Climate factors as determinants of food security in semi-arid Kenya: a longitudinal analysis

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Abstract

Food security in the arid and semi-arid areas (ASALs) of Kenya is linked to climate and socio-economic factors. This study was conducted in two ASAL counties of Kenya, Kajiado and Makueni, inhabited by pastoral communities. Both primary and secondary data were collected on climate and socio-economic aspects from published and unpublished documents. Time series data covering a 31 year period were collected on rainfall amounts, rain days, temperature, beef and maize prices, stocking, livestock sales and land under cultivation to generate descriptive statistics and regression results based on the OLS, GLS and AR models. Livestock contributed 78.2% and 38.3% of total income in Kajiado and Makueni Counties respectively. Crops contributed more to the total income in Makueni County at 52.7% compared to Kajiado County at 6.9%. Of the three models tested, the GLS was found to be the most appropriate based on the number of significant variables and the estimated R^2 value. The model showed that rainfall, temperature, rain days, and beef and maize prices influence income in Kajiado and Makueni Counties. Therefore, creation of micro-climates through agroforestry moderates temperatures, attracts rainfall, sequesters carbon and provides services such as food, timber, raw materials and employment. Moreover, initiatives that regulate beef and maize prices ensure predictable markets and income in both counties.

1. Introduction

Agriculture is critical for pro-poor economic growth in Africa, including Kenya given its role in over 80% of rural households' income. In Kenya, the sector is composed of crops, livestock and fisheries which contribute about 26% of the national GDP, accounts for 65% of national exports, provides 18% of formal employment and over 70% of informal employment in the rural areas (ROK, 2010). Livestock accounts for 50% of the country's agricultural GDP, provides 90% of employment and more than 95% of household income in the ASALs (Nyariki, 2008). Therefore, improvements in agricultural performance targeting rural people have great potential to increase household income, purchasing power and consequently reducing poverty (NEPAD, 2002; Wiggins, 2006). Despite the role agriculture plays in the country's economic growth, it only receives 10% of the government's agricultural expenditure and less than 1% of total national spending (Nyariki *et al.*, 2005). Quite often, this sector receives limited attention given its vulnerability to impacts of climate variability and change, and as a result, the government prioritises other sectors which give consistently high returns rather than agriculture where productivity in uncertain (ROK, 2012). Therefore, Kenya's long-term goal of food self-sufficiency remains unmet. Frequent droughts precipitate requests for donor-provided food aid to mitigate the ravages of famine, especially in the ASALs, inhabited largely by pastoral tribes. With a population annual growth rate of 3%, and

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more than 43 million people, 10% are classified as food insecure. Moreover, Kenya imported about USD 725 million in agricultural products during 2009, up from about USD 525 million in 2007 in order to mitigate food crisis (USDA, 2009), thus it was the largest import market for food and agricultural products in East Africa.

Food security is a human right, climate variability and change have pushed some medium rainfall areas to rainfall deficient zones, making them food deficit regions. Besides, the food price crisis of 2008 has led to the re-emergence of debates about global food security and its impact on prospects to end poverty and hunger (Jaspars and Wiggins, 2009). Besides, a number of shorter-term triggers leading to volatile food prices, the longer-term negative impacts of climate variability and change need to be resolved (Ludi, 2009). In the last decade, the government of Kenya has been declaring a state of food emergency almost on yearly basis. In January 9, 2009, about 10 million Kenyans, comprising 25% of the population were at risk of food shortage (USDA, 2009). The non-govermental and government instititions singly or as a group have devised innovative mechanisms to enhance food production, access, availability and affordability through programmes, projects, policies, capacity strengthening and financing. Despite all these efforts, over 70% of ASALs communities in Kenya still live below the poverty line and are therefore prone to food insecurity and are dependant on external food aid (Amwata *et al.*, 2015).

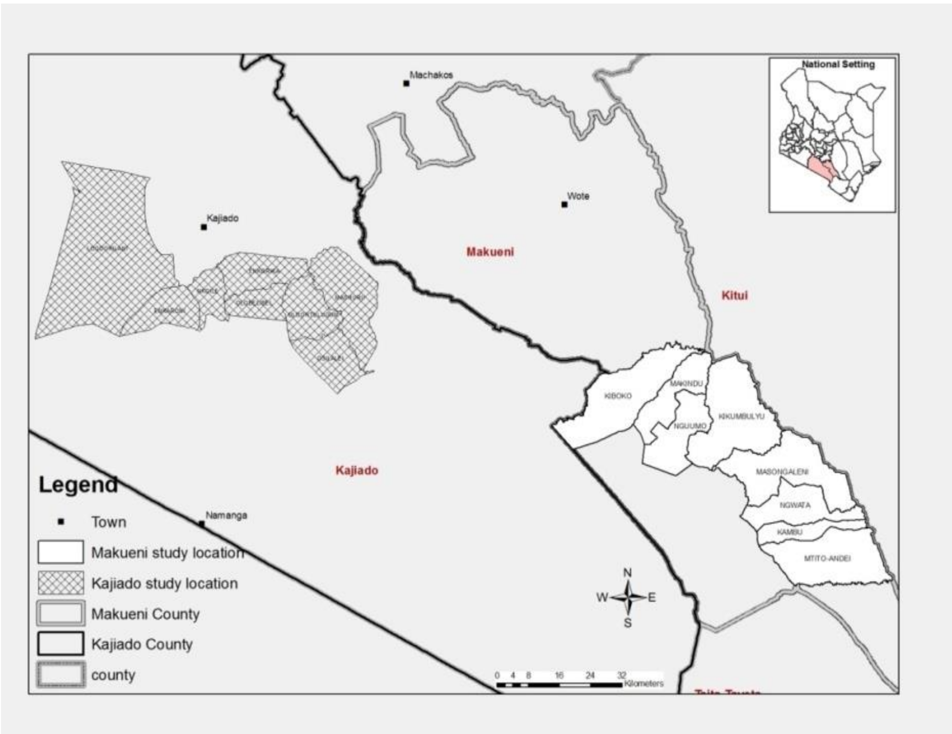
The problem of food security at the micro level is formulated in different ways. Maxwell (1990) and Robinson (1994) reports food security as a proxy for poverty. In these studies, the use of food security approach imparts a biased understanding of poverty and neglects emphasis on asset holding or dependency while emphasising consumption-oriented interventions. As a result of this shortcoming, the current study adopts the use of poverty approach with income per adult equivalent as a measure of food security. Further, vulnerability could not be measured in real terms; hence food security was used as a proxy. The argument holds for the vulnerable households where access to food is the first and foremost priority, whether from their own production or from purchase (Maxwell, 1990; Kristjanson *et al.*, 2002; Nyariki *et al.*, 2002; Ludi, 2009; Tasokwa *et al*., 2011).

2. Study Area and Data Collection

The study area comprises of two sites in the ASALs of Kenya namely Makueni and Kajiado Counties (Figure 1). Both counties are characterised by unpredictable rainfall patterns, dry spells and frequent droughts. Kajiado County covers about 21,909.9 km^2 and has a human population of 687,312 people (ROK, 2009). It lies between longitudes 36º 5’ and 37º 5’ east and 1º 0’ and 3º 0’ south. Most of Kajiado County lies in semi-arid and arid zones V and VI characterized as livestock production zones with only 8% of having potential for rain-fed cropping (zone IV). Makueni County covers an area of 7,965.8 km^2 and lies between latitude 1°35′S and longitude 37°10′ and 38°30′E . The county has a population of 884,527 (de Leeuw *et al.,* 1984; ROK, 2009 ; 1994) with an annual growth rate of 2.8%. In both counties, the population is composed of small-holder subsistence farmers and/or livestock keepers who wholly depend on rainfall for their livelihood. This gives a wide range of agro-ecological zones, from the hills where coffee may be grown, to the lower plateau perhaps best suited for grazing livestock but where crops may be planted at the risk of frequent harvest failures.

The rainfall regime in both counties is bimodal, with ‘long’ rains falling in March to May and ‘short rains’ in October to December, giving two cropping seasons with the short rains being the more reliable in time and the most important for crop production. However, the average annual rainfall varies across the counties, 300 to 800 mm in Kajiado and 500 to 1300 mm in Makueni respectively (Amwata, *et al.*, 2015; Gichuki, 2000; Musimba *et al.*, 2004). The counties temperatures range between 12ºC and 32ºC. The main food crops for both counties include maize, beans, and pigeon peas, millet and sorghum.

Figure 1: Location of study sites in Kajiado and Makueni Counties



Climate has spatial characteristics and is highly variable, and thus requires site specific data, such as rainfall amounts and distribution, rain days and temperature, for proper understanding of its influence. Further, climate interacts with socio-economic factors to influence livelihoods. As a result, time series data were collected from various publications, Ministry of Agriculture, Ministry of Livestock and Fisheries, National Statistics Office, Department of Meteorology, Food and Agriculture Organisation Statistical Database (FAOSTAT), and relevant technical reports. Data for a period of 31 years, from 1980-2010, were collected on socio-economic aspects on livestock numbers, maize and livestock sale prices, remittances, wages, annual maize production, area under maize, human population, stocking rate and livestock offtake. The variables relating to livestock production were obtained by using comparative data based on animal units (Nyariki, 2008). Similarly, climate parameters such as annual rainfall amounts, number of rain days and temperature were computed for the same period using the daily and monthly records.

3. Model Formulation

3.1 Variables

In model formulation, 12 variables that were hypothesised to influence the counties' vulnerability to food insecurity were selected *a priori.* A preliminary correlation analysis was carried out and an appropriate choice was made between those variables that were found to be highly correlated. The variables used in the final regression include total income per adult equivalent, livestock offtake per hectare, per cent livestock offtake, maize prices, beef prices, human population, land area under maize production, annual rainfall, rain days, temperature, stocking rate and drought. These variables are discussed below.

a) *Total income per adult equivalent* is the dependent variable and refers to the net flows from household assets; land, labour, livestock, entrepreneurship and relationships, non-marketed food production and remittances (Walker and Ryan, 1990; Kimuyu *et al.,* 2012) divided by the county population in adult equivalents (Nyariki *et al.,* 2002; Tasokwa, 2011; Amwata *et al.,* 2015).
b) *Rainfall amounts* influence agricultural production and food security (Amwata, 2013; Tasokwa, 2011). More rainfall leads to more grazing resources, increased maize production, and consequently higher household income and the ability to purchase more food and reduce vulnerability to food insecurity.
c) *Number of rain days* is critical for rain-fed agriculture. More rain days means more maize production, better pastures and increased income.
d) The intensity of *temperature* regulates water balance and evapo-transpiration; thus very high or low temperatures are likely to have a negative influence on income.
e) *Drought* influences income and food security. For the study area, years with less than 300 mm of rainfall were considered drought years and those with above 300mm were considered normal years (Nyariki, 2008). These swings of dry and wet years necessitated the use of a shift dummy to take care of the dramatic changes in total income per adult equivalent, thus:

$$D_{0t} = \begin{cases} 0, \text{if observed t is a drought} \\ 1, \text{ if otherwise} \end{cases}$$

$$D_{1t} = \begin{cases} 0, \text{if observed t is a drought} \\ 1, \text{if otherwise} \end{cases}$$

Where D is the dummy and t is the year of observation.

f) Maize is a staple crop and contributes about 50% of daily caloric intake for most households (USDA, 2009) in both counties. Thus more *maize production* leads to higher household income. Further, maize had consistent data on production per hectare, total production, sales and consumption from 1980-2010.

g) *Ratio of area under maize to total cultivated area* influences household income. The greater the ratio, the more the maize production and subsequently the more the county income.
h) *Livestock offtake* refers to the proportion of the current year's herd that is removed through sales, deaths, gifts, home-slaughter, or even theft (Nyariki and Munei, 1993; Nyariki *et al.,* 2005; Grandin and Bekure, 1982; Sullivan *et al.,* 1982).
i) *Beef price* influences income. When prices are high, more is likely to be produced for sale, thereby increasing income (Nyariki, 2008).
j) *Maize price* is defined as the price a consumer is willing to pay per unit of maize. Higher maize prices would stimulate maize production, leading to increased income.
k) *Stocking rate* refers to the number of livestock units grazed per unit area of land over time. Correct stocking rate ensures correct intensity of utilization of available forage and water. Animal numbers above optimum stocking rate would adversely affect the performance of other animals, causing a drop in output (Nyariki, 2008; Veysset *et al.,* 2008).
l) *Human population* influences agricultural production and household income (Jabbar *et al.,* 2007). Higher human population implies more labour available to produce more crops and livestock products, in turn increasing income.

3.2 Model Selection

Three models were tested, namely ordinary Least Squares (OLS), Generalised Least Squares (GLS) and Autoregressive models, to determine the one that fitted the data best. The three models give unbiased and consistent parameter estimates, and the main criterion for discrimination would, therefore, be that of efficiency (Nyariki *et al.,* 2002; Davidson and Mackinnon, 1993; Pindyck and Rubinfeld, 1998; Wooldridge, 2003). OLS is based on the assumption that the independent variables and the dependent variable have a uni-directional relationship and that the errors would be uncorrelated. However, this assumption can easily be violated for time series data.

In the AR model, the dependent variable is lagged and used as an explanatory variable. For example, an output of a product today may affect its future output, and the current value of the output depends on the previous value. Therefore, there is likely to be autocorrelation of the error term due to the use of lagged dependent variable as an explanatory variable.

The GLS model is based on a time-series auto-correlation technique and it uses the Cochrane-Orcutt procedure, which considers the fact that the error-term may be correlated over time and cross-section units (Thomas, 1993; Baltagi, 2001). For exposition of the Cochrane-Orcutt procedure, consider a simple model:

$$Q_{it} = \alpha + \beta P_{it} + \mu_{it} \;;\quad \mu_{it} = \rho_i \mu_{i,t-1} + \nu_{it}$$

Where

$$\nu_{it} \sim N(0, \delta^2_{\nu});\quad E(\mu^2_{it}) = \delta^2;\quad E(\mu_{it}\mu_{jt}) = 0;\quad E(\mu_{i,t-1}\nu_{jt}) = 0 \quad i \neq j$$

Each error structure is fixed to involve first-order serial correlation but ρ is allowed to vary from individual to individual unit. So the model is first-order autoregressive AR(1) in structure. With this model, efficient parameter estimates can be obtained by using a form of GLS process (Gujarati, 1995). The Cochrane-Orcutt coefficients, ρ_i, are estimated from ρ_{i*} and are then used as a basis for the GLS regression.

To formulate an appropriate GLS model for estimation, the unit root test of stationarity of the variables was carried out. To illustrate with the deflated prices, the following equation was used:

$$\Delta P_t = \alpha_1 + \delta P_{t-1} + \mu_t$$

where ΔP_t is the first-difference of the panel of prices, and the null hypothesis is set at $\delta = 0$. If there was a unit root problem in the data, δ would be equal to zero. The results were as follows:

a) The Kajiado County total annual rainfall (P_t):
   $\Delta P_t = \alpha_1 + \delta P_{t-1} + \mu_t$
   $\Delta P_{t-1} = 5.801 - 0.0837 P_{t-1}$
   t = (0.837) (-7.942)
   $r^2 = 0.700$; $d = 2.139$

b) The Makueni County total annual rainfall (P_t):
   $\Delta P_t = 5.801 - 0.0837 P_{t-1}$ `
   t = (0.689) (-5.026)
   $r^2 = 0.689$; $d = 1.944$

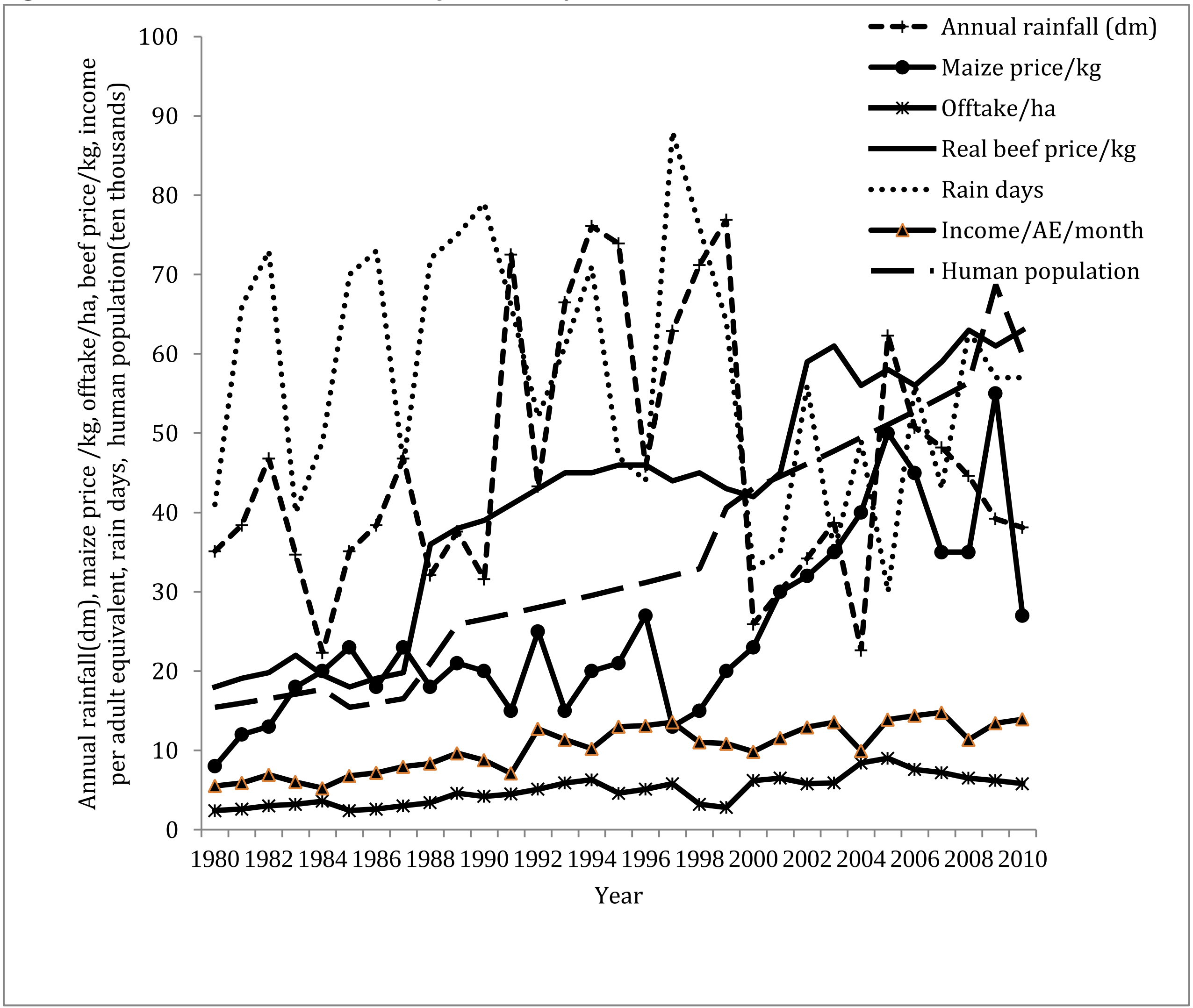
Since the error term is not autocorrelated—based on the Durbin-Watson (*d*) test—the stationarity of deflated prices can be proved by the Dickey-Fuller (DF) test. As can be seen from the estimated equation, at a significance level of 5%, the data did not exhibit random walk.

4. Results and Discussion

4.1 Descriptive Analysis

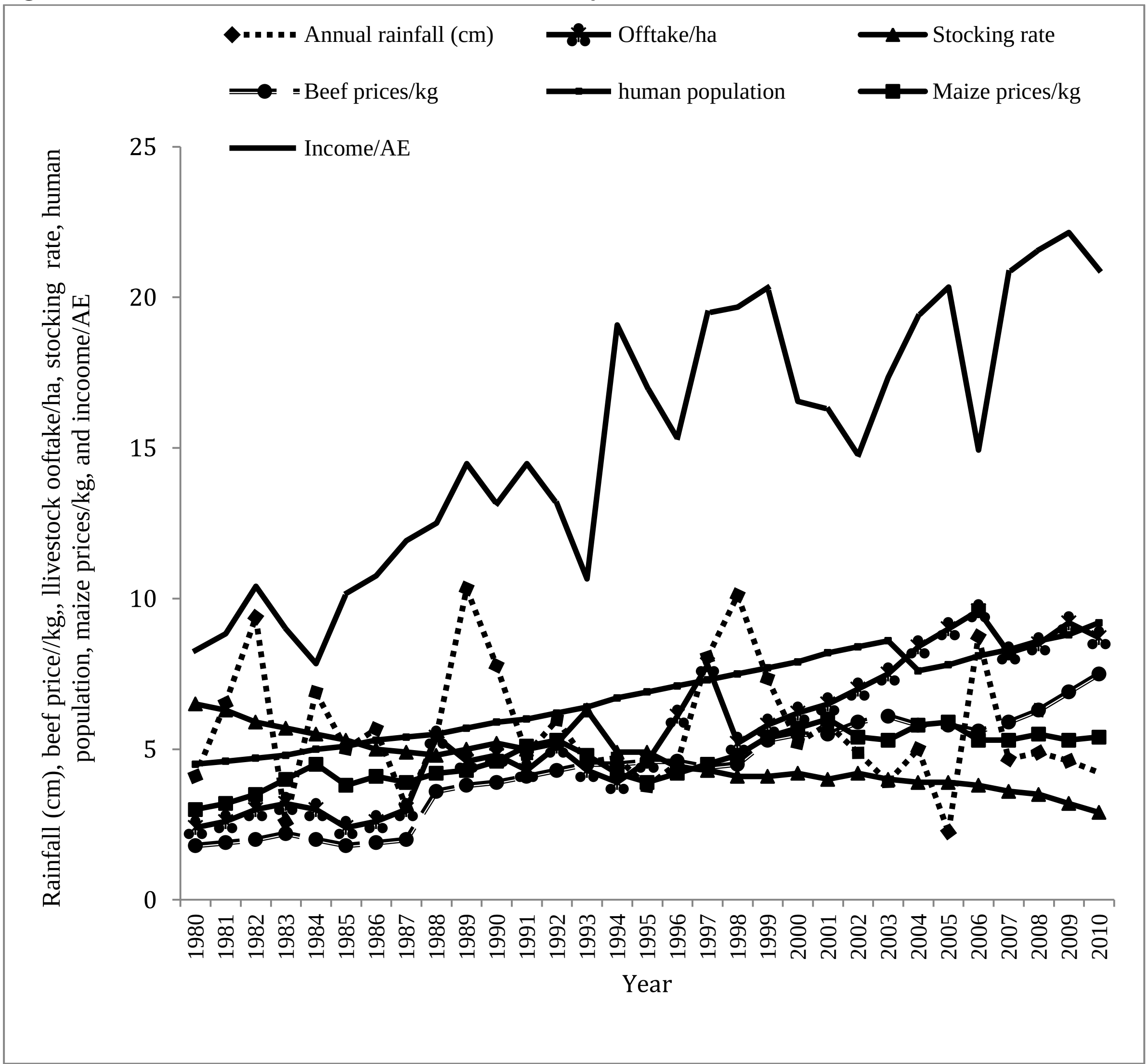
The trends of the variables used in the time series analysis for Kajiado and Makueni are presented in Figures 2 and 3. The data indicate that livestock offtake increased slowly but with some spikes and dips from 1980 to 2009 for Kajiado and Makueni Counties. The lowest livestock offtake and stocking rate reported in mid 1980s were linked to the droughts of 1983/84. The situation is repeated immediately after 1991/1992 and 1995/96, which were also periods of drought. A similar scenario is seen after 1997/1998, a year of *El Niño* rain that resulted in flooding, leading to loss of pasture and diseases such as pneumonia and foot rot, in turn causing losses in livestock and reduced incomes.

Figure 2: Trends in various factors in Kajiado County, 1980-2010



Source of Data: KIPPRA (2010); Kajiado Meteorological Station, Kajiado District Development Plans (1994-1998; 1998-2002; 2002-2008; 2008-2012); Kajiado District Ministry of Agriculture and Livestock Annual Reports, 1990-2010).

Figure 3: Trends in various factors in Makueni County, 1980-2010



Source of Data: KIPPRA (2010); DWA, KEFRI, Makindu Meteorological Stations, Makueni District Development Plans (1994-1998; 1998-2002; 2002-2008; 2008-2012); Makueni District Ministry of Agriculture and Livestock Annual Reports, 1993-2010).

Annual rainfall had a relationship with livestock offtake. From early 1980s to early 1990s, these two exhibited a similar trend. However, from mid 1990s to 2005, they depicted divergent trends, after which they continued to show a somewhat similar trend. The explanation could be that in the 1980s to 1990s, rainfall patterns were more predictable and households in Kajiado County were able to adequately plan their pastoral activities. Conversely, from 1990 to 2004, rainfall became more erratic and unpredictable (Figure 2). Thus, with low rainfall, pasture and water were less available, leading to an increase in livestock offtake; the pastoral households of Kajiado County, the Maasai, tend to dispose of their animals just as the animals lose their body condition or die due to lack of pasture and water.

Total income showed no clear relationship with human population. In the early 1980s to 1990s, human population showed some growth, but at a slow pace. However, there was a decline in human population in 1985/1986. Similarly, total income has continued to show upward and downward swings. This implies that there are factors other than human population interacting to influence total income.

Beef price has generally shown an upward trend since the 1980s. The lowest real beef prices were reported in 1984/1985, 1999/2000 and 2004/2005. These years coincide with the drought periods, as reported by Orindi *et al.* (2006). The probable reason could be that when rainfall is adequate, most pastoralists tend to hold on to their livestock and release few animals to the market. Conversely, many pastoralists sell off their livestock to minimise the devastating effects during drought. This makes beef prices to drop leading to reduced income.

Maize price has been highly variable. From the early 1980s to 1989, maize price was fairly stable but variability has increased since then. The highest maize prices were reported in 1985, 1987, 1992, 1997, 2005 and 2009. These periods correspond to just before drought or just after drought. For instance, the 1983/1984 drought affected agricultural production in 1985; thus maize prices shot up due to reduced maize production. The likely explanation is that climate parameters such as rainfall have a lagged effect and may not affect agricultural production in the same season, but in future seasons.

Figure 3 shows rainfall as one of the factors closely associated with total income. The two variables moved together during the period of study. Total income continued to increase but with down swings in 1984, 1994, 1997/1998, 2001 and 2007. These downswings in total income correspond to periods of weather extreme events such as droughts (1984, 1994 and 2001) and flooding (1997/1998). However, the decline in income noted in 2007 may have been caused by post election violence that saw many people lose their property and assets, thus reducing income levels.

Stocking rate has been declining irrespective of the rainfall levels. This implies that there are factors other than rainfall influencing the variable. Some of these factors may include size of land holdings, government policies and legislation. On the other hand, human population has shown an upward trend, though a decline was noted in 2004.

Beef and maize prices have also shown some degree of trending with rainfall in the opposite direction. When rainfall levels are low, maize and beef prices are high. This can be explained by the fact that during periods of low rainfall, drought limits moisture availability to crops, which leads to reduced output and total income. For beef, at the onset of drought, prices will be low, since most households will be offering their livestock for sale. However, as the intensity of drought increases, fewer animals are offered for sale, resulting in high beef prices. In addition, the plots of trend showed variability (zigzag shapes) in annual rainfall, stocking rate, and maize and beef prices (Figures 2 and 3). The trends in annual rainfall and maize prices support results from the USA, which showed that high variance in climatic conditions results in greater variability in crop yields and prices (McCarl *et al.*, 2008; Tasokwa, 2011).

Similarly, high livestock offtake per ha was noted in periods of droughts (1983/84, 1987, 1992/93 and 2009), and floods (1997/98). This implies that during extreme weather events, households tend to dispose of their animals, and hold on to a few that could be sustained during the period. Also, in the early 1980s, livestock offtake continued to increase with real beef prices and maize prices irrespective of the rains, indicating that prices and other socio-economic factors rather than climate triggered this increase. Likewise, there have been down-swings in livestock offtake, though the general trend has been upward. Figure 2 shows that offtake trend closely follows real beef prices, stocking rate is not influenced by rainfall levels and prices, and land being allocated to stock units is declining compared to 1980s. Further, the year 1994 had the lowest stocking rate, the likely reason being that the 1991/1993 drought may have resulted in the death of livestock, thus leading to fewer stock units per hectare in the subsequent year.

There was a marked increase in stock per unit land area and offtake between 1990 and 2010. In this period real beef prices rose steadily. The rise in real beef prices and the accompanying improvement in both stocking rate and offtake occurred after the liberation of the beef markets in the late 1980s when producer and consumer prices were decontrolled, and at the beginning of the 1990s when a total waiver of controls in the beef and dairy industry in the country took place (ROK, 1996; Nyariki, 2008).

The contribution of different economic activities to the total income per adult equivalent is presented in Table 2. In Kajiado County, livestock was the greatest contributor (78.2 per cent) to the total income per adult equivalent with remittance being the least; while for Makueni County, the greatest proportion was from crop production followed by livestock, and the least being remittances.

Table 2: Contribution of different economic activities to total income per adult equivalent in Kajiado and Makueni Counties*

Economic activity	Kajiado (Kshs)	Makueni (Kshs)
Farm-based		
Livestock	810 (78.2)	581.0 (38.2)
Crops	71.4 (6.9)	802 (52.7)
Non-farm based		
Employment	117(11.3)	12 (8.2)
Remittances	37.3 (3.6)	14 (0.9)
Total	1,035 (100.0)	1,521 (100.0)

*Figures in brackets are percentages

Remittances were considerably higher in Kajiado County than Makueni County. The likely explanation is that most households in Kajiado County are livestock keepers, and due to increased frequency of drought, livestock are lost in masses; thus young household members have to search for jobs to support their households. In support, Amwata (2004) reported high remittances in transhumant households than in agropastoral households of Kajiado County.

4.2 Regression Results

The descriptive analysis of variables used in regression analysis are summarised in Table 1. The climate factors represented in the models include mean annual rainfall, rain days and mean annual temperature. The total income per adult equivalent was higher for Makueni County (Kshs 1,521), which is predominantly agropastoral, and lower for Kajiado County (Kshs 1,034 per adult equivalent), a typical pastoral setting. Comparing these values to the recommended rural poverty line of Kshs 1,239 per adult equivalent (Kristjanson *et al.*, 2002), Makueni County households were likely to be less vulnerable to food insecurity than their counterparts in Kajiado County. The likely explanation is that Makueni County is a predominantly mixed farming area, growing both crops and livestock, which act as insurance for either. For instance, when prices of cereals are expected to increase due to drought, farmers in Makueni County may hold on to their cereals and use it for consumption rather than sell. Conversely, for Kajiado County, when there is drought, pastures become limited and livestock are often sold at through away price. At this time, cereal prices become very high. This reduces the purchasing power of households thereby increasing their vulnerability to food insecurity.

Table 1: Summary of variables in the regression analysis

Variable	Kajiado				Makueni		
	Unit definition	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Dependent Variable							
Total income per adult equivalent	Kenya shillings	1,034.0	523.0	1,477.0	1,521.0	785.0	2,216.0
Explanatory Variables							
Total annual rainfall	Decimetre (dm)	45.9	22.3	76.9	56.5	22.6	103.4
Rain days	Days	57.0	30.0	88.0	62.00	30.0	88.0
Mean temperatures	Degrees Celsius	28.1	18.0	38.0	25.1	20.0	32.0
Area under maize	Hectares	28,987.8	9,300.0	44,800	78,794.7	45,000.0	147,350.0
Maize producer price	Kenya shillings/kg	24.9	8.0	55.0	4.7	3.0	6.0
Maize production	Metric tonnes	43,219.7	1,946.0	64,890.0	55778.6	11,251.0	96401.0
Real beef prices	Kenya shillings/kg	4.3	1.8	7.5	4.3	1.8	7.5
Stocking rate	Tropical livestock unit	-	-	-	4.7	2.9	6.5
Labour	Human population	326,399.3	40,500.0	59,8365.0	677,110.8	446.430.0	919,024
Livestock offtake/ha	Tropical livestock unit	6.2	3.2	12.7	5.6	2.4	9.6
Livestock offtake	Per cent	5.6	2.4	9.6	18.526	4.1	31.3

Source of Data: Ministry of Agriculture; County Annual Reports; National Statistical Office; National Meteorology Departments; FAOSTAT (2010); KIPPRA (2010).

OLS and AR model results (Table 2) show R^2 values above 93.5%, too high to be explained by the few significant explanatory variables, suggesting the presence of serial correlation. OLS showed that out of the ten explanatory variables tested in each county, only two variables (mean annual temperature and per cent livestock offtake) and three variables (beef prices, livestock offtake per ha and stocking rate) were significant at $p \leq 0.05$ for Kajiado and Makueni Counties respectively. Further, Durbin Watson (*d*) values were 1.524 and 1.475 for Kajiado and Makueni Counties respectively, values less than 2, thus confirming the problem of positive serial correlation (Gujarati, 2003). The GLS results, on the other hand, show that four variables (lagged annual rainfall, maize price, mean annual temperature and livestock offtake), and four variables (lagged annual rainfall, beef price, livestock offtake, and stocking rate) were significant at $P \leq 0.05$ in Kajiado and Makueni Counties respectively. Therefore, this leaves the GLS model as the most appropriate.

Table 2: Regression result

Variables	**GLS Model**		**AR Model**		**OLS model**	
	Kajiado	**Makueni**	**Kajiado**	**Makueni**	**Kajiado**	**Makueni**
Constant	0.33	0.88	-1.42	-2.47	-1.68	-2.96
Human population	-0.93	-0.79	-0.96	-	0.95	-
Drought (Yes or No)	1.35	-1.71	-1.75*	-0.70	-1.3	-0.75
Lagged total annual rainfall	3.56**	-1.97**	0.97	-0.61	0.91	-0.45
Rain days/per year			0.71	1.36	0.35	1.55
Maize price per kg	3.10**	1.43	2.31**	1.25	1.89*	1.21
Beef prices per kg	0.83	2.20**	1.01	1.99**	-0.58	2.55**
Mean annual temperature	-3.70**	-	-1.65	-0.30	-2.01**	- 0.08
Area under maize cultivation	-	-	-	0.46	1.24	0.59
Maize production(metric tonnes)	1.73	-	1.82*	-0.65	0.52	-0.68
Per cent livestock offtake	4.71**	4.98**	2.79**	-	4.46**	-
Livestock offtake/ha		-	-	4.59**	-	5.50**
Rainfall days per year	1.82*	1.90*	-	-	-	-
Stocking rate	-	4.40**	-	3.20**	-	3.27**
Lagged income /AE	-		0.97	0.62	-	-
Kajiado: R^2=0.801, F-Value=8.516 ($p \leq 0.05$), Durbin Watson (*d*) =2.098; Makueni: R^2 = 0.813; F-Value = 10.886 ($p \leq 0.05$), Durbin Watson (*d*) = 1.9991			Kajiado: R^2 = 0.935, F = 27.545 ($p \leq 0.05$), H-Value = 37.97 Makueni: R^2 = 0.970, F = 53.48 ($p \leq 0.05$), H-Value = 36.41		Kajiado: AdjustR^2=0.955, F= 40.184, Durbin Watson (*d*)=1.524 ($p \leq 0.05$); Makueni: R^2=0.954, F=60.769, Durbin Watson (*d*)=1.475 ($p \leq 0.05$)	

** Significant at $p \leq 0.05$, * Significant at $p \leq 0.10$

Focussing on the GLS model, lagged total annual rainfall had a positive and significant influence ($P \leq 0.05$) on total income in Kajiado County. This implies that an increase in rainfall increases the income per adult equivalent. This may be possible for pastoral households that grow maize along the river valleys. Higher rainfall would mean greater maize production thereby increasing total income. Moreover, more rainfall implies more pastures for the livestock. Hence pastoralists may be unwilling to dispose of animals, leading to reduced total income. Thus, in as far as livestock production in pastoral systems is concerned, this may as well be an unexpected result.

In Makueni County, lagged rainfall had a negative and significant ($P \leq 0.05$) influence on total income. It implies that an increase in rainfall amounts leads to a decrease in total income. The negative effect may occur if the rains are too high to cause floods, resulting in reduced crop production and pasture growth. Some parts of Makueni County are prone to flooding and this may explain the negative effects of the total rainfall. Alternatively, since total income is from various sources, including remittances, the flows from other sources might be reduced during times of high rains due to expectations of adequate harvests. In contrast, Tasokwa (2011) found a negative influence between rainfall and maize production in Malawi. She reported that a decrease in rainfall due to droughts results in a decrease in maize production. Also, Raddatz (2005) acknowledges the role of rainfall shocks on agricultural output. His work reveals the importance of weather shocks especially droughts, extreme temperatures and windstorms to the overall growth performance in low income countries like Nigeria. Further, Sissoko *et al*. (2011) established that in Ghana, annual rainfall levels and their temporal distribution have a far-reaching impact not only on water availability and quality but also on crop yields, consequently influencing food security at household and national levels.

Other variables that were significant at $P \leq 0.05$ in Kajiado County were maize price per kg, mean annual temperature and per cent livestock offtake. Maize price has a positive response to total income. It is understood that with higher maize prices, less food will be purchased with the available income. However, the households that grow maize along the river valleys or through irrigation normally have higher incomes due to higher maize producer prices. Similarly, for these households that grow maize, higher maize prices imply more income to purchase extra livestock, which increases their capital base.

The mean annual temperature exhibited a negative and significant ($P \leq 0.05$) relationship with income per adult equivalent in Kajiado County. Since the county is mainly involved in livestock production, this implies that an increase in temperature will negatively affect the production of livestock, which will in turn lead to a decrease in total income. In support, Frank *et al.* (nd) showed that an increase in air temperature markedly reduces milk production levels in the central Great Plains of the United States unless counter-acting measures were taken by producers. He further elaborated that increased ambient temperatures led to depressed voluntary feed intake, thus reducing livestock output.

According to Osbahr and Viner (2006), the annual average temperature in Kenya is projected to increase by between 3^0C to 5^0C by the end of the millennium because of climate variability and change. The increase in temperature brings consequences such as loss of moisture and increased evaporation rate. Coupled with declining precipitation, climate variability and change worsen the aridity of pastoral rangelands and affect a number of resources such as water, pasture and the edible fruits that pastoralists depend on. The ensuing consequences would be the decimation of livestock in large numbers, which could significantly affect pastoral livelihoods and security (Savatia, 2009). This implies that the Kajiado County population is threatened by food security if appropriate technologies and policies are not formulated.

The results of the current study are consistent with those of similar studies in other agricultural systems. For example, Tasokwa (2011) established that higher temperatures lower maize production. She further explained that in areas exposed to higher temperatures such as Chikhawawa, which have average temperatures of 32.48^{0}C, maize production was slightly lower than in Ntcheu that has mean temperatures of 30.52^{0}C. Also, Battisti and Naylor (2009) showed that an increase in temperature in the tropics may reduce maize and rice yields by 20 to 40 per cent at the end of this century. Likewise, Schlenker and Roberts (2006) showed that in North-eastern US, an increase in temperature beyond a threshold of 30^{0}C will result in sharp reduction of maize yields.

In lower altitudes, IPCC (2007) projects reduced crop productivity for even relatively small local temperature increases of 1 to 2^{0}C. In addition, IPCC projects that in the tropics and subtropics, crop yields may fall by 10 to 20 per cent by the year 2050 due to warming and drying, but there are places where yield losses may be much more severe (Jones and Thornton, 2003; Thornton *et al.*, 2007).

Stocking rate had a positive and significant influence ($P \leq 0.05$) on total income in Makueni County. Nyariki (2008) noted that correct stocking rate ensures correct intensity of utilisation of available forage, water and other resources, and is therefore an indicator of capital investment and management quality. He further stated that if the stocking rates were too high, they would lead to overgrazing and possible range degradation. The positive effect of the stock rate on total income in the model indicates that there is a mismatch between livestock and the available forage. This implies that if stocking rates were to be increased, livestock production would increase and total income would also go up. In addition, Makueni County being an agricultural community, the crop residues at the end of every growing season complement natural pastures. This result is similar to those of previous studies such as Nyariki (2008).

5. Conclusion and Policy Implications

The results have shown that total county income is influenced by climate variability (rainfall and temperature) in Kajiado and Makueni Counties of Kenya. Therefore, those involved in policy interventions should ensure that relevant climate data are collected and recorded for each specific area so that forecasting can be more accurate and can provide better guidance for designing appropriate adaptation strategies. Besides, climate factors are highly variable and thus strategies for adaptation cannot be generalised and should therefore be more site specific. Initiatives that promote the creation of micro-climates such as agroforestry should therefore be encouraged and supported. This will help in moderating temperatures as well as attracting rainfall, while also offering other benefits, especially multipurpose trees and shrubs are emphasised.

The GLS analysis shows that per cent livestock offtake remains an important parameter for the livelihoods in both Kajiado and Makueni Counties. It had a positive and significant influence on total income for both counties. Therefore livestock plays an important role in the total income of communities in the two counties. In Kajiado County, livestock contributed 78.2 per cent of the county total income while in Makueni County it accounted for 38.2 per cent. Therefore, development interventions geared towards livestock improvement have greater potentials to improve total income. For example, decentralisation of bodies such as the Kenya Meat Commission, milk processing plants and leather industries to county level are fundamental. This will help minimise exploitation of farmers by middlemen. In addition, strengthening of extension services, provision of mobile veterinary care clinics, and improving education and awareness among the transhumant pastoralists and agropastoralists should be prioritised. Besides, relying on livestock sales alone may be unsustainable. There is therefore the need to create micro-industries that deal with the processing of livestock related products such as hides and skins to improve household income as well as create non-farm employment. Lastly, development initiatives that would specifically target Kajiado County should include implementing agroforestry and reforestation programmes to help moderate temperatures and attract more rainfall while also sequestering carbon.

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