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Comparative Analysis Of Rainfall Trends In Different Sub Counties In Kajiado County Kenya

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Bobadoye, A.O.
Forestry Research Institute of Nigeria (FRIN) P.M.B 5054 Jericho Ibadan Nigeria
Ogara ,W.O.
Institute for climate change and adaptation, University of Nairobi, P.O.Box 29053 Nairobi Kenya.
Ouma, G.O.
Institute for climate change and adaptation, University of Nairobi, P.O.Box 29053 Nairobi Kenya.
Onono, J.O.
Institute for climate change and adaptation, University of Nairobi, P.O.Box 29053 Nairobi Kenya.

Abstract: *This study analyzes the trends of rainfall in four (4) different Sub Counties (Kajiado North, Kajiado Central, Kajiado East and Kajiado West) in Kajiado County, Kenya. Average monthly rainfall data were collected from Ngong Forest station (Kajiado North), Kajiado Maasai rural training centre Isinya (Kajiado East), Magadi soda works (Kajiado West) and Mashuru (Kajiado Central). The study compares the trend of rainfall in the study area to determine the existence and level of climate variability in Kajiado County. It determines the rainfall variability both spatially, seasonally and inter annually in Kajiado County. Rainfall data for a period of 44years (1970 – 2013) from the various stations were organized and analyzed using Microsoft excel. Graphs for trend analysis, standard deviation, mean and co-efficient of variance (CV) for the four meteorological stations were calculated. Result shows that generally Kajiado County has a bi modal rainfall pattern with two distinct raining seasons. Ngong (Kajiado north) had the highest average annual rainfall of 1454.05mm, followed by Isinya (Kajiado east) 896.16mm and Mashuuru (Kajiado central) 674.70mm and least for Magadi (Kajiado west) 450.50mm. The result revealed that rainfall trend in Kajiado County has a high variability level both spatially, seasonally and inter annually. Spatial variation revealed that Ngong had the highest level of CV% of 27.5%, followed by Isinya 26.4% and Mashuuru 25.5% and least for Magadi 21.5%. With the exception of Ngong, the result shows that the short rain (October – December) had higher co efficient of variance than the long rains (March – May). The study recommends that more modern weather monitoring equipment be installed all over the Country for proper and accurate policy decision making especially in the arid and semi arid lands that are highly susceptible to climate change and climate variability.*

Keywords*: Kajiado County, Arid and semi-arid lands, Rainfall analysis*

1. Introduction:

Climate change and variability creates risks in many climate sensitive sectors like agriculture, water resources and health and its extremes affects mostly the livelihoods and welfare of rural communities. Among the climate parameters that has exhibited a shift in both short and long term trends are rainfall and temperature. These two have impacted the terrestrial waters, atmosphere, cryosphere and biosphere resulting in phenomena such as abnormal rainfall regimes, dry spells, floods and change in species composition in various ecosystems (Ombogo, 2013). IPCC (2007) noted that "the present recording of an increase in drought, floods, windstorm and other extreme negative phenomena will negatively affect water resources through reduced fresh water availability for the afflicted populations, competing needs for water for domestic, livestock and crops will further exacerbate access to dwindling supplies from degrading water catchments, drying underground reserves and declining precipitation".

Arid and semi arid lands (ASALs) are particularly vulnerable due to the dominance of pastoralism and rain fed agricultural food production system, and if the condition continues as they are, then impacts of increased temperature from global warming and variable precipitation resulting from climate change and variability are expected to further depress marginal lands that are currently under livestock grazing and crop production. In Kenya, the ASALs constitute about 80 percent of the total land surface area (Nyariki, 2002; Anwata 2013). The ASALs account for about 30 percent of the total national population and 50 percent of the total livestock population and vast amount of untapped natural resources (ROK, 2004; UNDP, 2010). Davis (2007) reported that livestock production contributes about 90percent of the employment in ASALs and about 95 percent of family income and livelihood security. He noted in his valuation of pastoralism that the system goes beyond simple mode of livestock production but it also includes consumption system that support a large global population and a natural resource management system that support a wide range of services and products that are of global value, such as biodiversity, tourism and raw materials.

In terms of rainfall, the ASALs receive an annual precipitation of between 500mm and 800mm, and lies within the ecological zone iv, with an extension to zone v. Rainfall pattern in the ASALs have historically dictated variability in water and fodder availability, influencing mobility and settlement patterns and leading to the development of pastoralism as

the most suitable livelihood (Swift, 1998; Fratkin et al., 1999; Wasonga, 2009; Wasonga et al., 2010). It is expected that weather patterns will be altered especially rainfall amounts, resulting in increased severity and frequency of extreme climatic events. Wasonga et al., 2010 argued that the effects of climate change and variability will be probably be the most acute for pastoralist and agro pastoralist especially those in Africa, including Kenya. However due to the different agro ecological zones in Kajiado County, this study have observed a wide variation in both the average monthly rainfall and the inter annual rainfall for different geographic location in the County. This study therefore gives a comparative analysis of the rainfall trends in the five different sub counties in Kajiado County. This analysis will be useful for the government and policy makers for resource allocation and climate change adaptation planning in Kajiado County.

2. Study Area:

The study was carried out in Kajido County of the southern rangeland of Kenya. Southern rangeland refers to the arid and semi arid counties found in the southern part of Kenya. It is characterized by low unreliable rainfall, infertile soils and high temperature (Amwata, 2013), making these region unsuitable for agriculture. Most of Kajiado County lies in the semi arid and arid zones (Beckure et al., 1999). The County has only about 8 percent of its land classified as having potential for rain fed agriculture; this includes mostly the Athi-kapiti plains close to Nairobi and in the southern part of the County along the Kilimanjaro foothills (Beckure et al., 1991).

Kajiado County are located between longitudes 36^0 5' and 37^0 5' east and between latitudes 1^0 0' and 3^0 0 south (Anwata, 2013). The County has two distinct rainy seasons (1) long raining season from March – May (2) short raining season from October – December. The distribution of rainfall between the two seasons changes gradually from east to west across Kajiado County. In eastern Kajiado more rain falls during the long rains (March-May). The mean annual rainfall ranges from 300 to 800mm (ROK, 2009a). However, heavy rains occur in areas around Ngong hills, Chyulu hills and Nguruman area, receiving average rainfall as high as 1,250mm per annum. Low lands like Magadi receives an average of less than 500mm of rainfall per annum (Berger, 1993).

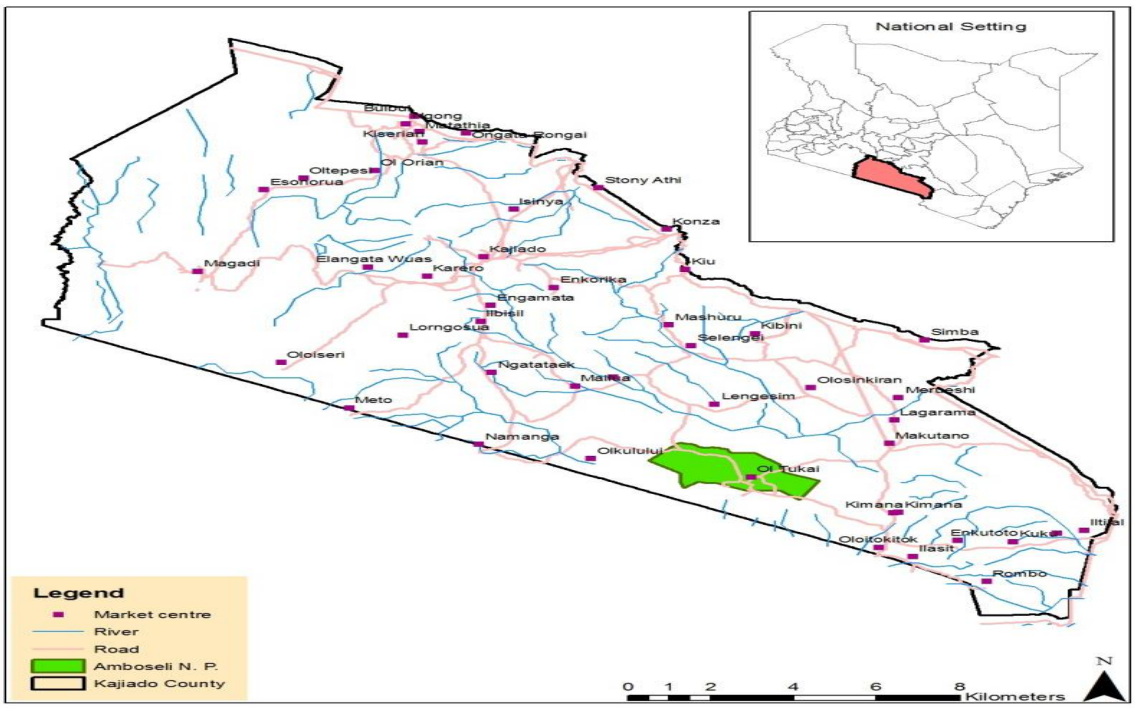

Figure 1: Map of the study area

3. Methodology:

Rainfall data from four different stations in Kajiado County were sourced and used for this analysis. Average monthly rainfall were collected Ngong forest station in Kajiado north area with location 1.31^0S, 36.65^0N, Mashuru meteorological station in Kajiado central area with location 2.10^0S, 37.10^0E, Magadi soda works in Kajiado west, located at 1.88^0S, 36.28^0E and Maasai rural trading centre Isinya in Kajiado east, located at 1.40^0S, 36.50^0E. The rainfall data were analyzed for a period of 44years (1970-2013). The stations were selected because of the availability of long term data and their presence within the different geopolitical zones in Kajiado County.

3.1. Data Processing And Analysis:

Rainfall data for Ngong meteorological station and Magadi soda works were available from 1970-2013 while few data were missing from Kajiado Maasai trading centre in Isinya and also the Mashuru station. Because we only have few missing months for Kajiado trading centre in Isinya and also Mashuru station, the missing data for the stations were estimated using the regression equation below

$a + bx$

$a = \bar{y} - bx$

$$b = \frac{\Sigma\left(x - \bar{x}\right)\left(y - \bar{y}\right)}{\Sigma\left(x - \bar{x}\right)^2}$$

Where x = time in years

y = amount of rainfall

Graphical representation was done to demonstrate seasonal and inter – annual rainfall characteristics at the five selected stations. The analysis of inter – annual and seasonal components for the data was done to provide general information for a time series within a year and between different years. Standard deviation and coefficient of variance was (% C.V) was also calculated to reveal the degree of seasonal and inter – annual climate variation in the different station using the formula below.

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

X= sample mean average

n = sample size

% C.V = standard deviation/ mean

Microsoft excel was used for the rainfall trend analysis, graphical representation and the co efficient of variation calculation.

Comparative values of coefficient of variation among the different stations were also conducted to determine the spatial differences in variability between the different locations of the meteorological stations. Climate variability factors such as years of successive poor rainfall, below normal rainfall and heavy rainfall were also identified by the graphical representation.

4. Results And Discussion:

The average monthly rainfall variation from 1970 – 2013 is presented in Figure 2. The rainfall pattern shows a bimodal trend in annual rainfall characteristics. It depicts two main raining seasons; the first and the long raining season starts in March and gets to its peak in April and starts reducing May. The rainfall amounts for the long rain are 88.84mm, 135.49mm and 59.65mm for March, April and May respectively. The second raining season begins in October and ends in December. The amount of rain in the short raining season is less than that of the long raining season, giving an average amount of 39.44mm, 92.10mm and 71.42mm respectively for the months of October, November and December. These result agrees with (ROK, 2002a; ROK 2009a; Opole, 2013; Amwata, 2013) which states that Kajiado County exhibits a bimodal trend in annual rainfall characteristics. The average rainfall for Isinya meteorological station is 51.01mm and six months of the year (February, June, July, August, September and October) has rainfall lower than the average. The lowest rainfall is recorded in the months of July, August and September with rainfall amounts of 13.7mm, 2.7mm and 20.4mm respectively. Opole 2013 also reported that July has the lowest rainfall in the year.

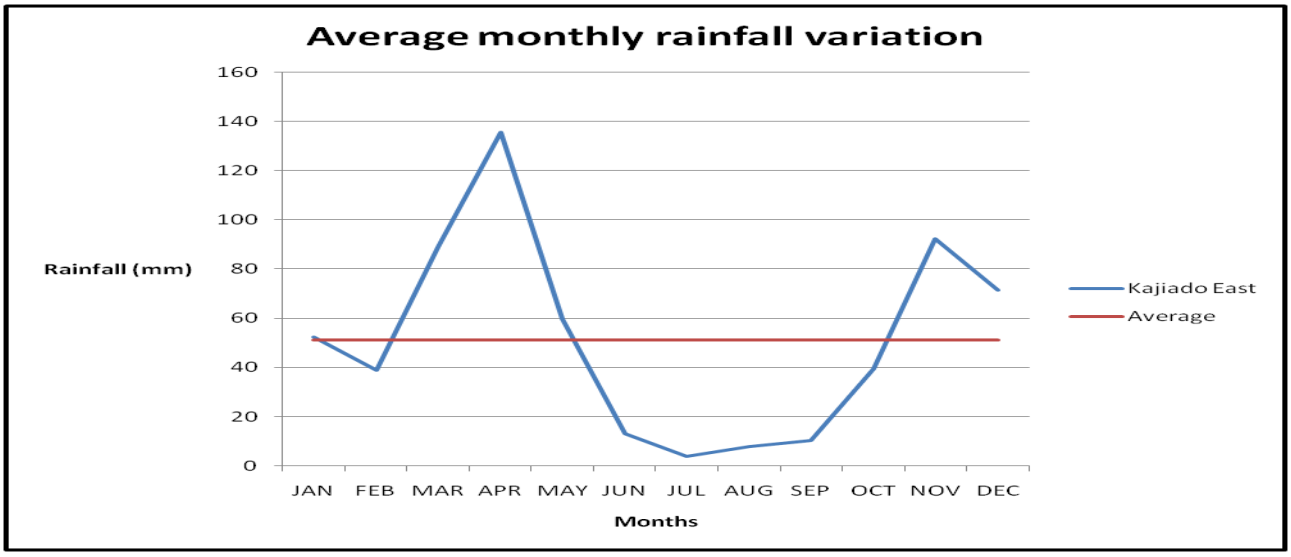

Figure 2: Average annual rainfall characteristics for Kajiado Maasai rural trade centre (Isinya Kajiado East) from 1970-2013

Figure 3 shows inter annual rainfall for Isinya meteorological station, Kajiado east from 1970 – 2013. The Figure shows that the average annual rainfall for Isinya over the past 44years (1970 – 2013) is 896.16mm. This is within the range of between 500mm and 1200mm reported for Kajiado County by ROK, 2009b, but higher than the annual average rainfall of

458.9mm reported by Amwata 2013 for Kajiado County. Semi arid regions are areas with average annual rainfall of between 500mm -900mm (Bekure et al., 1991). This further confirms Isinya as one of the semi arid regions in Kenya. The station recorded a total of 23years that are above average and 20years below average. A total of 14years 1970, 74, 78, 88, 89, 90, 92, 97, 2001, 2002, 2005, 2010 and 2012 has rainfall higher than 1000mm per year with the highest continuous spell of rainfall been between 1989 and 1992 with an annual rainfall of 1340mm, 1098mm, 975.1mm and 1086.6mm for 1989, 1990, 1991 and 1992 respectively. The driest years were found in year 1973, 75, 76, 84, 99, 2000, and 2008 with rainfall of 730.6mm, 681mm, 475.9mm, 441.9mm, 690.9mm, 276.4mm and 676.6mm respectively. This finding agrees with work of Orindi et al., (2006); ICPAC (2007) and Amwata (2013) that in Kajiado drought phenomenon has occurred during the years 1973, 1975, 1980, 1984, 1994, 2000 and 2008.

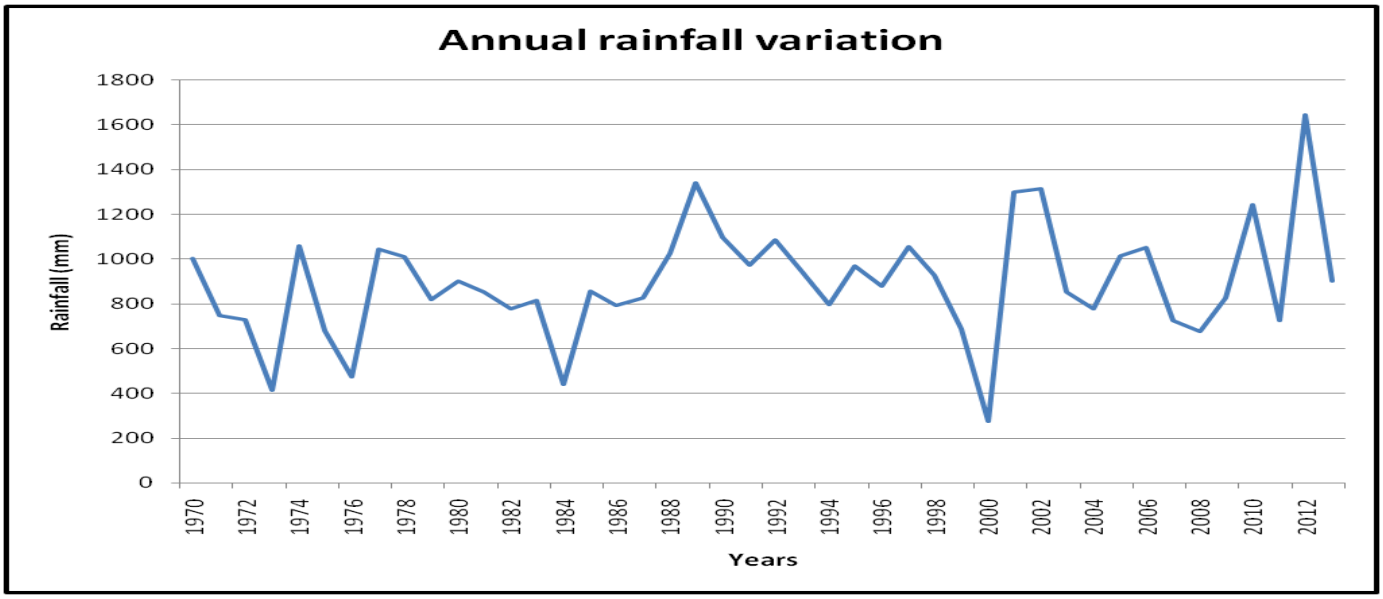

Figure 3: Inter-Annual rainfall variation for Kajiado Maasai rural trade centre (Isinya, Kajiado East) from 1970 - 2013

The average annual rainfall and seasonal characteristics for Ngong meteorological station is presented in figure 4. The station has an average rainfall of 79.5mm in a year. It shows a bimodal rainfall seasonal trend with the long raining season in March, April and May with rainfall of 100.14mm, 224.02mm and 154.03mm respectively. The short raining season is in the months of October, November and December with the rains extending to January. The short raining season records lower rains of 55.75mm, 140.00mm, 88.44mm and 57.98mm for October, November, December and January respectively. The result of this research agrees

with the findings of Opole (2013), who reported a peak rainfall of 88.8mm, 175.9mm and 147.9mm for March, April and May in Ngong respectively. It also agrees with Ogallo (1993) and ROK, (2009a), which reported that long rains (March to May) contributes between 50% to 70% of the annual rainfall and the short rains about 20%. The driest months of the year are June, July, August and September with average rainfall of 32.23mm, 13.72mm, 21.01mm and 20.60mm respectively.

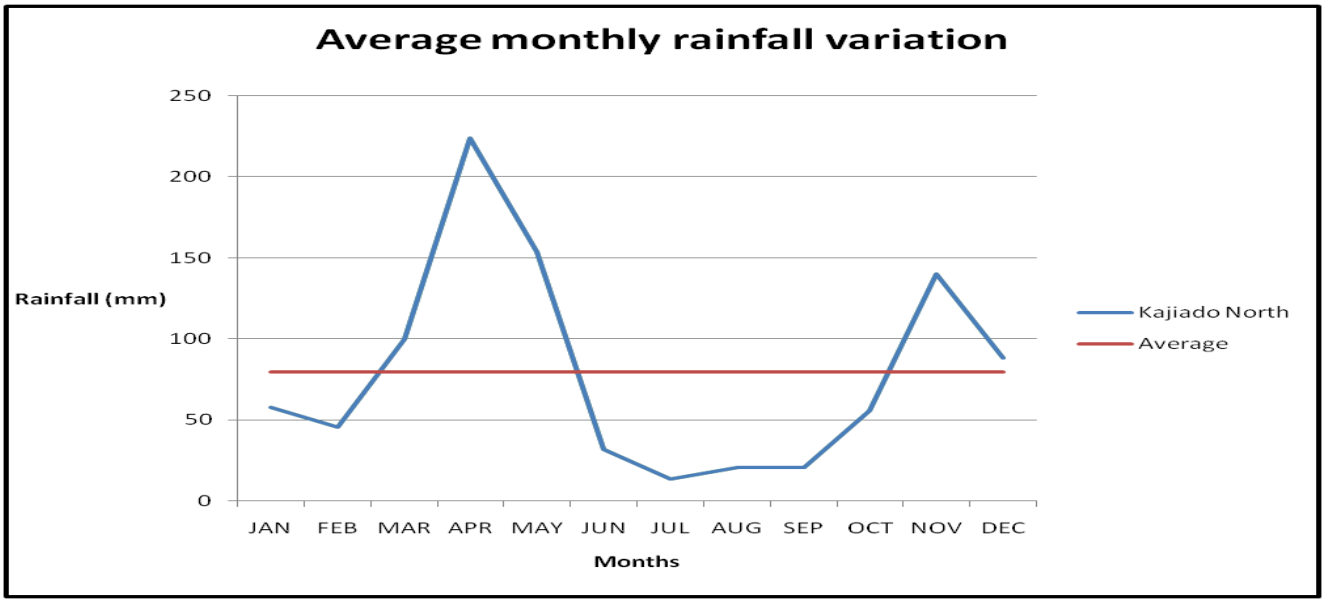

Figure 4: Average annual rainfall characteristics for Ngong forest station (Ngong, Kajiado North) from 1970-2013

The inter annual rainfall variation for Ngong (Figure 5) over the past 43years (1970 to 2013) shows that Ngong has an average annual rainfall of 1454.04mm. A total of 16years had rainfall higher than the average while 27years had rainfall lower than the average. The longest dry spell was between 1971 and1976 which was followed by heavy rains in 1977 (2301.25mm) and 1978 (1963.13mm) and also the dry spell of 1983 to 1987 followed by the longest wet period of 1988 (2144.8mm), 1989 (1809.5mm) and 1990 (1969.9mm). Generally 1984 (466.4mm) had the driest year followed by 2000 (668.1mm) and 1976 (721.33mm). This confirms the reports of UNEP and GOK, (2000); GOK (2005); Orindi et al., (2006); ICPAC (2007) and Anwata (2013) that severe drought occurred in Kajiado County in these years. The years with the highest rainfall are 1981(2362.97mm), 1977(2301.25mm), 1988(2144.8mm), 1997(2250.6mm), 2004(2045.8mm) and 2010 (2236.15mm). The trend shows that a year of heavy rain is usually preceded by one or two years of low rains. Generally the average rainfall in Ngong is higher than that of the other stations in Kajiado

County studied in this research. The rainfall pattern in Kajiado is strongly influenced by altitude with the high areas around loitokitok and Ngong receiving high rainfall when compared to low areas around lake Magadi and Amboseli (Bekure et al., 1991; Ogallo 1993; and GOK 2009a).

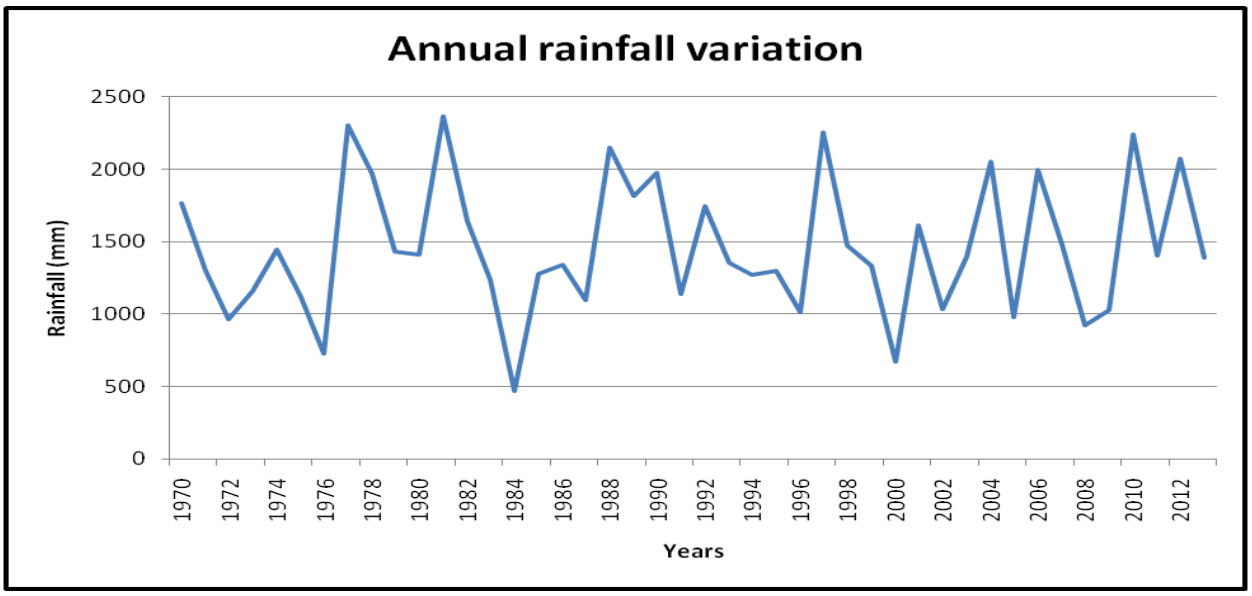

Figure 5: Inter-Annual rainfall variation for Ngong Division meteorological station (Ngong, Kajiado North) from 1970 - 2013

The average rainfall characteristic of Magadi area (Figure 6) shows that magadi area is the driest part of Kajiado County with an average annual rainfall of 37.5mm. This according to Bukure et al. (1991) classifies Magadi as one of the arid regions of Kajiado making it unsuitable for rain fed agriculture. Amwata (2013) reported that low amount of rainfall and its erratic distribution prevent sustainable cropping in Magadi area for most part of the year. Magadi also shows a bimodal rainfall pattern with the long rains mainly in March (75.77mm) and April (96.71mm). The short rains are mainly in December and January with a rainfall of 45.74mm and 52.81mm respectively. The months of June, July, August and September are the driest months of the year with rainfall of 5.27mm, 4.59mm, 3.84mm and 11.53mm respectively. The rainfall pattern in arid areas like Magadi has developed pastoralism as the more suitable livelihood (Swift, 1988; Fratkin et al., 199; Wasonga 2009; Wasonga et al., 2010).

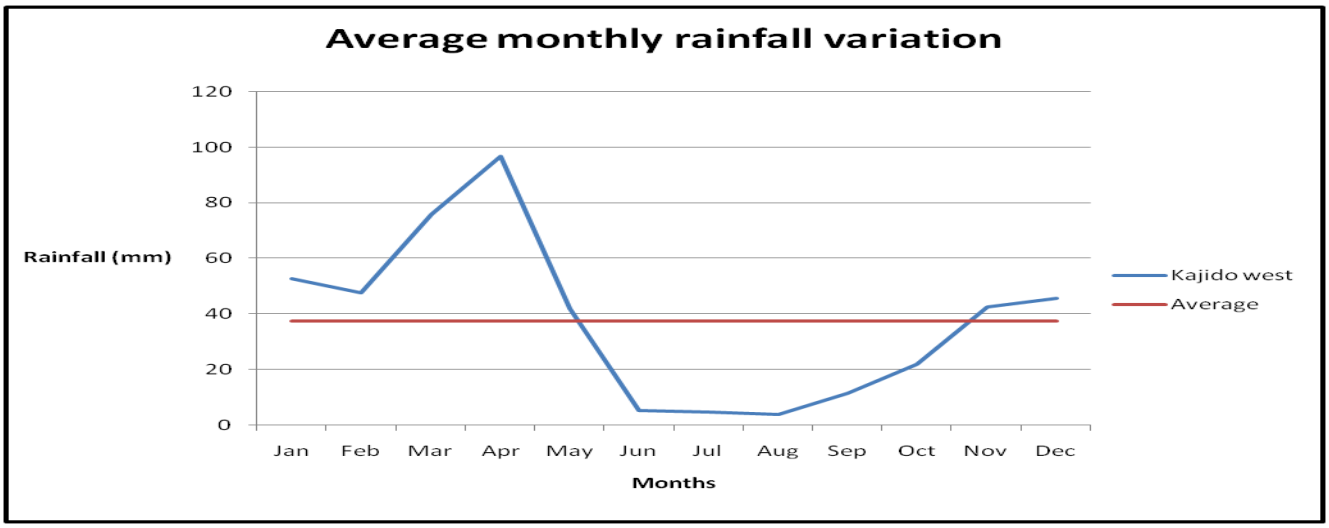

Figure 6: Average annual rainfall characteristicsfor Magadi soda work meteorological station (magadi, Kajiado west) from 1970 - 2013

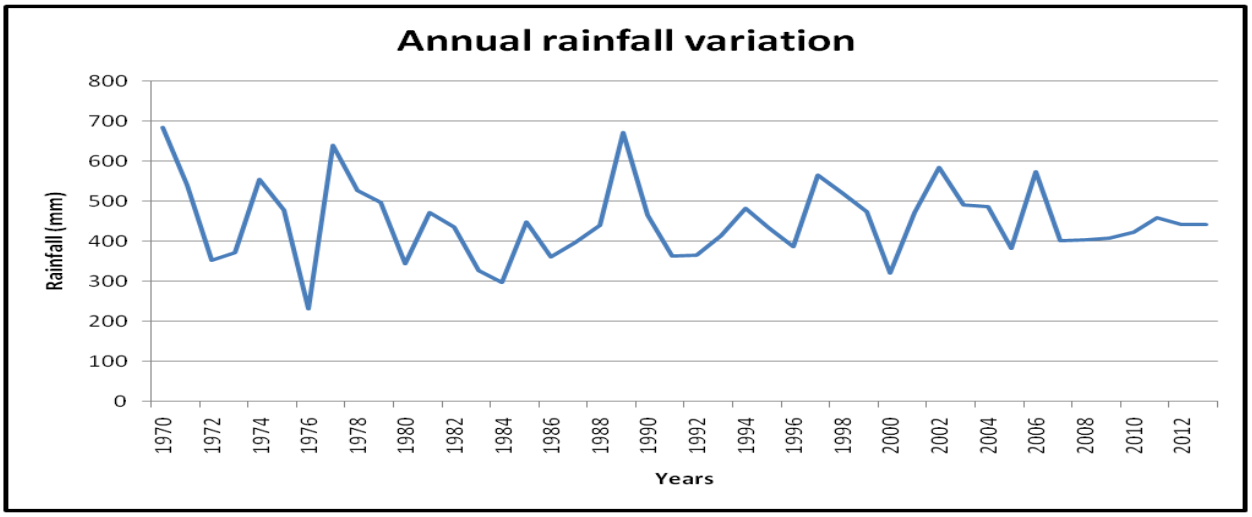

Figure 7: Inter-Annual rainfall variation for Magadi Soda Works station (Magadi, Kajiado West) from 1970 - 2013

The graph on inter annual rainfall characteristics shows that Magadi has an average annual rainfall of 450.05mm per year, this compares with annual average of 490mm reported by Opole (2013) and confirms Magadi as one of the arid regions in Kenya (Bekure et al., 1991). A total of 20years had rainfall lower than the average while 24years had annual rainfall higher than the average annual rainfall. The period of this research (1970 to 2013) shows that only 3years; 1970 (685.2mm), 1977 (640.3mm) and 1989 (673.4mm) had rainfall higher than 600mm per year. The result also shows that between the year 2000 and 2013 only the year 2002 (585.2mm) and 2006 (575 0mm) had rainfall higher than 500mm per year. This

confirms the reports of Orindi et al., (2006) and Action Aid (2009) that since 1990 the rate of occurrence of drought in some part of Kajiado County has increased to every two to three years. The years with the poorest rainfall are 1976 and 1984 with rainfall of 230.3mm and 296.00mm respectively. The longest period of dry spell was recorded between the years 1982 – 1987.

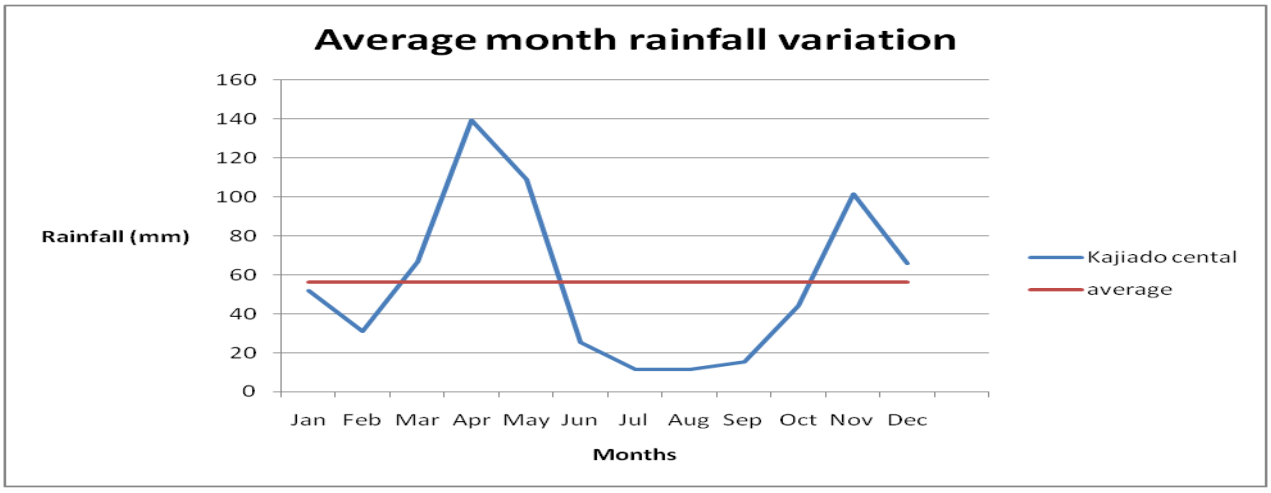

Figure 8: Average monthly rainfall for Mashuuru meteorological station (Mashuuru, Kajiado Central) from 1970 – 2013

Figure 8 shows that Mashuuru meteorological station bimodal rainfall trend with two distinct raining seasons and two dry seasons. Generally the year starts with a short dry season in January (52.0mm) and February (31.21mm). This is followed by a long raining season in March, April and May with rainfalls 66.70m, 139.51mm and 108.87mm respectively. The driest months of the year are June, July, August and September with rainfall values of 25.49mm, 11.63mm, 11.67mm and 15.53mm respectively. The short raining period is in the months of November and December with rainfall values of 101.45mm and 66.18mm. The average rainfall for the year in Mashuuru is 56.21mm and only 5months of the year (March, April, May, November and December) have rainfall higher than the average. The rainfall trend for Mashuuru in this research compares to Opole (2013) who reported peak rainfall of 144.6mm in April and a minimum of 10.5mm in July for Mashuuru region in Kajiado County over a period between 1970 to 2013.

The inter annual rainfall variation for Mashuuru meteorological station between 1970 to 2013 shows that Mushuuru area has an average annual rainfall of 674.7mm which confirms it as one of the semi arid areas in Kenya (bekure ea al., 1999). The figure shows that a total of 25year has annual rainfall lower than the average while 19years have rainfall values higher

than the average. The years 1977, 1998 and 2001 had the highest rainfall values of 1111.80mm, 1063.50mm and 1040.10mm respectively and only the three years had rainfall values higher than 1000mm per year. A total of five years 1975 (423.00mm), 1976 (419.10mm), 1984 (370.60mm), 1996 (453.60mm) and 2000 (371.50mm) had rainfall lower 500mm in a year. This agrees with UNEP and GOK (2000) that in Mashuuru drought events were recorded in 1975/76, 1984, 1994, 1996 and 2000. The year 1972 to 1976, 1983 to 1985, 1990 to 1996, 2003 to 2005 and 2007 to 2009 recorded the highest spell of dry seasons.

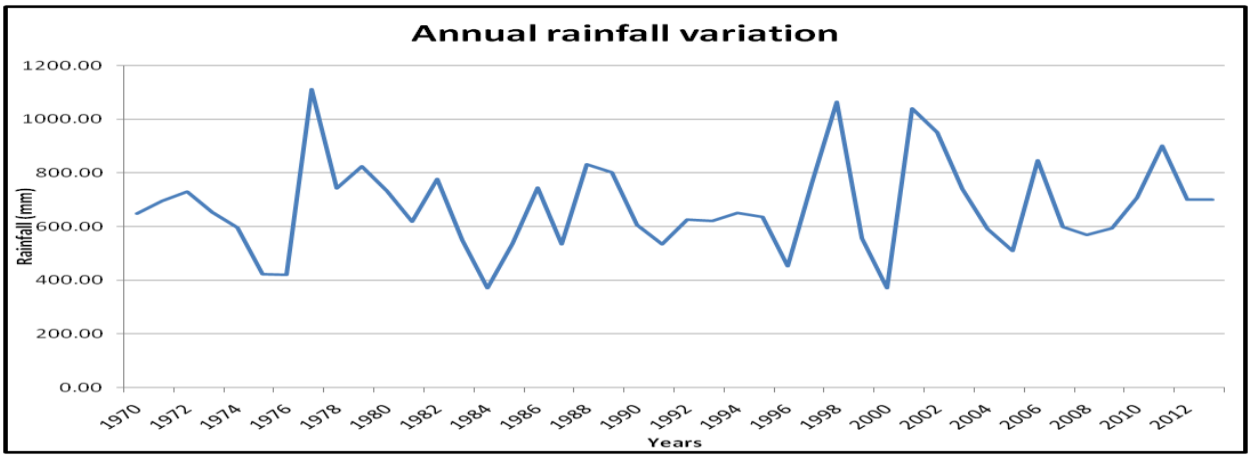

Figure 9: Inter annual rainfall variation for Mashuuru meteorological station (Mashuuru, Kajiado central) from 1970-2013

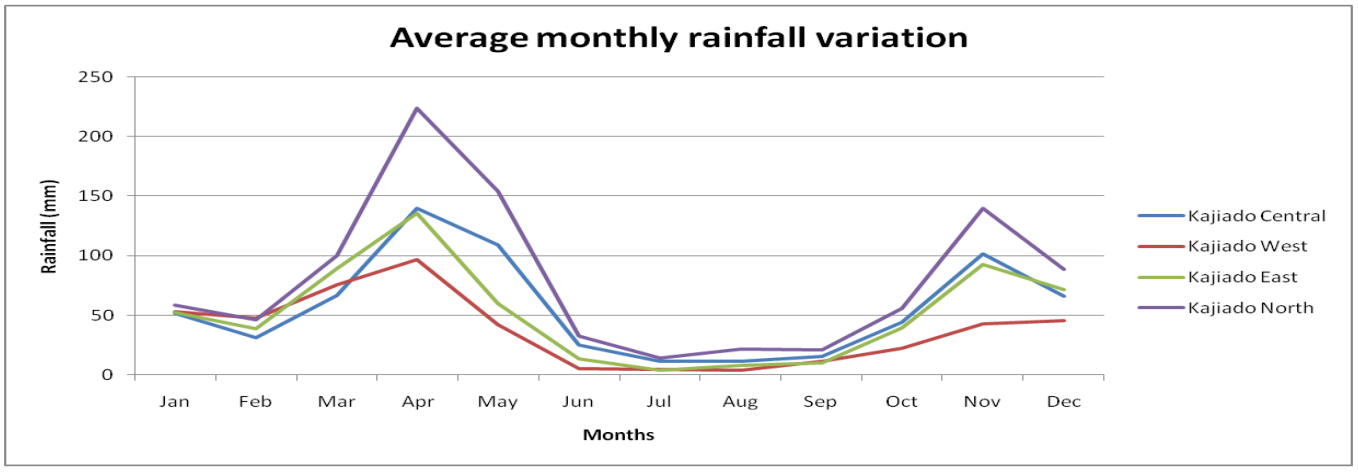

Figure 10: Average seasonal and monthly rainfall variation for the four stations from 1970 to 2013

Figure 10 shows the seasonal and monthly rainfall variation for the four stations considered in this research. The figure shows a bi modal rainfall pattern, confirming the assertions of Bekure et al., 1999, Ogallo, 1993, GOK, 2009a, GOK, 2000 and Opole, 2013 that Kajiado

County has two raining season, the long and the short raining season. The long raining season begins in March for all the stations and ends in May, while the short raining season generally starts around October and ends in December. Ngong has the highest annual average rainfall of 79.5mm followed by Mushuuru (56.21mm), Isinya (51.01mm) and least for Magadi (37.5mm). The rainfall pattern in Kajiado County is strongly influenced by altitude with the high areas around Loitokitok and Ngong receiving high rainfall when compared to low areas around Magadi and Amboseli (Bekure et al., 1999; GOK, 2000 and Amwata, 2013). The long rains reach a peak of 224.02mm in April in Ngong, Mashuuru has 139.51mm in April, Isinya has apeak of 135.49mm in April and Magadi has a peak of 96.72mm in April. The amount of rainfall in high altitude areas of Ngong is more than twice that of the low areas of Magadi. The short rains starts in Kajiado County in the month of October and reach its peak in November with Ngong having a rainfall of (140mm) in November, followed Mushuuru has (101mm) and Isinya (92.18mm). The late rains start around December (45.75mm) in Magadi and reach its peak in January (52.81mm). Generally the months of June, July, August and September are the driest months in Kajiado County with Magadi having a rainfall of 5.27mm, 4.59mm, 3.84mm and 11.53mm for the months of June, July, August and September respectively.

	Station							
	Ngong (KN)	MS	Magadi (KW)	MS	Isinya (KE)	MS	Mashuuru (KC)	MS
	Long rains	Short rains	Long rains	Short rains	Long rains	Short rains	Long rains	Short rains
Mean	478.2	284.2	214.6	110.4	284.0	203.0	315.1	211.8
Standard deviation	215.0	124.1	84.7	47.1	111.9	102.9	118.0	102.5
CV%	45.0	43.7	39.5	42.7	39.4	50.7	37.4	48.4

Table 1: Seasonal variability levels between the four stations

The seasonal variability for the four stations is presented in Table 1. The long rains (March to May) shows that Ngong station has a coefficient of variation of 45%, Magadi has a CV% of 39.5%, Isinya has a CV% of 39.4% while Mashuuru has a CV% of 37.4%. Ngong has the

highest CV% while Mashuuru has the lowest CV% for the long rains. The short rains show that Ngong has a CV% of 43.7%, Magadi has a CV% of 42.7%, Isinya has 50.7% while Mashuuru has a CV% of 48.4%. The table shows that Isinya has the highest CV% for the short rains and Magadi has the lowest CV%. Generally with the exception of Ngong station, the coefficient of variation in Magadi, Isinya and Mushuuru are higher during the short rains (March to May) than during the long rains (October to November), agreeing with the reports of Herrero 2010 and Opole 2013 that in Kajiado region, there is higher variability during the short raining season compared to the long raining season.

	Station			
Statistic	Ngong (KN) MS	Magadi (KW) MS	Isinya (KE) MS	Mashuuru (KC) MS
Mean(mm)	979.2	450.6	612.2	674.5
Standard Deviation	268.4	96.8	161.3	171.7
CV%	27.5	21.5	26.4	25.5

Table 2: Inter-Annual and spatial variability between four stations

The table on inter annual and spatial variability for Kajiado County (Table 2) shows that wide spatial variation in rainfall in Kajiado County. Kajiado north represented by Ngong has the highest average annual rainfall of 979.2mm followed by Kajiado central (Mashuuru) having average rainfall of 674.5mm, Kajiadi east (Isinya) has an average annual rainfall of 61.2mm while the least average annual rainfall was recorded in Kajiadi west (Magadi) having average annual rainfall of 450.6mm. The average annual rainfall in Kajiado north (Ngong) is twice that of Kajiado west (Magadi), this confirms Magadi region as one of the arid area in Kenya and highly susceptible to drought. The CV% is highest for Ngong (27.5%), followed by Isinya (26.4%) and Mashuuru having (25.5%) and lowest for Magadi (21.5%), this agrees with Opole 2013 that variation reduces with aridity of the area.

5. Conclusion And Recommendation:

Kajiado County is classified as one of the (ASALs) in Kenya which is highly susceptible to climate related events such as drought and dry spell. Findings of this study show high rainfall variability both inter-annual and seasonal as such makes rainfall unpredictable and unreliable in the County. The result shows that sub counties in Kajiado falls under different agro ecological zones and are therefore impacted differently by climate related events such as drought, dry spell and floods. It is therefore important that adaptation strategies to climate change and variability in Kajiado County should be location dependent to be effective. A comparison of coefficient of variation shows that there existed spatial climate variation to a tune of 6% and between seasons rainfall variability was wider to a tune of between 2.7% to 11%.

The result shows that rainfall in Kajiado County is highly influenced by altitude with areas of high altitudes like Ngong having annual rainfall that are more than twice the annual rainfall of lowlands like Magadi. The high variability in rainfall has also lead to increase in drought event in most areas in Kajiado County especially in low land areas like Magadi. It is however important to note that climate variability is not only about negative impact as it also present vast opportunities for livelihood diversification, proper and effective land use and management. Arid and semi arid lands present an opportunity for pastoralism if appropriately managed.

Response to climate change and variability involves the development of effective adaptation strategies to minimize the effect and maximize the available opportunities and also mitigation to reduce the amount of green house gases emitted and thereby reducing the magnitude of climate change impact in the long run. These are however founded on strong and effective policies. Policy makers should therefore come up with strong, effective and implementable policies for the management of ASALs in Kenya. However the quality of policies depends on the quality and amount of information available to the policy makers. There is therefore need to provide accurate and reliable climate and weather information for research purpose and decision makers. This will only be achieved by installing effective weather stations in each ecological zones to enhance precision and data availability.

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