Livestock response to long-term precipitation variability in the arid and semi-arid lands of Baringo County, Kenya

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Abstract

A research was conducted to validate the livestock market response to long- - term observed precipitation variability. The precipitation data covering 1974-2003 was obtained from five Kenya Meteorological Department stations in the entire County. Theissen polygon method was used to estimate mean areal precipitation. The livestock marketing data for 1999-2003 was obtained from annual reports of the Department of Livestock Marketing. It included; unit annual average price and quantity sold for slaughter of cattle, goat and sheep. The information obtained from, Focus Group Discussion and Key Informant interviews enhanced the explanation of the findings. The descriptive analysis of the long-term observed precipitation data from the five stations showed 763 mm Â± 178 mm, n = 30. This implies that the amount of mean areal precipitation observed and recorded was between 941mm and 595mm within the span period of 30 years. It means that the SD was very high, relative to the mean. It indicates the rainfall is erratic, highly variability and unreliable. The correlation coefficient (covariance) between mean areal precipitation and annual average price of cattle, goat and sheep for 1999-2003 was r= -0.865, r= -0.7.11 and r= -0.652 respectively. Based on the aforementioned findings it is evident that there has been increasingly variable climate in the study area. This has adverse effects on the livestock marketing. Seasonal weather forecast-based livestock marketing plan is the way forward as an adaptation strategy to climate change in the ASAL.

Key words: *adaptation, climate change, global warming, price, season*

Introduction

The erratic rainfall and increasing temperature are the most serious global problems associated with the climate change and it is affecting many sectors in the world. They are considered to be the most serious threats to sustainable development with adverse impact on the environment, human health, food security, economic activities, natural resources and physical infrastructure (Jiri et al 2014). The arid and semi-arid lands (ASALs) account for more than 40% of the world's land area and are home to over 2 billion people, 325 million of them in Africa, yet they are among the regions in the world where climate change impacts on ecosystems, livelihoods and human health are potentially the greatest (IPCC 2014). The main challenge that confronts farmers in arid and semi-arid areas of Sub-Saharan Africa is managing unreliable rainfall (Tumbo et al 2010). In Kenya's ASALs, for example, more than 3 million pastoralist households are regularly hit by drought, costing the economy an estimated $12.1 billion in 2008 – 2011 (ILRI 2014). The risks expose the ASALs in the region to the challenge of high costs of inputs occasioned by unreliable, highly variable, and scarce rainfall for their livestock and crop production (Tol et al 1998; Bhatt et al 2006; Cooper et al 2012).

Netherlands Development Organization-SNV (2012) reported that, climate change and variability in the ASAL is evidenced by more extreme oscillations between dry and wet periods and between the availability of natural resources in different areas, leading to greater variability in livestock production. Therefore, increasingly climate change and variability have become a serious problem to pastoralists. According to Saitabau (2014) the pastoralists have used indigenous knowledge to predict weather events which have assisted them to manage their livelihoods. However, Saitabau (2014) further reported that unpredictable weather variations have become a common occurrence and the drought that used to occur every ten years is now occurring every two years or less and the trend continues to worsen. The Oxfam International (2010) argued that the annual rainfall is more erratic and figures continue to decline while people experience warmer dry months.

The study by Kibria et al (2017) reported that pastoral communities living in arid and semi-arid lands (ASALs) are highly dependent on natural resources, which are sensitive to even slight changes in climatic conditions, for their livelihoods. This makes pastoralists more vulnerable to climate change and variability. The influence of seasonal weather patterns on crop and livestock production suggests that applications of seasonal weather predictions to agriculture (and pastoralism) may be highly valuable to society (Jones 2000). Climate information (including observations, research, predictions and projections) has a central role to play in both adaptation and mitigation of climate change (Zillman 2009). The objective of this paper was to validate the livestock market response to long-term observed precipitation variability, in the context of an increasingly variable climate and change in the study area

Methodology

Study area for Livestock Market Response to Observed Precipitation

Variability

The study was conducted in Kenya and focused on Baringo County which is in the Arid and Semi-Arid Lands (GOK 2015). Figure 1 shows the location of the study area covering Mogotio and Baringo South Sub-Counties of Baringo County. The two sub-counties are among the six sub-counties that comprise Baringo County. They share some similarities in relation to agricultural, ecological zones and livelihoods. Most of Baringo Sub-County is located in Agricultural Ecological Zone (AEZ) five while Mogotio is in four. The residents in the two counties practice pastoralism and agro-pastoralism.

Baringo South Sub-County receives an average rainfall of 500mm per annum; the rainfall is erratic, highly variability and unreliable (Wasonga et al 2011). This climatic variability considerably affects the settlement patterns and economic activities in the Sub-County. According to GOK (2013a), the rainfall is bimodal with long rains running from March to July and short rains run from the end of September to early November. Mogotio Sub-County average annual rainfall is 654mm with weakly bimodal peaks in March to May and June to August. Annual evapotranspiration is 1360mm and exceeds precipitation in every month of the year by as little as 19 mm in May and as much as 109mm in February.

The average annual temperature is about 27Â°C. The mean annual maximum and minimum temperatures are 32.4Â°C and 16.8 Â°C, respectively. The extreme lowest is 10.2Â°C in June and

December, and the highest is 37.7 Â°C in February and March. The period between January and March is the hottest. Solar radiation values total 545 Langley's per year and hence can ensure crop production levels if not limited by other factors especially moisture (GOK 2013b).

Figure 1. Map of Mogotio and Baringo South sub-counties in Baringo County and Location of Meteorological Stations

Livestock Marketing Data collection and Analysis

The livestock marketing time series data on: unit annual average price and quantity sold for slaughter of cattle, goat and sheep was sourced from annual reports of the Department of Livestock Marketing, Focus Group Discussion (FGD) and Key Informant (KI) interviews. In both Sub-Counties two FGDs comprising of twelve participants each were conducted, drawing participants from livestock farmer, traders, extension agents' abattoirs owners and managers. Further, ten KI interviews were conducted involving government agencies, non-governmental organizations and livestock traders in the study area. To establish whether there was a correlation coefficient between the mean areal precipitation and the livestock marketing variables, a correlational analysis was done and scattered diagrams were plotted and presented to display the relationship (Figures 4 and 5).

Precipitation Data Collection and Analysis

The monthly observed precipitation data for the period 1974-2003 was obtained from five Kenya Meteorological Department (KMD) weather stations. The percentage of missing rainfall data in the aforementioned weather stations was less than 10% and the data spreads over 20 years hence meeting the requirements of World Meteorological Organization with regard to climatological analysis.

The data was quality controlled to ensure no missing data and any inconsistencies. According to Saeed et al (2016) the presence of missing rainfall data is inevitable due to error of recording, meteorological extremes and malfunction of instruments. Radi et al (2015) imputation approaches are used to fill in missing rainfall data. For this study multiple imputations method was used to overcome underestimation of standard errors and confidence intervals typical of single imputation. The method involves replacing missing data with substituted values. The imputed data sets were combined and average worked out. The method involves estimation of missing rainfall data from the observations of rainfall (rainfall data sets) at the same station and period but different years. The missing rainfall data *PX* was estimated using the following formula:

Where:

n= the number of rainfall data sets

Pi = rainfall data from the ith data set

PX= missing rainfall data

Microsoft Excel was used to analyse the Baringo County rainfall trend for 30 years (1974-2003). This involved plotting the mean areal precipitations trends against the time series. The trend line or the regression line, together with the R^2 was inserted. The regression equation was used to project the precipitation from 2003 to 2018 (Figure 3).

Theissen Polygon Method

There are three (3) common ways to estimate mean areal precipitation, namely the station average method, Theissen polygon method and isohyetal method (Chin 2007). Every method has its own advantage and constraint. The station average method is recommended for very small catchments, up to one (1) km radius (Vaes et al 2004) with evenly installed with rain gauges. The Theissen polygon method is appropriate for large coverage (Linsley et al 2000; Chin 2007). In this paper we focus on the Theissen polygon methods since the five stations (Table1) had coverage of 3105km^2 in the larger Baringo County (Figure1).This method is widely used because of its practicability and less time consuming with relatively high accurate estimates (Damant et al 1983). Individual station annual and areal average annual precipitation trends were generated using ArcGIS software (Figure 2). To better visualize the association between mean areal precipitation and annual average prices of individual unit livestock species, quantity of livestock sold for slaughter in Baringo County, the researcher employed scatter diagrams (Figure 4 and 5).

Results

The table1 below shows the five meteorological stations and their respective area coverage in square kilometers (km^2) in the study area. The Kimose Agricultural Holding ground station covered the largest area (889 km^2) relative to other stations.

Table 1. Area in km2 covered by each of the five Meteorological Stations in Baringo County

S/No.	Station Name	Area in Kilometers squared
1.	Snake Farm - Lake Baringo	307
2.	Chemususu Forest Station	349
3.	Kimose Agricultural Holding Ground	889
4.	Lake Bogoria National. Park Reserve	880
5	Perkerra Agricultural Research	680

Source: Author 2016

Figure 2. Mogotio and Baringo South sub-counties showing generated polygons and area each meteorological station is covering

The mean areal precipitation maximum recorded was 1150 mm in 1978 while the minimum was 340mm in 1984, and the amount of precipitation has been reducing through time (Figure 3).To quantify the amount of variation or dispersion of the set of mean areal precipitation data values; the researcher conducted the mean and standard deviation (SD) analysis. The result of the aforementioned aspect showed 763 mm Â± 178 mm, n = 30. This implies that the amount of mean areal precipitation observed and recorded was between 941mm and 595mm within the span period of 30 years. It means that the SD is very high, relative to the mean. This is clear indicator that there has been climate variability. The predicted mean areal precipitation for 2018 will be 667mm. As indicated by the slope of -3.27, it means that the study area experienced a decreasing trend of total annual average rainfall.. From the regression line, the R^2 = 0.03 indicating that the time series explains only 2.6% of the changes in the mean areal precipitation.

Figure 3. Mean Areal Rainfall Trend for the 5-Set Stations, 1974-2003
Source: KMD Observed Precipitation data (2016)

Mean Areal Precipitation Response to Annual Average Livestock Prices, 1999-2004

Table 2 below shows unit average prices for cattle, goat and sheep for period 199-2003 under review**.** The highest prices sold per unit cattle, goat and sheep were Ksh. 11,870; 2,100 and 1,280 equivalents to $115.1, 20.4, 12.4 using conversion rate of I US dollar equals to Ksh.103.12 respectively. The lowest prices sold per unit cattle, goat and sheep were Ksh. 8,250; 1,500 and 850 ($80, 14.5, 8.24) respectively.

Table 2. Annual Average Prices of Livestock in Baringo County (1999-2003)

Parameter	**Livestock Species**		
	Cattle	**Goats**	**Sheep**
N (years)	5	5	5
Minimum	8250	1500	850
Maximum	14550	2850	1550
Mean	11870	2100	1280

Std. Deviation	331	486	257

Source: Authors 2017

Figure 4. Scattered Diagrams for the prices of individual unit livestock species sold for slaughter in Baringo County

Figure 4 above shows scattered diagrams and correlation coefficient (covariance) between the mean areal precipitation and annual average price of cattle, goats and sheep for period 1999-2004 under review. The analysis shown correlation coefficient of r=-0.87, r= -0.71, r= -0.65 for cattle, goats and sheep respectively. This implies that there was a negative relationship between unit price of cattle and goats sold for slaughter and mean areal precipitation. However, this relationship varied across the three species of livestock where cattle, goat and sheep yielded very strong, strong and moderate relationship respectively.

Mean Areal Precipitation Response to Quantity of livestock Sold for Slaughter 1999-2004

Figure 5. Scattered diagrams for the quantity of cattle, goat and sheep sold for slaughter in Baring

Figure 5 above shows scattered diagrams and correlation coefficient (covariance) between the quantity of cattle, goat and sheep sold for slaughter and the mean areal precipitation, period 1999-2004 under review in Baringo County. The analysis showed correlation coefficient of r= -0.87 **,** r= -0.3, r=0.0 for cattle, goats and sheep respectively. This implies that there was very strong negative relationship between mean areal precipitation and quantity of of cattle sold for slaughter, while for the goat yielded weak relationship. There was no relationship between the mean areal precipitation and the quantity of sheep sold for slaughter at all.

Table 3. Role of Weather Forecast on Livestock Marketing

Aspect	**Frequency**
1. Preparedness before weather extreme event strikes has a positive impact on the performance of livestock marketing	5
2. Adequate or inadequate pasture and water as a result of seasonal climate variability has an impact on the performance of livestock marketing	3

3. Late arrival or no weather forecast information has an adverse effect on livestock marketing	4
4. Relaible weather forecast information has positive impact on the performance of livestock marketing	4
Total	**16**

According to the table 3 above, 31% of the interviewed key informants reported that the level of the farmer preparedness before weather/climate extreme event strikes has a positive impact on the performance of livestock marketing. This was further supported by findings derived from the FGDs conducted.

Market response to seasonal weather forecast-based plan

In the two FGDs conducted for this particular study, it came out clearly that, the study area experience two distinct rain seasons and one dry season. This includes March, April and May for long and short rain season in October, November and December. The dry spell period occupies the largest portion of the year (December, January, February, March, and some part of June and July). However, the majority of the participants in the Focus Group Discussion (FGD) argued that the amount of rainfall experienced in the long and short rain seasons is continuously decreasing and the dry spell is increasing. This is confirmed by the mean areal precipitation trend in figure 3.

Discussion

Figure 3 shows the annual mean areal rainfall trend of the 5-Set Stations from 1974-2003 in Baringo County (Table 1). The trend of variation in the amount of rainfall observed annually demonstrates a continuous decrease throughout the study period. This study finding agrees with Ochieng et al (2017) who reported a declining long-term seasonal rainfall trend in the Drylands of Baringo County. Also, it corroborated with Omoyo et al (2015) where rainfall trend analysis for 1994–2008 revealed that four out of the six weather stations, the amount rainfall had decreased by up to 3mm per year. A similar research finding was reported by Mwaura et al (2017) that rainfall in semi?arid Ijara in Garissa, Kenya has increasingly become uncertain and the trend analysed using KMD data (40 years) period indicate a definite decline. However, Recha (undated) also analysed observed precipitation data for 10 years in Semi-arid Tharaka District, Kenya and reported similar results that revealed declining trend between the 1970s and mid 1980’s.

The study found that the amount of rainfall experienced within the study period under review had a negative strong relationship with the prices of cattle, goat and sheep. According to Mankiw (2001) the law of supply and demand, states that if all other factors remain equal, the higher the price of a good, the less people will demand that good while the quantity of a good supplied rises as the market prices rises and fall as the prices falls. Therefore, for this paper the unit price of livestock cattle, goat and sheep decreases as the mean areal precipitation increases and verse versa the prices increases as the mean areal precipitation decreases. This is perhaps because, when there is high amount of rainfall the pasture and water for the livestock is available and there is high productivity that leads to high supply of livestock in the market. When there is less mean areal precipitation, there is low supply and the demand is high in the market and eventually the unit price is high.

This finding corroborates with Abdow (2014) arguments that the important variables in explaining the average market price of the cattle are: gender; both male and female, age of the cattle; both mature and young, the body condition of the cattle and the season in which the transaction happens. However, this is contradicted by the relationship between the quantity of cattle, goat and sheep sold for slaughter which was $p>0.05$.

According to the livestock farmer, traders, extension agents' abattoirs owners and managers as participants in the FGDs and key informants' interviews of this study, reported that in Mogotio and Baringo south sub-counties in Baringo County a prolonged dry season is being experienced that never used to be there before. Also they further claimed that the rainfall pattern has changed and they are unable to predict the seasons as they traditionally used to do long time ago. This argument corroborates with Ochieng et al (2017) findings that, of late droughts are more frequent in the dry areas of Baringo County, Kenya. This suggests that, climate variability and change is consciously being felt in the study area. Also the finding agrees with Herrero et al (2010) that increased drought frequencies to more than a drought every five years could cause major, irreversible decreases in livestock numbers in arid and semi-arid areas.

In the long rainfall season (MAM) the following is experienced by the livestock farmers in the auction sales yard; prices of the livestock increase, there is high demand for young stock; farmers buy young stock for breeding and fattening from the livestock traders, farmers not willing to sell their livestock. There is plenty of pasture and the livestock show good body condition. This finding corroborate Abdow (2014) report that highlighted that characteristics that are likely to influence the price of live cattle include; age, sex, grade as well as other related factors such as weather or seasons. According to the participants of the FGDs, during long rainfall season there is more food for the households and little demand for money and therefore many farmers are not willing to sell their livestock.

Short rainfall season runs from September-November (SON). Within this period the livestock prices are high and such it is good time for the farmers to sell their livestock. It is termed as the “field day for farmers”. This is because the demand for livestock is high in the sales auction yards. They confirmed that, during this season livestock farmers maximize the sales, categorized as the “best” sales period. The festive season in the month of December which concedes with the aforementioned period contribute greatly in the creation of the high demand of livestock species. This finding corroborates with Republic of South Africa (2017) that in some seasons beef prices were lower due to lower post-holiday demand. The weaned calves (calves are ideally weaned when they are 7 to 8 months old and are completely removed from the mothers and no more access to the mothers' milk) prices weakened due to lack of demand.

During dry season period there is high concentration of cattle, sheep and goat in the livestock market (auction sales yard). This implies that, the supply of the aforementioned - livestock species is high and consequently the prices are low. The reasons were; the dry season usually commence in January, schools open in January and the parents who are the livestock farmers are to pay school fees and the local consumers have no purchasing power to buy meat due to the live pressure. Therefore, the whole period January up to March is the “field days of the livestock brokers in the market”

Conclusion

- The aim of the study was to establish the response of the livestock market to the long-term observed precipitation.
- The station average and Theissen polygon methods were used in measuring the average amount of precipitation experienced in the study area for the period 1974-2003. The long term observed precipitation has been continuously declining.
- This context evidently confirms climate change and variability in the ASAL.
- The livestock market data aspects covered the period 1994-2003, on; average unit price and quantity of cattle, goats and sheep sold for slaughter.
- The linear association between the mean areal precipitation and the aforementioned livestock market data aspects were established by use of the scattered diagrams.
- There was a strong negative linear association between the annual average prices of cattle, goat and sheep and mean areal precipitation for period1999-2003.On the other hand, there was a very strong negative linear association between quantities of the cattle sold for slaughter in particular and mean areal precipitation. The prescribed situation has implication to the prices of cattle, goat and sheep which is the livelihood of the Pastoralist.

Area for Further Studies

Further research should be conducted on the assessment of the ASAL communities' adaptive capacity to climate change and variability.

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