 99-113

Lybbert, T., Barrett, C., Mcpeak, J. & Luseno, W. 2007. Bayesian herders: Updating of rainfall beliefs in response to external forecasts. World Development, 35**,** 480-497.

Munyua, P., Murithi, R., Wainwright, S., Githinji, J., Hightower, A., Mutonga, D., Macharia, J., Ithondeka, P., Musaa, J. & Breiman, R. 2010. Rift Valley Fever Outbreak in Livestock in Kenya, 2006-2007. The American Journal of Tropical Medicine and Hygiene, 83**,** 58.

Ndayitwayeko et al., (****), Determinants of Beef Meat Supply in Burundi: A Vector Error Correction Model Approach Applied to structural Nerlov paradigm. The 8th AFMA Congress, Moi University

O'Connor, D., Hennessy, D. Shalloo, L., Hurtado-Uria, C. (2012), An Examination of the Volatile Nature of Grass Production in Ireland, Paper prepared for the 123rd EAAE Seminar Price Volatility and Farm Income Modeling Outcomes and Assessing Marketand Policy Based Responses Dublin, February 23-24, 2012

O'Reilly & McCarthy (2005), Trends in the Irish beef market during the 1990s - identification and analysis of change drivers, 15th Congress - Developing Entrepreneurship Abilities to Feed the World in a Sustainable Way, IFMA Brazil

Otieno, D.J., Ruto, E., Hubbard, L.J. (2010), Cattle farmers' preferences for Disease Free Zones: a choice experiment analysis in Kenya, The 84th Annual Conference of the Agricultural Economics Society Edinburgh 29 – 31 March, 2010

Roh, J.S, Lim, S.S., Adam, B.D. (2006), The Impact of Foot-and-Mouth Disease (FMD) on Hog, Pork, and Beef Prices: the Experience in Korea, Paper presented at the NCCC-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management St. Louis, Missouri, April 17-18, 2006

Schlenker, W. Villas-Boas, S.B (2006), Consumer and Market Responses to Mad-Cow Disease Columbia University University of California, Berkeley
Silva Neto, W. A da, Bacchi, M.R.P., (2003), Growth of Brazilian Beef Production: effect of shocks of supply and demand
Sterman, J. D. 2000. Business dynamics: systems thinking and modeling for a complex world, Irwin McGraw-Hill.
Ford, A. (2009), Modeling the environment: Island Press.
Forrester, J.W. (1995). Counter intuitive behavior of social systems. Collected papers of Jay W. Forrester.
Meadows, D.H. (1989), System dynamics Meets the press. System Dynamics Review, 5(1), 69-80