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THE EFFECTS OF CLIMATE VARIABILITY ON LIVESTOCK PRODUCTION IN KENYA

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Abstract

Purpose: This study examined the effects of climate variability on livestock production in Kenya.

Methodology: The study used the Ricardian cross-sectional approach to measure the relationship between climate variability and net revenue from livestock. Net livestock revenue is regressed against various climate and socio-economic variables to help determine the factors that influence variability in net livestock revenues. This study is based on data from ASDSP household baseline survey of 1871 livestock farming households interviewed across the country.

Results: The empirical results show that climatic variables (temperature and precipitation) have significant effects on net livestock revenues in Kenya. The net livestock revenues are affected negatively by increases in temperature and rainfall.

Unique contribution to theory, practice and policy: The study recommends that there is a need to provide adequate extension information services to ensure that farmers receive up-to-date information so as to ensure increased production. Similarly, policies that increase farmer training and access to credit can help improve net livestock revenues.

Keywords: *climate variability, livestock production, net revenue, extension, credit access*

1.1 INTRODUCTION

Climate change refers to the state of the climate that can be identified by changes in mean and/ or the variability of its properties that persist for an extended period, decades or longer. Climate variability on the other hand is variations in the mean state of the climate (Intergovernmental Panel on Climate Change -IPCC, 2007; 2001). Current climatic variation has significant impacts on agricultural production, constraining agricultural income and forcing farmers to adopt new agricultural practices in response to altered conditions. The risks of future climatic changes such as higher temperatures, changes in precipitation and increased climate variability can result in significant effects on crops and livestock (Molua et al., 2010).

Globally, livestock is likely to face serious effects of climate change and variability including the risk of extinction of between 20-30 percent of all animal species. Climate variability has severe impacts on the environment, more so on water availability, agriculture and food security, human health and biodiversity. The IPCC's report of 1990 pointed out a global average increase in temperature between 0.15 and 0.3oC per decade. Greenhouse gas emission could be raised globally between 25-90 percent by 2030 and temperatures could be increased by 3 percent by the year 2050. It is further predicted that even with a small temperature rise of 1-2.5 percent, the consequences could still be severe, exerting far-reaching effects on the livelihood of many people (IPCC, 2007).

Like the rest of the world, Africa is already a continent under pressure from climate stresses and is highly vulnerable to the impacts of climate variability. It is estimated that one third of African people already live in drought-prone areas and that 220 million are exposed to drought each year. African countries are prone to greater impacts of climate change and variability partly because they often lack adaptive capacity. Africa is particularly vulnerable to climate variability because a large proportion of the population lives in rural areas and is heavily dependent on climate sensitive livelihoods such as agriculture-crops and livestock (Nkondze et al., 2014; United Nations Framework Convention on Climate Change-UNFCCC, 2007).

In Kenya, Global Circulation Models (GCMs) predicted that global warming will lead to increased temperatures of about 40C and cause variability of rainfall by up to 20 percent in Kenya by the year 2030. From these predictions, the two extreme climate events that may adversely impact on the agricultural sector are droughts and floods in both the low, medium and high potential areas (Kabubo-Mariara & Karanja, 2006). At present, the frequency of droughts averages between two to three years compared to between five to seven year cycles experienced in the 1960s and 1970s. So far, five severe droughts have been realized over the past two decades - 1996/1997, 1999/2001, 2004/2006, 2008/2009 and 2010/2011 (Kenya Institute for Public Policy Research and Analysis-KIPPRA, 2010; GoK, 2013; UNDP, 2013).

1.1.1 Livestock Production and Climate Variability

Livestock production is the mainstay of most rural households in Kenya and contributes significantly to their livelihoods. Over 60 percent of all livestock is found in the Arid and Semi-Arid Lands (ASALs), where it employs about 90 percent of the population. It is further noted that even in the non-ASAL areas, the livestock sub-sector constitutes an important source of family income and food security. ASAL occupy 89 percent of the country and is a home to about 14 million people. The livestock sub-sector accounts for over 12 percent of the National Gross Domestic Product (GDP) and about 42 percent of the agricultural GDP. It also supplies the domestic requirements of meat, milk and dairy products, and other livestock products while accounting for about 30 percent of the total marketed agricultural products. The sub-sector earns the country substantial foreign exchange through export of live animals, meat, hides, skins, dairy products and processed pork products. It also employs about 50 percent of the country's agricultural sector labour force. The sub-sector provides raw materials for agro-industries hence contribute substantial earnings to households through sale of livestock and livestock products (GoK, 2014; GoK, 2012).

Arid and semi-arid counties have large concentrations of livestock, mostly in mixed systems with some degree of dairying and a significant number of free-ranging sheep and goats. The humid and sub-humid areas, however, have low concentrations of livestock due to high human population triggered by high agricultural potential and are closer to larger cities, services, markets and other infrastructure (Herrero et al., 2010). Table 1 below shows the livestock population in the three agro-ecological zones in Kenya.

Table 1: Livestock Population in the Different Agro-Ecological Zones in Kenya

AEZs	Classification	Counties in the AEZs	Livestock population			
			Cattle	Sheep	Goats	Camels
Zone 1 & 11	Humid (High potential)	Kisii, Nyeri, Kirinyaga, Meru, Bomet, Nyandarua, Kiambu, Murang'a, Kericho, Nandi, Busia Kakamega, Vihiga, Bungoma Nyamira, Embu, Homa Bay, Uasin Gishu, Transzoia, Nakuru, Migori.	5,626,651	3,316,699	2,606,021	121
Zone III & IV	Semi-humid (Medium potential)	Makueni, Siaya, Kisumu, Machakos, Taita Taveta, Kajiado, Narok, Nairobi, Tharaka Nithi, West Pokot.	3,294,069	3,113,997	3,821,451	7,192
Zone V, VI & VII	Very arid to Semi-arid (Low potential)	Laikipia, Lamu, Kitui, Kwale, Mombasa, Kilifi, Baringo, Samburu, Elgeyo Marakwet, Turkana, Marsabit, Mandera, Wajir, Garissa,Tana River, Isiolo.	6,894,351	8,795,984	14,556,737	2,758,805

Source: Agricultural Sector Development Support Project; Ministry of Agriculture, Livestock and Fisheries, 2013.

The livestock farming in Kenya has been constrained by poor governance of agricultural institutions, inadequate infrastructure, insufficient markets, weak marketing systems, and lack of access to farm credit, high costs of farm inputs, inappropriate technology and inadequate funding for research and extension (Food and Agriculture Organization-FAO, 2005). Some of the indirect effects are brought about by changes in feed resources linked to the carrying capacity of rangelands, the buffering abilities of ecosystems, increased desertification processes, increased scarcity of water resources. This has led to a decrease in livestock population which has further affected production of milk, milk products and meat (FAO, 2008).

Generally, livestock farming depends on natural systems. This makes it highly sensitive to climate change and variability particularly changes in temperature, rainfall and extremes. High temperature degrades the resources in the rangelands and cause starvation and death of livestock. The decimation of animals has severe consequences for livestock farmers as their survival depends predominantly on their livestock (Mwiturubani & Van Wyk, 2010). Rainfall on the other hand, could benefit livestock farmers in that more rainfall could result in longer access to wet-season pasture. It could also result in less frequent drought, which may mean more time for people to rebuild their assets between lean and good times. However, there are also significant negative consequences including loss of livestock through heat stress, loss of land to agricultural encroachment as the rise in rainfall raises the productive potential of arid areas, an increase in frequency of flooding, and the spread of human and livestock diseases that thrive during the wet season (Oxfam International, 2008).

1.2 Problem Statement

Climate variability is acknowledged in Vision 2030 as a threat to achievement of annual economic growth rate of 10 percent. If climate variability effect is unchecked, it will cause substantial damage and loss to the livestock sector. Through the National Disaster Management Authority (NDMA), the Government of Kenya has focused on various interventions including integrated drought early warning systems, livestock off-take as well as restocking programmes with the main aim of reducing the effects of climate on livestock farmers, especially in the ASALs. Despite the rigorous efforts by the government, continued loss of livestock at the household level is still a serious national concern. Extreme climatic events have persistently led to massive loss of livestock thus negatively affecting the livestock industry hence raising concerns on how to secure livelihoods for the livestock farmers. Climate variability has been known to increase abundance and distribution of livestock diseases, as well as the destruction of infrastructure which is an important enabler for livestock farming. If long term measures to address climate related risks such as livestock diseases are not put in place, the welfare of the livestock farmers in ASALS is threatened (GoK, 2013).

Although climate variability is expected to have effects on both crops and livestock production, most of the studies (Di Falco et al., 2011; Deressa & Hassan, 2009; Kabubo-Mariara & Karanja, 2006) concentrate on crops, disregarding the role of livestock. This study takes a different direction by analyzing the effects of climate variability on livestock production in Kenya in order to inform policy on strategic interventions to reduce livestock losses thereby increasing income, employment opportunities as well as boost the welfare of the livestock farmers.

1.3 Research Questions

i. What is the extent of climate variability in Kenya?
ii. What are the effects of climate variability on livestock net revenues in Kenya?
iii. In what ways have livestock farming households responded to climate variability in Kenya?

2.0 LITERATURE REVIEW

2.1 Theoretical Literature

2.1.1 Profit Maximization Theory

This study is grounded on the profit maximization theory. This theory postulates that the farmer makes animal husbandry decision that enhances their resilience to climate variability. According to Seo and Mendelsohn (2006), in cases of extreme weather events, a farmer aims at optimizing their livestock production subject to climatic constraints. In order to lower the cost, reduce the risk and maximize profit, a farmer's decision will entail choosing the level of inputs, number of livestock and optimal combination of species that will enhance their tolerance. The decision of a farmer is pegged on profit maximization, where exogenous environmental factors such as temperature and precipitation act as individual loci beneath which the decision is made. This implies that under climate variability, the farmer must choose the most profitable animal and also the inputs that will maximize the value of that animal (Mendelsohn, *et al.*, 1994).

Hence the level of livestock husbandry influences the profitability. If the farmer's i's profit in choosing a level of livestock husbandry j (j = 1, 2, and 3…..J) is given as:

$$\pi_{ji} = V(Kj, Sj) + \varepsilon(Kj, Sj) \quad \text{eq. 1}$$

Where K *is* a vector of exogenous characteristics of the farm and S is a vector of characteristics of farmer *i*. For example, K could include climate, diseases and access variables and S could include the age of the farmer and family size. The profit function is composed of two components: the observable component *V* and an error term, ε. The error term is unknown to the researcher, but may be known to the farmer. The farmer will choose the level of livestock that gives him the highest profit.

2.2 Empirical Literature

There is a growing body of empirical research done on the effects of climate change on agriculture (crop) production while there is a dearth of literature on the effects of climate change on livestock production both in Africa and Kenya (Kabubo-Mariara, 2008). Most of the studies use the Ricardian approach in measuring the effects of climate change and variability on crops and livestock.

Gebreegziabher *et al*., (2014) analyzed the effects of climate change and weather variation on livestock production. The study showed that temperature and rainfall greatly affect livestock net revenue. Changing rainfall and temperature patterns due to climate change exhibited different effects on livestock. Increase annual average temperature would lead to an increase in net revenue from livestock while an increase in annual rainfall would have a significant negative effect on livestock net revenue.

Nkondze and Mantyatsi (2014) investigated the effect of temperature and rainfall on livestock production at the Mpolonjeni Area Development Programme in Swaziland. A survey of 323 sampled livestock farming households was used for analysis. Perceptions of households and climate data were used to establish climate patterns in Mpolonjeni Area Development Programme. Results of the Ricardian model showed that goats net revenue was sensitive to winter temperature, winter temperature squared, winter rainfall and winter rainfall squared. None of the climate change variables affected Cattle net revenues. The study concludes that climate change affects livestock production negatively and thus livestock owners need to use climate change adaptation strategies.

Taruvinga *et al*., (2013) estimated the effects of climate variability and adaptations on small-scale livestock production. The study was based on a survey of 1484 small-scale livestock rural farmers across the Eastern Cape Province of South Africa. Regression estimates found that with warming, the probability of choosing the following species increases; goats, donkeys and ducks. High precipitation increases the probability of choosing the following animals; beef, goats and donkeys. Further, socio-economic estimates indicated that livestock selection choices are also conditioned by gender, age, marital status, education and household size. The paper therefore concluded that as climate changes, rural farmers switch their livestock combinations as a coping strategy. Unfortunately, rural farmers face a limited preferred livestock selection pool that is combatable to harsh climate which might translate to a bleak future for rural livestock farmers.

Gebreegziabher *et al*., (2013) looked into the economic effects of climate change and variability on agricultural production. Climate change and agricultural productivity in Ethiopia was analyzed in a broader sense, inclusive of livestock production. A Ricardian approach was used to estimate the effects of climate change and variability on both crops and livestock. The results showed that warmer temperature is beneficial to livestock production. Moreover, increasing/decreasing rainfall associated with change in climate damage livestock. As far as the socio-economic variables are concerned, access to formal extension services and level of education of household head turned out significant. Distance to input markets also remained significant but negative. Farm size turned out significant and positive.

Seo and Mendelsohn (2008) used a cross-sectional approach to analyze the effects of temperature and rainfall variations on animal husbandry and the way farmers adapt. The study was based on surveys of almost 5000 livestock farmers across ten countries in Africa. A Ricardian regression found out that the livestock net revenues of large farms in Africa are more sensitive to temperature than those of small farms. Cross-sectional analysis also revealed that warming increases income on small farms by US$ 100 per degree. For large farms, warming reduces income by US$330 per degree. The temperature elasticity of small farms is about +24 whereas the temperature elasticity of large farms is -2.3. A marginal increase in precipitation reduces net revenue per farm for both small and large farms. Small farms decline by about US$ 20 per mm of monthly precipitation and large farms by about US$65 per mm, and both effects are significant. The precipitation elasticity is about -13 for small farms and -1.2 for large farms. Small farms have such a large elasticity because they shift from livestock to crops. All livestock farms have a negative elasticity with precipitation because natural ecosystems shift from grasslands to forests and there is an increased prevalence of animal diseases such as trypanosomiasis.

Kabubo-Mariara (2008) focused on the economic impact of global warming on livestock production in Kenya. The main data for this study were based on a sample of 722 households. The data were collected from six out of eight provinces between June and August 2004. The study also made use of satellite and ARTES (Africa Rainfall and Temperature Evaluation System) climate data. The Ricardian regression results showed that livestock production in Kenya is highly sensitive to climate change and that there is a non-linear relationship between climate change and livestock productivity. The estimated marginal impacts suggested very modest gains from rising temperatures for instance a 1 unit rise in temperature would result in approximately 5 percent increase in net livestock revenue. In addition, increased precipitation will lead to a fall in the net value of livestock that is, a 1 percent rise in rainfall would lead to between 1.35 percent and 1.19 percent decline in livestock net value. Age of household head remained significant but negatively correlated with livestock net incomes.

Kurukulasuriya *et al*., (2006) analyzed the economic effects of temperature and rainfall on African agriculture using data from a survey of more than 9,000 farmers across 11 African countries. A cross-sectional approach estimated how farm net revenues are affected by climate change compared with current mean temperature. The results showed that revenues fall with warming for dryland crops (temperature elasticity of -1.9) and livestock (-5.4). This clearly shows that livestock are highly vulnerable increasing temperature as compared to crops. On the other hand, increase in precipitation will lead to elasticities of 0.4 for dryland crops and 0.8 for livestock across Africa. Generally, Increases in precipitation will have an unambiguously beneficial effect on African farms on average, whereas decreases in precipitation will have a harmful effect.

Thornton and Herrero (2010) investigated the impacts of increased frequency of drought on livestock herd dynamics. They ran a herd dynamics model to investigate the impacts of increased drought frequencies on herd dynamics and livestock numbers, based on baseline information on mortality, reproduction and herd structures from pastoralist herds in Kajiado, Kenya. Their results indicate that drought every five years keeps the herds stable as it allows sufficient time for the herds to re-establish. A once in 3 year drought interval by contrast drives livestock density to lower levels, as a result of increased mortality and poorer reproductive performance. Hence, greater frequency of drought under climate change might have lasting impact on stocking density, and the productivity of pastoral production systems.

2.3 Review of Literature on Choice of Approach/Methodology

There are two approaches that can be used to estimate the effects of climate change on livestock- the production function approach and the Ricardian approach. The traditional studies have used the production function approach (Rosenzweig & Iglesias, 1994). This approach relies upon empirical or experimental production function to predict environmental damage. The approach has been criticized since it overestimates the damage of climate change on farming because of failing to take into account the infinite variety of substitutions, adaptations and old and new activities that may displace obsolete activities as climate changes (Kabubo-Mariara & Karanja, 2006).

Most studies employ the Ricardian approach in estimating the impact of climate change on agriculture (Mendelsohn *et al*., 1994). The Ricardian approach is based on the original observation by David Ricardo (1772–1823) that land rents reflect the net productivity of farmland and it examines the impact of climate and other variables on land values and farm revenues (Ricardo 1817, 1822). Since 1994, studies on climate change and agriculture that employed the Ricardian model have been undertaken. The model can be used to analyze the cross-sections of farms under different climatic conditions and examines the relationship between the net revenue (Mendelsohn *et al*., 1994; Kabubo-Mariara & Karanja, 2006; Gebreegziabher et al., 2013) and climatic factors (Mendelsohn *et al*., 1994), soils and socio-economic variables. The model has been applied to value the contribution of environmental factors to farm income by regressing farm performance, with net revenue taken as dependent variables, on a set of independent variables, including environmental factors, inputs (land and labor) and support systems (infrastructure). Besides measuring the contribution of each factor, the Ricardian approach is also used to detect the effects of long-term climate change on farm values (Mendelsohn *et al*., 1994; Gebreegziabher, 2013).

The Ricardian model was initially applied in the context of developed countries in general and US agriculture in particular (Mendelsohn *et al*., 1994). It has recently been applied in specific developing countries. Some of these recent studies include Deressa and Hassan (2009), Kurukulasuriya and Mendelsohn (2008), Kabubo-Mariara and Karanja (2006) and Gebreegziabher, 2013). Surprisingly, most of these studies have shown that agriculture in developing economies is very susceptible to climate change. Most of these studies also reveal that the magnitude and direction of the impact may differ from one region to another.

The Ricardian approach has been criticized by different scholars. Some of the criticisms include: First, the approach does not measure transition costs, where a farmer changes from one livestock species to another suddenly, yet transition costs are clearly very important in sectors where there is extensive capital that cannot easily be changed. Second, it generally assumes prices to be constant, which introduces bias in the analysis, overestimating benefits and underestimating damages. Mendelsohn *et al*., (1994) have shown that the Ricardian model is useful for predicting the impact of climate change because the way farmers respond to alternative climate scenarios over space is the same way that farmers will respond in the long run to those same changes in climate over time.

In spite of these criticisms, increased evidence has shown that the bias introduced by the Ricardian assumptions is likely to be small (Kurukulasuriya & Mendelsohn, 2008). This approach has been found to be useful because it corrects the bias in the production function approach (Rosenzweig & Iglesias, 1994). By directly measuring farm prices or revenues, the approach also accounts for the direct effects of climate on the yields of different crops and livestock as well as the indirect substitution of different inputs, the introduction of different livestock types and other potential adaptations to different climates (Mendelsohn *et al*., 1994). It is also attractive because it includes not only the direct effect of climate on productivity but also the adaptation response by farmers to local climate. This study will therefore use the Ricardian approach.

2.4 Synthesis of Literature

Two issues stand out from the literature review drawn from Kenya. First, climate variability is a real threat to agricultural production (both crops and livestock). Thus, there is a real need to come up with policies and interventions geared towards the anticipated effects of climate variability for specific agro-ecological zones. Secondly, previous study has concentrated on the impacts of climate change and variability on agriculture (crops and livestock). There is need to undertake similar studies on livestock only. Studies done in Kenya on the effects of global warming on mixed crop livestock systems excludes North Eastern region; yet, it’s an area with the highest livestock population as per 2009 census. There is need therefore to undertake a study which includes this region.

2.5 Government Interventions on Livestock Sub-sector

The market liberalization initiatives of the mid-1980s affected marketing of livestock products, such as beef, pork and milk. This, partly, contributed to the collapse of Kenya Meat Commission (KMC). With liberalization and collapse of such livestock marketing institutions, marketing was left in the hands of private livestock dealers who were not adequately prepared to undertake the challenges (GoK, 2014). The KMC was then revived in 2005 and since then it has created a Red Sea Livestock Marketing Authority to facilitate increased exports from Kenya, and the rest of the Horn of Africa, to the Arabian Peninsula, or both. One objective of livestock marketing intervention is producer price stabilization in the net exporting regions of Kenya.

The most significant interventions for medium and low potential areas was the establishment in 2008 of the Ministry of State for Development of Northern Kenya and other Arid Lands (MNKOAL) renamed (Directorate of Arid and Semi-Arid Lands) under the Ministry of Devolution and Planning. The Directorate has spearheaded significant policy and institutional reforms to address the development challenges facing the ASALs. With renewed interest in livestock production, The Kenyan government has established National Drought Management Authority (NDMA) which is under the directorate to assist pastoral communities during hard times such as droughts. This has been done by providing support to livestock farmers through food aid, emergency livestock off-takes and re-stocking programmes (GoK, 2014).

Despite the government interventions in the early warning systems and livestock off-take programmes, Climate change and variability has continued to affect livestock more so in the ASALs. There are several different but related challenges. First, the most appropriate time to invest in resilience is when conditions are good; however, substantial finance is generally triggered by crisis rather than by normality. Second, the allocation of budgets, whether from government or its development partners, remains weighted towards emergency response. Third, decision-making on early warning information is slow and cumbersome, such that funds are released too late in the drought cycle to mitigate its impacts. Fourth, the significant resources which government make available are channeled through each sector's normal financing and procurement channels, which are not nimble enough to support timely action (GoK, 2013).

In the past, it is clear that the government of Kenya has focused on short term measures to counter extreme climatic events. There is need therefore to come up with long term interventions such as establishment of disease free zones in the affected areas as well as the development of infrastructure such as abattoirs. This will go a long way in building resilience to climate variability by ensuring disease free livestock thereby ensuring access to local, regional and international markets.

3.0 METHODOLOGY

3.1 Conceptual Framework

The conceptual framework presented in figure 3.1 shows the linkages between the climate variables and the livestock net revenues. The climate variables (temperature and rainfall) affect the livestock net revenue either positively or negatively. Increased temperatures cause scarcity of pasture and water. These results in emaciated animals which fetch lower prices in the market hence lower livestock net revenue. On the other hand, increased rainfall guarantees plenty of water and pastures hence increased livestock production thereby fetching higher revenue while

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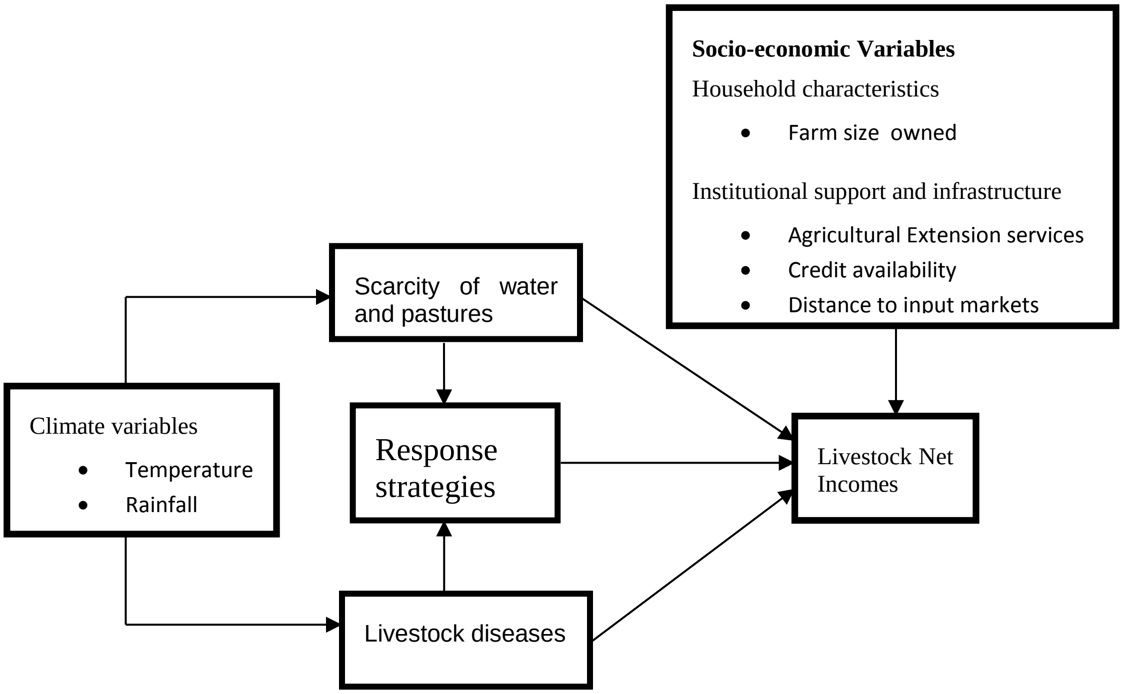
extreme rainfall is disastrous to livestock because of diseases breakouts associated with high rainfall. Due to the effects extreme events (high temperature and rainfall), livestock farmers are forced to respond in order to cushion themselves against these events through migration, herd accumulation, livelihood diversification, feed conservation, intensification of animal diseases among others (Kabubo-Mariara, 2005; Food and Agriculture Organization, 2010; Nkedianye, 2011). Socio-economic variables (household characteristics, institutional support and infrastructure) also play a key role in livestock net revenues. Farm size owned, access to agricultural extension services, credit as well as distance to output markets may trigger higher livestock net revenues. Response strategies such as feed conservation also determine the livestock revenues.

Figure 1: Conceptual Framework



Source: Author's Conceptualization.

3.2 Analytical Framework

To analyze the effect of climate variability on livestock production in Kenya, This study uses a Ricardian analysis. Following Seo and Mendelsohn (2006a), we start by assuming that the farmer maximizes net income by choosing which livestock holding level to keep and which inputs to apply:

$$Max\ \pi = P_{qj}\ Q_j\ (L_G, S, H, K, F, A, Z) – P_F F - P_L L - P_K K \qquad (1)$$

Where:

P is net income

Pqj is the market price of animal j

Qj is a production function for animal j

L_G is grazing land, F is feed

L is a vector of labor inputs

K is a vector of capital inputs

C is a vector of climate variables

W is available water

S is a vector of soil characteristics

P_F is a vector of prices of each type of feeds

P_L is a vector of prices for each type of labor

P_K is the rental price of capital.

The farmer chooses the number of animals that maximizes profit. The resulting net income can be defined as:

$$\pi^* = f(Pq, C, W, S, P_F, P_L, P_K) \quad (2)$$

The Ricardian function is derived from the profit maximizing level of equation (2) and explains how profits change across all the exogenous variables facing a farmer. The change in welfare (ΔU) resulting from climate change from C_0 to C_1 can be measured using the Ricardian function as follows.

$$\Delta U = \pi^*(C_1) - \pi^*(C_0) \quad (3)$$

The Ricardian model treats a farmer as though he is an income generating entity. Seo and Mendelsohn (2006a) have shown that although this assumption fits large farms, it can be applied to small farms by addressing issues of valuation of household labor and own consumption. This Ricardian approach has been found attractive because it corrects the bias in the production function approach (Rosenzweig & Iglesias 1994) by using economic data on the value of land, by directly measuring farm prices or revenues. The Ricardian approach accounts for the direct effects of climate on the yields of different crops and livestock as well as the indirect substitution of different inputs, the introduction of different activities/livestock species and other potential adaptations to different climates (Mendelsohn *et al.*, 1994). It is also attractive because it includes not only the direct effect of climate on productivity but also the adaptation response by farmers to local climate.

In this paper, the net revenue of livestock is estimated. The final model is specified as:

$$\pi = \alpha_0 + \alpha_1 Temp + \alpha_2 Temp^2 + \alpha_3 Rainf + \alpha_4 Rainf^2 + \alpha_5 Livd + \alpha_6 FarmS + \alpha_7 AgriA + \alpha_8 CriditA + \alpha_9 Dmkts + \alpha_{10} FeedC + \alpha_{11} WaterH + \varepsilon \quad (4)$$

Where;

π is livestock net revenue

Temp and $Temp^2$ capture levels and quadratic terms for temperature

Rainf and $Rainf^2$ capture levels and quadratic terms for rainfall

LivD is a vector of livestock diseases

FarmS is the farm size owned

AgriA is the agricultural extension access

CreditA is the access to credit

Dmkts is the distance to markets

FeedC is the feed conservation

WaterH is the water harvesting

α_{0}- α_{5} are coefficients

ε is the disturbance term

The quadratic terms for temperature and rainfall are expected to capture the non-linear shape of the climate response function. When the quadratic term is positive, the net revenue function is U-shaped, but when the quadratic term is negative, the function is hill-shaped. From equation (4), we can derive the expected marginal impact of temperature and rainfall changes on livestock production as in equations (5) and (6) respectively;

$$E\left(\frac{\delta\pi}{\delta T}\right) = \alpha_1 + 2\,\alpha_2\,E\,(Temp) \qquad (5)$$

$$E\left(\frac{\delta\pi}{\delta R}\right) = \alpha_3 + 2\,\alpha_4\,E\,(Rainf) \qquad (6)$$

Cross-sectional data are often faced with the major econometric problems such as outliers, Multicollinearity, heteroskedasticity, and endogeneity of explanatory variables. In light of the fact that these econometric issues is likely affect the robustness of the regression results, the following remedies were undertaken: Outliers were dropped from the model by truncating the top 20 percent and the bottom 20 percent, hettest test was undertaken for Heteroskedasticity and variance inflation factor for Multicollinearity. The model was finally run in a reduced form. This ensures that the X matrix is uncorrelated with the error term hence solved the problem of endogeneity.

3.3 Data Types and Sources

Household data: The dataset used for this study was obtained from a cross-sectional Agricultural Sector Development Support Program (ASDSP) household baseline survey carried out by Kenya Agriculture and Livestock Research Organization (KALRO) in collaboration with University of Nairobi for the implementation of ASDSP during the 2012/13 financial year. The study made use of data from 43 Counties in Kenya. Three cities-Nairobi, Mombasa and Kisumu were excluded due to urbanization. The households from the different counties were categorized into the three agro-ecological zones - low potential, medium potential and high potential. A total of 10,336 observations were considered for analysis.

Climate data: Data on temperature and rainfall was obtained from the Kenya Metrological Department (KMD). This dataset captured average annual temperature and rainfall data from weather stations in all the counties in Kenya. This data was then categorized into the 47 counties to make it compatible with the household data.

3.4 Variables and Method of Analysis

In this paper, the dependent variable is livestock net revenue. The independent variables included the linear and quadratic temperature and rainfall, socio-economic (household characteristics-education of household head and farm size owned, institutional support and infrastructure - access to livestock extension services, credit and electricity). STATA version 13 was used to analyze the impact of climate variability on livestock production in Kenya.

Table 2: Definition of Variables to be used in Empirical Analysis

Symbol	Description of variables	Measurements	Expected sign
FarmS	Farm size owned	Acres	(+/-)
AgriA	Access to agricultural extension access	1=Yes: 0=No	(+)
CreditA	Access to credit	1=Yes: 0=No	(+)
Dmkts	Distance to output markets	Kilometers	(+/-)
LivD	Livestock disease shock	1=Yes: 0=No	(-)
FeedC	Feed conservation	1=Yes: 0=No	(+)
WaterH	Water harvesting	1=Yes: 0=No	(+)
Temp	Average annual temperature	Degrees Celsius	(+/-)
Rainf	Average annual rainfall	Millimeters	(+/-)
$Temp^2$	Temperature squared	Degrees Celsius	(+/-)
$Rainf^2$	Rainfall squared	Millimeters	(+/-)

4.0 RESULTS AND DISCUSSIONS

4.1 Descriptive Statistics of Variables

This section presents the results and discussions from the empirical estimation of the Ricardian analysis.

Table 3: Descriptive Statistics of Selected Variables

Descriptive Statistics	Mean	Std. Deviation
Farm size owned	44.4876	575.4039
Disease shock	0.5575	0.4967
Agricultural extension access	0.2018	0.4016
Credit access	0.0340	0.1959
Distance to input markets	6.0830	9.8566
Distance to output markets	18.5142	21.1711
Feed conservation	0.7010	0.2568
Water harvesting	0.1256	0.3314
Temperature average	21.0504	4.7492
Rainfall average	100.3347	52.7360
Net livestock incomes	75,292.4	794,183.7

Table 1 presents the descriptive statistics of the variables used in the analysis. The results clearly show that the annual livestock net revenue was approximately KShs 75,292. The mean annual temperature and rainfall was 21.05^{0}C and 100.33 MM respectively. Nearly 13 percent of the livestock farmers harvest water, 70 percent conserve feeds, 20 percent had access to agricultural extension services while only 3 percent have access to credit. About 56 percent of the livestock farmers experienced diseases shock. The mean distance to input and output markets was 6.08 and 18.5 kilometers respectively. The mean land size was 44.49 acres.

4.2 Climate Variability in Kenya

From the table 2 below, the low potential areas had a significantly higher average temperature compared to medium and high potential areas. The variability of temperature as measured by the standard deviation was also highest in low potential areas. This implies that the low potential areas are mostly affected by temperatures as compared to high potential areas. On the other hand, high potential areas had a higher average rainfall compared to the medium and low potential areas. Similarly the rainfall variability was also highest in the high potential areas.

Table 4: Climate Variability across the Three Agro-Ecological Zones in Kenya

Climate variables	Category	N	Mean	Std. Deviation	f stat (p-value)
Average temperature	Low Potential	2378	25.7256	4.833182	
	Medium Potential	1690	20.80249	2.74068	
	High Potential	6273	19.04525	2.908059	
	Total	10341	20.86864	4.378316	f=3280.8(p=0.000)
Average rainfall	Low Potential	2378	46.03644	26.85733	
	Medium Potential	1690	71.3079	28.39735	
	High Potential	6273	132.0121	44.89524	
	Total	10341	102.3206	54.22855	f=4830.4(p=0.000)

4.3 Effects of Climate Variability on Livestock Net Revenues

In this paper, the net livestock revenue is a function of two sets of regressors: (i) climate variables (ii) Livestock disease shock (iii) socio-economic variables (household characteristics, institutional support and infrastructure). The empirical equation aims to find out how and to what extend would the three explanatory variables help explain the variability in livestock net revenue. The results showed that climatic variables (temperature and rainfall) have significant effects on net farm revenue in Kenya. In other words livestock net revenue is negatively affected by increases in both temperature and rainfall. The study estimated the impact of climate variability on net value of livestock per farm. Results for linear and quadratic temperature and rainfall, livestock diseases and socio-economic variables were presented as shown in (Table 3).

The analysis in (Table 5) displays three model results. The second column introduces model results with climate variables only, the third column presents livestock disease variables and the forth column introduces the socio-economic variables (household characteristics, institutional support and infrastructure). It is clear that both linear and quadratic terms are significant, implying that climate has a non- linear effect on livestock net revenue. This is consistent with the findings by Gebreegziabher *et al*., (2013). Concerning the linear terms, results showed that high temperature is significant and negatively affects livestock net revenue. This is because high temperature leads to the degradation of the natural resources such as pasture and water. As a result of these, the livestock health and productivity will decline thereby fetching lower prices in the market hence lower livestock net revenue. In addition, higher temperatures will force the livestock farmers to dispose their stocks or risk losing them.

Table 5: Ricardian Regression Estimates for Livestock Net Income model

Variable	Climate only variables model	Climate and disease variables model	All variables model
Temp_av	-0.3824 (-15.10)*	-0.4046(-16.96)*	-0.4765 (-17.13)*
Temp_sq	0.01096 (13.39)*	0.0089 (15.56)*	0.0110 (15.81)*
Rainf_av	-0.0180 (-11.73)*	-0.0169 (-11.66)*	-0.0130 (-6.16)*
Rainf_sq	0.00004 (8.54)*	0.00005 (9.25)*	0.00004 (4.12)*
Liv_dis		-1.0526 (-36.35)*	-0.6043 (-16.07)*
Farm size owned			0.0001 (0.00003)*
Agricultural extension access			0.0305 (0.68)
Credit access			0.1616 (1.91)
Distance to output markets			-0.0228 (-26.08)*
Feed conservation			0.2782 (5.32)*
Water harvesting			0.1250 (1.79)
F	219.99	462.81	141.18
Prob>F	0.0000	0.0000	0.0000
R-Squared	0.0785	0.1829	0.2065
Adj. R-Squared	0.0781	0.1825	0.2051
Root MSE	1.5388	1.449	1.3946
N	10,336	10,335	5,979

*Denotes significance at 95 %.

Similarly, linear rainfall exhibits a negative relationship with net livestock income. The negative effect of the linear term implies that increasing rainfall would result to damage in the stocking levels of the livestock. This is consistent with findings by Seo and Mendelsohn (2006b) which show that livestock production in Africa is quite sensitive to changes in rainfall. The justification for this are in threefold; first, with increasing rainfall, it is most likely that livestock farmers are likely to switch from livestock to crops due to the conducive environment for crop production. This is consistent with the findings by Kabubo-Mariara (2008). Second, high rainfall leading to floods is associated with livestock diseases such as Rift Valley Fever which significantly reduce the levels of livestock and consequently the net revenues. Third, heavy rains cause livestock losses as animals drown. This is has been realized in Kenya in the recent past where excessively heavy rains sweep away livestock.

The quadratic terms of temperatures and rainfall are significant in all the three models. This is consistent with the hypothesis that the relationship between climate and net livestock revenue is non-linear (Seo & Mendelsohn, 1994). Both the temperature and the rainfall show a downward trend. This implies that the increasing temperature and rainfall will not auger well for livestock farming in Kenya, confirming that climate variability have devastating effects on livestock unless livestock farmers practice adaptation strategies to counter the effects of increasing temperatures and rainfall. At 5 % level of significance, the R-squared of climate variables model is 7.9%. This shows that the model explains only 7.9% of the total variation in livestock net revenue.

In the second model, livestock diseases were introduced and it turned out negative and significant. Livestock diseases were inversely correlated with livestock revenue which implies that these diseases had a negative effect on livestock revenue. The R-squared increased by more 100% from 7.9% to 18.3%. The occurrences of livestock diseases lower the quality of meat, hides, skin and other animal products thereby fetching low prices in the market. Furthermore, livestock diseases hinder the capacity of Kenya to export beef and other livestock products to markets in Middle East and Europe.

Finally, the socio-economic variables were introduced. The R-squared increased from 18.3% to 20.7%. Among the variables, farm size owned by the households and feed conservation was positively correlated with livestock revenue. The farm size owned by households was however positive and significantly increased the net livestock revenues. This implies that the larger the size of land, the higher the number of animals which can be reared hence higher livestock net revenue. Similarly, large tracts of land ensure adequate pasture for livestock. Feed conservation turned out positive and significant supporting the fact that increased adaptation strategies such as feed conservation is associated with increased livestock productivity and revenue. Distance to output markets turned out negative and significant showing that it was inversely correlated with livestock revenue. Perhaps because livestock keepers incur more transaction cost in terms of money as they transport livestock from their farms to the output markets.

There was no significant effect of access to agricultural extension, access to credit facilities and water harvesting on livestock net revenue but the signs of the coefficients implies that the three variables are associated with higher livestock net revenues.

4.4 Marginal Effects of Climate Variables on Livestock Net Revenues

The Ricardian model results for the marginal effects of climate variables on livestock net revenues are presented in (Table 6). The results showed that increase in temperature would be harmful to livestock activities in the country. Increase in temperature by 1 percent would decrease the livestock net farm revenue by about 38.2 percent. Similarly, an increase in rainfall is destructive to livestock production. Increase in rainfall by 1 percent would reduce the livestock net farm revenue by about 1.8 percent. The quadratic terms of temperature and rainfall are positive which implies that the livestock net revenue function is U-shaped. From Table 6, it is clear that the effect of temperature is more than the effect of rainfall.

Table 4.4: Marginal Effects of Climate Variables

Climate Variables	Coefficients	t-statistic
Temperature	-0.3824	-15.10
Rainfall	-0.01801	-11.73
P=0.05		

The optimal values of rainfall and temperature can be obtained from the first order condition of model 1 and model 2

5.0 Conclusions and Policy Recommendations

5.1 Conclusion

This study assessed the economic effects of climate variability on livestock production in Kenya using the Ricardian model. The annual livestock revenue was first regressed on climate variables only, and then followed by livestock diseases and socio-economic variables (household characteristics, institutional support and infrastructure).

The conclusion that can be drawn from the findings of the study is that, first, low potential areas had a significantly higher average temperature compared to medium and high potential areas. The variability of temperature was also highest in low potential areas. On the other hand, high potential areas had a higher average rainfall compared to the medium and low potential areas. Since temperature has greater effect than rainfall, it is therefore expected that the low potential areas will be greatly hit by the increasing temperatures as compared to high potential areas.

Secondly, the results clearly showed that climate affects livestock net revenue. Increased temperatures and rainfall led to decline in livestock revenue. The results further depicted that there is a non-linear relationship between temperature and livestock net revenue on one hand and between rainfall and livestock net revenue on the other hand. This finding is consistent with studies on the effects of global warming on agriculture (Mendelsohn et al., 1994; Kurukulasuriya & Mendelsohn 2006). High temperature reduces grassland productivity, leading to decline in animal health and productivity thereby fetching lower prices in the market hence lowers the revenue. Higher temperatures will also force the livestock keepers to sell their stocks or risk losing them. As far as increasing rainfall is concerned, livestock farmers may switch from livestock to crops due to the conducive environment for crop production. High rainfall also causes floods and livestock diseases such as Rift Valley Fever which significantly reduce the levels of animals and consequently the livestock revenues. Furthermore, the results showed that farm size owned and feed conservation are positively correlated with livestock revenue, while livestock diseases and distance to output markets are inversely correlated with livestock revenue.

Third, the marginal effects of climate variables showed that increase in temperature would be disastrous to livestock activities. An increase in temperature by 1 percent would decrease the livestock net farm revenue by about 38.2 percent. Equally, an increase in rainfall is destructive to livestock production. An increase in rainfall by 1 percent would reduce the livestock net revenue by about 1.8 percent. This clearly shows that the temperature component may have serious repercussions on livestock than rainfall.

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5.2 Policy Recommendation

The study showed that climate variability significantly affects livestock revenue. Efforts should therefore be put in place so as to reduce these effects. If this is done, then it is more likely that livestock farmers will realize higher revenue. In the past, The Kenyan government have focused on short term emergency responses such as livestock-off take, restocking and feed provision to mitigate the effects of climate variability which have yielded less outcome. To enhance their resilience to climate variability both the nation and county governments should put more emphasis on the long term interventions.

First, since the low and medium potential areas have large number of animals and are badly affected by livestock diseases, the national government in collaboration with the county governments should establish these areas disease free zones by strengthening disease surveillance, monitoring and control as well as providing rapid response to disease outbreaks. This will ensure quality beef, hides and skins hence ensure adherence to international sanitary requirements on trade in animals and animal products thereby maintain markets that has been gained especially in Middle East and Europe.

Secondly, the government through the KMC should facilitating livestock marketing so as to increase household incomes and contribute to poverty reduction. KMC should construct livestock marketing infrastructure such as abattoirs in the low and medium potential areas so as to lower transport cost by farmers and also reduce the spread of diseases.

Third, the county government should play a lead role in encouraging strategic activities to reduce the effects of climate variability. The county government needs to invest resources in equipping farmers so as to cushion them against further adverse climatic conditions. For instance feed conservation should be introduced to livestock farmers and adoption encouraged, more so in the low and medium potential areas. Furthermore, there is need to increase strategic feed storage facilities to facilitate enough animal feedstuffs during periods of pasture scarcity. This will in turn increase livestock production and revenue and at the same time reduce migration in search of the same.

Fourth, the national government in collaboration with the county government should strengthen the early warning systems for the outbreaks of livestock diseases and provide accurate disease early warning information to all actors and provide triggers for response. Fifth, emergency responses should not be neglected. The county governments should create their own financing mechanisms including disaster funds such as County livestock enterprise fund to build the capacity of the livestock farmers to manage climate variability episodes more efficiently and thus facilitate early response.

Sixth, animal improvement programmes have in the past concentrated on ‘up-grading’ of indigenous animals towards the exotic breeds. This has resulted in suppression of the indigenous genetic material giving rise to the ‘up-graded’ animals that are not as equally adapted to the local environment as the indigenous animals. This has led to lower livestock productivity and income. The Kenyan government should therefore promote the livestock species that are heat tolerant.

5.3 Areas for Further Research

This study analyzed the economic impacts of climate variability on livestock production using the Ricardian approach but did not explore any welfare effects on the same. Future research

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should therefore focus on the effect of climate variability on the welfare of livestock farm households in Kenya.

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