THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Forage Dynamics in the Face of Rainfall Variability across Pastoral Plains of Kajiado, Kenya

Ombogo M. Opole
Tutorial Fellow, Department of Geography and Environmental Studies, KIBABII University, Kenya

Abstract:
The study aimed to examine forage changes and change dynamics relative to rainfall variability in Kajiado county of Kenya. Forage was examined as a key factor influencing pastoral productivity. Rainfall data from Ngong Divisional Office, Mashuru and Magadi Soda Works Meteorological Stations, representing different ecozones, were analyzed through standard deviation, mean, range and coefficient of variation (C.V.) over the period 1964 - 2011. Data on forage levels for the period 1982 – 2004 were processed in the form of Normalized Differential Vegetation Index (NDVI) for sampled areas within the four ecozones. Time series of these data were then averaged into dekadal means and annual averages then regressed and correlated with corresponding rainfall data at lags 0 and 30days. Findings for this research suggested that rainfall over Kajiado had overtime revealed high variability; spatially, seasonally and inter-annually. Spatial variations revealed that Mashuru to the East had exhibited higher variability (C.V. = 26%) compared to areas around Ngong in the North (C.V. = 24%) and areas around Lake Magadi in the West (C.V=21%). Similarly, there was higher variability during the short-rain seasons as compared to long-rain seasons over the three stations. The results indicated that forage indices strongly correlated to rainfall amounts at Magadi Soda Works Meteorological Station, accounting for 74% of forage at onset and 92% at peak vegetation performance, while at Mashuru Meteorological Station it accounted for 48% at onset and 89% at its peak.

Keywords: *Rainfall variability, forage, normalized difference vegetation index*

1. Background

Climate Change and variability creates risks in many climate sensitive sectors such as agriculture, biodiversity, livestock, water resources and health, with its extremes affecting mostly the welfare and livelihoods of rural populations. Among the climate parameters that have exhibited a shift in both short and long-term trends are rainfall and temperatures. These two have impacts upon the terrestrial waters, atmosphere, cryosphere, and biosphere resulting into phenomena such as the abnormal rainfall regimes, droughts, floods and changes in species composition in various ecosystems. These changes have led to competition among organisms and human adjustments in a bid to cope.

Developing countries are among the high climate variability risk prone nations. Arid and Semi-Arid Lands (ASALs) of Africa are particularly vulnerable because of the dominance of pastoralism and rain-fed rather than irrigated agricultural food production systems. In Africa, high levels of vulnerability and low adaptive capacity have been linked to factors such as limited ability to adapt financially and institutionally, low per capita gross domestic product (GDP) as well as high poverty rates. As reported by Kenya Food Security Steering Group (2009), Livestock production contributes 50 percent of all household incomes in Kenyan ASAL districts compared to marginal farming which contributes 30 percent.

To enhance productivity of pastoral systems, it is essential to understand the time-series interactions and dynamisms among system such as climate, water resources, and forage conditions. One of the most suggested methods for evaluating forage statues with time is through satellite observations of vegetation and synthesis of the reflectance values; mainly through calculation of vegetation indices such as the Normalized Difference Vegetation Index (NDVI). It assesses whether the target being observed contains live green vegetation or not. It is a remote sensing based index (ranging from 0 to 1) reflecting vegetation greenness with NDVI < 0.20 - 0.25 for bare soil and dead vegetation and NDVI of 0.6 to 0.7 for green vegetation with closed canopy (Zwaagstra *et al*, 2010). In most cases NDVI is correlated with photosynthesis, and since photosynthesis occurs in the green parts of plant material, the NDVI is normally used to indicate green vegetation cover (Nicholson, 1994). It is often directly related to other ground parameters such as percentage of ground cover, photosynthetic activity of the plant, surface water, leaf area index and the amount of biomass (Nicholson *et al*, 1998). These aspects make NDVI an instrumental tool in determining rain-use efficiency because the net annual increase of biomass, or net primary production, is a measure of the productivity of an ecosystem and this quantity bears a direct relationship to photosynthesis and NDVI is strongly correlated with both, particularly in arid lands (Nicholson *et al*, 1998).

2. The Study Area

The study area is located in the semi-arid southern rangelands of Kenya at an altitude ranging from 600m at the floor of Rift Valley, around Lake Magadi to 1,100m above sea level. Enclosed within longitude 36.0^0E – 37.8^0E and latitude 1.25^0S – 3.12^0S, it is bordered by the Nairobi-Mombasa railway to the north-east, Machakos County to the East, Nairobi National Park to the North, to the south is the Tanzania border, and the western wall of the Rift Valley to the West.

Kajiado county has an estimated population of 405,685 and an area of 21,902.9 km^2, (GOK, Kajiado District: District Strategic Plan 2005 – 2010), translating to an average density of 19 persons per km^2. The Maasai form the bulk of population by ethnicity and are mostly organized into group ranches, owning 90% of the cattle in Narok and Kajiado Districts (Bukure *et al*, 1991). The county is divided into three main physiographical divisions namely; ground occupied by the basement system, the volcanic plains and the plateau and the Rift Valley (Matheson 1966). These also form the ecozones of the Rift Valley, the upland Athi Kapiti Plains, the Central Hills, and the Amboseli Plains (Bekure *et al*. 1991).

2.1. Climate and Vegetation

Most of Kajiado County lies in the semi-arid and arid zones (Bekure *et al.* 1991). It is characterized by warm and hot climate with temperatures ranging between 20ºC and 28ºC with a mean of 25ºC (GOK, 2008). Only eight percent of its land is classified as having some potential for rain-fed cropping, mostly in the Athi-Kapiti Plains, close to Nairobi and in the south of the District, along the Kilimanjaro foothills (Bekure *et al.* 1991). Mean annual rainfall ranges from 300 to 800mm, while the average annual potential evapotranspiration ranges from 1600mm to 12200mm (GOK, 2008), which means there is moisture deficit for the greater part of the year. Rainfall is bimodal with short rains from October to December and long rains from March to May. The distribution of rainfall between the two seasons changes gradually from east to west across Kajiado District (Bekure *et al.* 1991). In eastern Kajiado more rain falls during the short rains than during the long rains while in western Kajiado the majority of rain falls during the long rains (Bekure *et al.* 1991). The temperatures also vary with altitude where the low laying areas record high temperatures of about 30 degrees (GOK, 2005). Temperatures too vary from mean maximum of 34^0C around Lake Magadi to a mean minimum of 10^0C on the foothills of Mount Kilimanjaro and Ngong Hills (GOK, 2008). According to Bekure et al., 1991, the county is colonized by a total of92% of ASAL ecosystems with only Athi-Kapiti ecozone free of arid patches. Rift Valley Ecozones lead in percentage of semi-arid lands (71%) while vast areas of Amboseli Ecozones are arid (69%).

Woody cover	**Percent of area**					
Percentage	**Vegetation type**	**Rift Valley**	**Athi-Kapiti Plains**	**Central Hills**	**Amboseli Plains**	**Total**
0 - 2	Open grassland	9	71	14	37	26
2 - 20	Wooded and bushed grassland	74		10		26
20 - 40	Bush and woodland	16	29	75	59	44
> 40	Forest and other types	1		1	4	2

Table 1: Percentage of land area under vegetation of different types in the four ecozones of Kajiado County
Source: Adopted from Bekure et al., 1991

3. Methodology

3.1. Data Sources and Description

A long-term, 48 year monthly rainfall data for Mashuru Meteorological Station in the East of the study area, location; 2.10^0S, 37.10^0E, Magadi Soda Works to the West, located at 1.88^0S, 36.28^0E (here after referred to as M.S.W) and Ngong Division Office in the North; 1.31^0S, 36.65^0N (here after referred to as N.D.O) Meteorological Stations recorded from 1964 to June 2011 were obtained from the Kenya Meteorological Station in Dagorretti and Magadi Soda Works (M.S.W Meteorological Station) in Magadi. The three stations were selected for the study because they had a long-term data, their presence within different ecozones of the county and spatial spread.

Statistical data on forage for the period between the months of January 1982 to December 2004 was acquired in the form of Normalized Difference Vegetation Index (NDVI) from http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.ADDS/.NDVI. The values were a calculation from Advanced Very High Resolution Radiometer (AVHRR) data from National Oceanic and Atmospheric Administration (NOAA) polar orbiting satellite. Selections were discriminately done to avoid ecozones that could lead to a large distortion of signals such as the slopes of Mount Kilimanjaro to the South East, slopes of Chiulu Hills to the East, Ngong forest, and Lake Magadi. The choice of this parameter was informed by arguments by Nicholson *et al*. 1990; and Nicholson and Farrar 1994 that the ratio of NDVI to rainfall provides a useful proxy for rain-use efficiency. Selections for each ecozones were restricted between longitudes and latitudes: 37.22^0E-37.75^0E and 2.56^0S-2.83^0S for Amboseli; 36.08^0E – 36.39^0E and 1.53^0S-1.74^0S for Rift Valley; 36.62^0E-36.92^0E and 1.533^0S-1.81^0S for Athi Kapiti; and 36.69^0E-37.07^0E and 2.01^0S-2.28^0S for Central Hills Ecozones. The total forage sampled area was 4886.36Km^2.

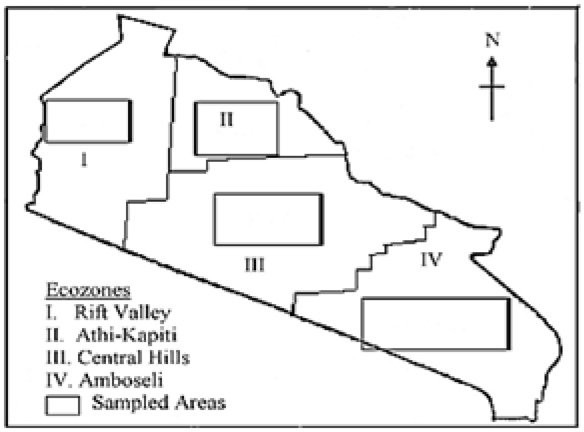

Figure 1: Map of Kajiado County showing forage sampled areas in every area in every ecozone
Source: Researcher, 2012, base map adopted from bekure et. al, 1991

3.2. Data Processing and Analysis

Rainfall data for N.D.O Meteorological Station was fully available. However, data for Mashuru Meteorological Station was only available for the period 1964 to 1985 while M.S.W Meteorological Station was available for the period 1964 to 1990. The missing data for the two stations were therefore reconstructed using the formula:

$$a + bx,$$

$$a = \overline{y} - b\overline{x}$$

and:

$$b = \frac{\sum (x-\overline{x})(y-\overline{y})}{\sum (x-\overline{x})^2}$$

At Mashuru Meteorological Station, available data were forecasted against rainfall data at Wilson Meteorological Station while M.S.W data was reconstructed against Narok Meteorological Station.

Where:
-Known xs=Data from Wilson Meteorological Station
-Known ys=Data from Mashuru Meteorological Station
-Known xs=Data from Narok Meteorological Station
-Known ys=Data from M.S.W Meteorological Station

Using Pearson's correlation (r), at a significance level 0.05, the correlations yielded 98% and 66% correlation between Mashuru-Wilson and M.S.W-Narok Meteorological Stations respectively.

<u>3.2.1. Rainfall Variability over Kajiado County</u>

Graphical presentations were done to demonstrate seasonal and inter-annual rainfall characteristics at the three stations. Analysis of inter-annual and seasonal components for the data was done to reveal general information for a time series within a year and between different years. It was also useful for comparing the general variations among the input data series, especially for different locations for the same time period. To achieve this, excel was used to calculate the standard deviation for the research data.

Standard Deviation (SD)

$$SD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \overline{x})^2}$$

Coefficient of Variation (%C.V.) was calculated to reveal the degree of seasonal and inter-annual climate variation at the three stations of study using the formula;

%C.V. = Standard Deviation / Mean

Comparative values of C. Vs among the three rainfall stations were conducted to determine the spatial differences in variability between ecozones of the study area represented by the respective meteorological stations. Variability factors of successive poor rainfall return rate of below normal rainfall seasons, and heavy rainfall events were graphically identified and analyzed.

<u>3.2.2. Relationship between Rainfall Variability and Forage</u>

Maximum NDVI values for the selected areas were considered then averaged over 10 days, for the period January 1982 to December 2004. Maximum values were used because it minimizes the influence of varying solar zenith angles and surface topography on the index (Nicholson, 1998). The formula applied in calculating NDVI was:

NDVI = (NIR - Red) / (NIR + Red)

Where:

NDVI: -Normalized Differential Vegetation Index
NIR: -Near Infra-red band of The Electromagnetic Spectrum
Red: -Red band of the Electromagnetic Spectrum

NDVI values were further averaged on dekadal and annual counts. Using SPSS, a simple linear regression was run for mean dekadal and annual rainfall against the dekadal and annual NDVI values for the corresponding periods; where Pearson's Correlation Coefficient (r) was used at 95% confidence interval to test the nature and strength between the variables. In this analysis, rainfall data used were from M.S.W and Mashuru Meteorological Stations since they were respectively representative of arid and semi-arid ecozones. Due to unavailability of daily rainfall data, monthly mean amounts were spread over the three dekads and applied in the analyses. Since vegetation does not immediately respond to changes in rainfall amounts, NDVI values were lagged at 0-3dekads since the maximum correlation fell within the third dekad. The maximum one-month lag obtained was lower than that suggested by Nicholson et al. (1990), Klein and Roehrig (2006) and Pasture Network for Eastern and Southern Africa, PANESA (1988). The lagged correlations were tested against un-lagged response (concurrent dekad) with rainfall records at the two Meteorological Stations. Two ecozones; Athi Kapiti, representing semi-arid climate zone (annual rainfall=450-900mm) and Rift valley (around Lake Magadi), representing arid zones (annual rainfall=300-550mm) were discriminately sampled. Graphical comparisons were made between individual rainfall stations data on one hand and corresponding ecozones on the other. Spectral images were generated to reveal average seasonal forage reflectance.

4. Results and Discussions

4.1. Rainfall Variability over Kajiado County

4.1.1. Spatial and Inter-Annual Rainfall Variability over Kajiado County

The three stations yielded Coefficient of Varriability (C.V.) values of 24% at N.D.O. Met. Station, 26% at Mashuru Met. Station and 21% at M.S.W. Met. Station (Table 2), indicating an existence of higher climate variability around Mashuru to the East and Ngong in the North compared to areas around Magadi to the West of the county.

	N.D.O. Met. Station	Mashuru Met. Station	M.S.W. Met. Station
Mean(mm)	830.3	671.1	449.3
STDEV(mm)	202.3	174.9	94.0
C.V	0.24	0.26	0.21

Table 2: Inter-Annual and spatial variability levels between the three stations

Northern parts of the county (represented by N.D.O Meteorological Station) recorded an average annual mean of 830.3mm over the period 1964 to 2011, Mashuru experienced a lower mean amount of 671.1mm while M.S.W Meteorological Station to the West registered a mean of 449.3mm over the same period. A comparison in coefficient of variation over Mashuru Meteorological Station (24%) and N.D.O Meteorological Station (26%) shows a high variability levels over areas receiving low rainfalls, an indication that climate variability increases with aridity (Ojwang *et al*., 2010). This assertion by Ojwang *et al*., 2010 is however, disputed by the existence of lower variability coefficient (21%) over more arid areas around M.S.W with mean annual rainfall of 449.3.

4.1.2. Seasonal Rainfall Variability

Analyses of variability yielded differences in Coefficient of Variability over seasons at the three stations (Table 3). During the long rains season (March - May), Ngong Divisional Office Meteorological Station had a C.V of 34%, Mashuru Meteorological Station had 40% while M.S.W. Meteorological Station experienced variability of 39%. Short rain season (October - December) had a comparatively higher C.V. of 49% at N.D.O., 50% at Mashuru and 44% at M.S.W. Generally, rainfall variability was higher in all the stations during the short rain seasons compared to long rainfall season, confirming assertions by Herrero, 2010 and Ojwang 2010 that in this region, there is higher variability during the short rain seasons compared to long rain seasons.

	N.D.O. Met. Station		Mashuru Met. Station		M.S.W. Met. Station	
Season	Long Rains	Short Rains	Long Rains	Short Rains	Long Rains	Short Rains
Mean(mm)	412.53	208.18	322.51	203.31	73.25	35.63
STDEV(mm)	139.26	102.54	128.03	101.65	28.23	15.82
C.V.	0.34	0.49	0.40	0.50	0.39	0.44

Table 3: Seasonal Variability levels between the three stations/Ecozones

The month of March appear to be the onset month for the long rains both around Ngong and Mashuru (Fig.2). However, there is variability in the onset amounts with Ngong in the North of the County recording a mean amount of 88.8mm, an amount higher than 65.9mm, which is the mean rainfall amount recorded for the onset month at Mashuru. April, which marks the peak of the long rain season in the area also experiences a higher rainfall mean amounts of 175.9mm around Ngong compared to 144.6mm at Masuru and

102.1mm around Magadi to the West. Throughout the long rain season, Northern Kajiado registers higher rainfalls compared to the central and Western parts of the county.

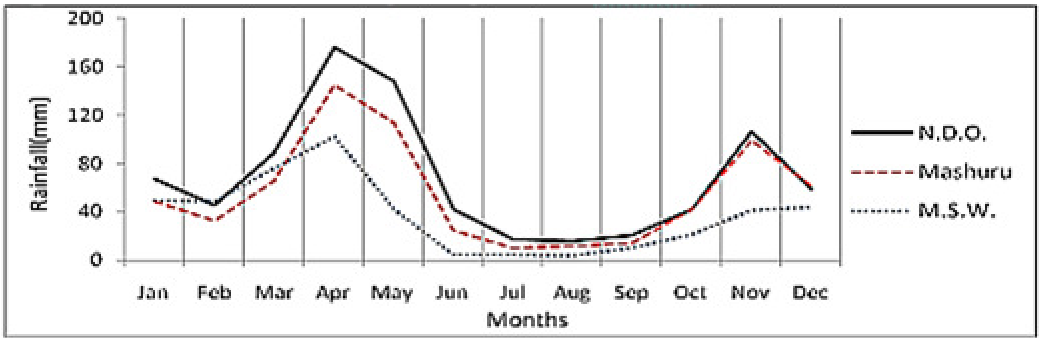

Figure 2: Seasonal and Monthly Rainfall over Kajiado from 1964 to 2011

During the second rain season, the three stations appear to record onset during the month of September but with lower rainfall at M.S.W(10.8mm) and Mashuru(14.2mm) Meteorological Stations as compared to N.D.O Meteorological Station (20.6mm). However, areas around Mashuru in the East tended to receive higher intensity rainfalls (42.2mm) in the month of October, negligibly falling below that over Ngong areas by 0.3mm. This also repeated itself in the month of December where areas around Mashuru (62.0mm) experienced mean rainfalls higher than Ngong (59.4mm). During this season, areas to the West around Magadi tend to have its long rains from September through to February. The rains are however of low intensity, starting to plateau in November (41.2mm) through to February (48.5mm) with a higher amount recorded in January (49.6). The dry month of February exhibited an observable level of spatial variability between Eastern, Western and Northern parts of the county in that whereas N.D.O and Mashuru Meteorological Stations recorded a bellow mean rains of 45.7mm and 32.5mm respectively, areas around M.S.W Meteorological Station recorded a higher and above mean amount of 48.5mm.

4.5. Forage Response to Rainfall Variability Over Kajiado County

4.5.1. Forage Characteristics over Kajiado County

With reference to the long-term mean NDVI value of 0.309 (Figure 3), the area had experienced fourteen years of below average forage cover and nine years of above average cover. The longest period during which suppressed forage were recorded were; 1982 – 1984, 1991 – 1994 and 2002-2004. A single notable year which saw vegetation sinking to its lowest was in 2000 in which an average NDVI value of 0.2524 was registered. On the other hand, the area evidently faced a long (three year) period of above average forage cover from 1988 to 1990. However, the following years only saw increased oscillation in performance where only 1996, 1998, and 2001 registered above average NDVI. Over the 23 years' research period, forage had followed continuous inter-annual fluctuations registering its highest annual average of 0.3997 in 1998.

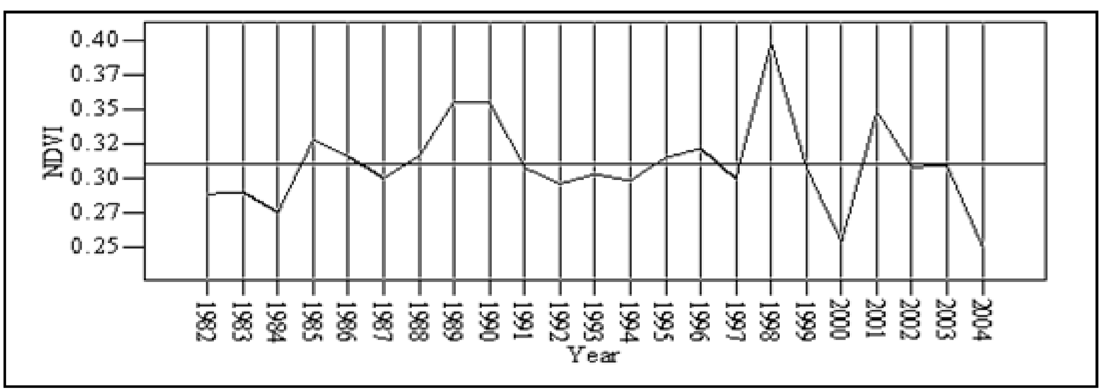

Figure 3: Integrated Inter-Annual Forage Variation Over Kajiado County, 1982-2004

An analysis of annual variations in forage levels revealed a seasonal pattern. Figure 3 shows that 10-day decadal averages for the 23-year research period revealed that 7 out of the 12 months (November 21 to June 30th) had above average forage yield. Most notable good growth season was between the last dekad of April and mid dekad of May which registered a performance of above 0.4 and peaked at 0.416 in mid-May (Figure 4). This was then followed by a gentle decline to the second third of June and a drastic reduction in the last third of the same month. From the 1st dekad of July to the second dekad of November, the area experienced a below average forage cover, a period which saw periods between 11th – 20th August through to 11th – 20th of October registering NDVI signatures bellow 0.2 and sinking to its average lowest of 0.1858 between 21st-30th September.

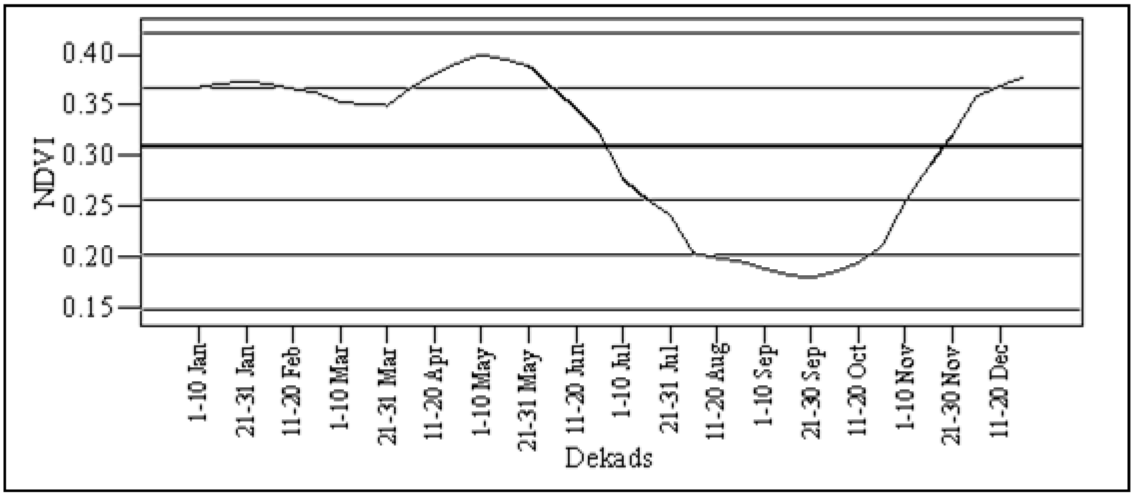

Figure 4: Integrated Seasonal Forage Variability Over Kajiado County, 1982-2004

Spatially, forage levels varied over the three study ecozones where Rift Valley ecozones (around Magadi area) registered an all-time low forage except for the first dekad of April when it recorded values (0.352) equaling values over Athi Kapiti ecozones (Figure 4) and between the last dekad of February through to mid-July. Unlike the other three ecozones, forage over Amboseli tends to perform higher in the second season (November to January) as compared to the first season (April to May). In as much as forage over Central Hills were higher during most of the seasons, a sharp decline between mid-June to mid-August saw Athi Kapiti registering a slightly higher NDVI values compared to Central Hills (Figure 5).

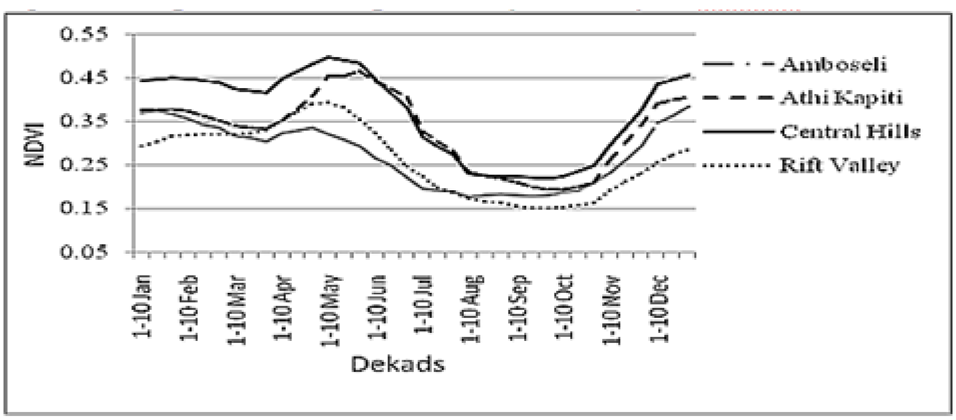

Figure 5: Average Seasonal Forage Variability over the four ecozones, 1982-2004

Analyses of both seasonal and inter-annual forage variabilities showed that between 1982 and 2004, Kajiado County never experienced either a year or season with total lack of vegetation since the lowest average NDVI signature the seasons registered was 0.233 (Figure 5) while an annual lowest average was 0.276. On the other hand, neither a year nor season recorded an average NDVI signature close to unity, a sign that the area never had a total canopy cover. Despite the poor general average forage performance, there were parches of good performing seasons registering signatures above 0.5, such as April – May of 1985, 1988, 1990, and 1991, and also seasons which registered slightly above 0.6 such as early 1998 and 2011.

4.5.2. Effect of Rainfall Variability on Forage over Athi Kapiti Ecozone

As shown in Table 4, at a lag of 0 (within 10days of rainfall onset), association between mean monthly rainfall at Mashuru Meteorological Station and mean dekadal forage levels over Athi Kapiti Ecozone had an r-value of 0.477. This indicated that there was a low significant association between forage levels and rainfall amounts measured within 10days of onset. However, a lag of 30days for this ecozone yielded a higher r-value of 0.892 indicating a very strong relationship between forage and rainfall within one month of onset.

Correlations		
	NDVI (Athi Kapiti), lag0	NDVI (Athi Kapiti), lag30
Rainfall(Mashuru)	.477	.892
Sig. (2-tailed)	0.003	0

Table 4: Correlation between Mean Monthly Rainfall and Dekadal NDVI over Athi Kapiti Ecozones within the first 10 and 30days of rainfall onset (lag0 and 30)

The analyses yielded test values of 0.003 and 0.0 at lags 0 and 30days respectively and were significant at 0.05 confidence level (Table3). Within the first 10 days (unlagged), rainfalls at this station influenced increase in forage availability over Athi Kapiti ecozones by a factor of 0.10 for every unit increase in rainfall amounts (Figure 12a). A regression line generated to check the degree to which rainfall impacted upon forage had a fair curve fitting with an r^2 of 0.23 - showing that the recorded rainfalls lowly explained the fluctuations in forage availability and quality.

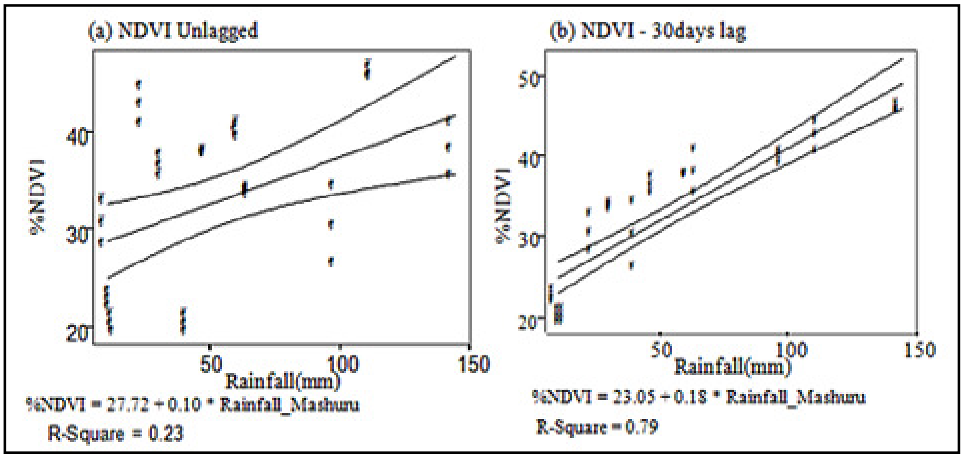

Figure 6: Regression diagram showing relationship between NDVI and Mean Monthly Rainfall at Mashuru Meteorological Station at a lag 0 and 30 days

On the other hand, a lag of 30days over the same ecozone generated a close to unity regression line with a good curve fitting and yielded an r^2-value of 0.79 (Figure 6b). This revealed that the magnitude to which rainfall influence forage levels within this period from the onset is very strong since other factors only accounted for a minimal degree of 21%. It also reflects that a unit increase in rainfall amounts led to a rise in forage level by a factor of 0.18. At the same time, the scatter plots are closely clustering around the regression line as compared to unlagged (Figure 6a).

4.5.3. Rainfall Variability on Forage over Rift Valley Ecozone

Within Ten days of rainfall onset, correlation between monthly rainfalls at M.S.W Meteorological Station against forage at the Rift Valley Ecozone yielded a strong correlation value of 0.739 significant at 0.05 confidence level (Table 5). This indicated an existence of a very strong significant association between rainfall and forage within this ecozones as rainfalls accounts for upto 74% of forage.

Correlations		
	NDVI (Rift Valley), lag0	NDVI (Rift Valley), lag30
Rainfall (M.S.W)	.739	.923
Sig. (2-tailed)	0	0

Table 5: Correlation between Mean Monthly Rainfall and Dekadal NDVI over Rift Valley Ecozones within the first 10 and 30days of rainfall onset (lag0 and 30)

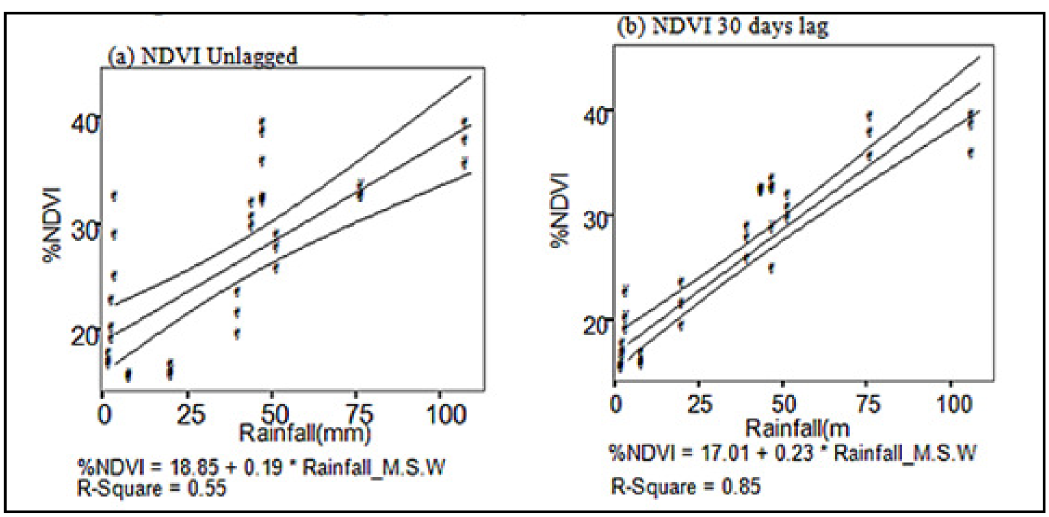

Figure 6: Regression diagram showing relationship between NDVI and Dekadal Mean Rainfall at M.S.W Meteorological Station at a lag 0 and 30 days

As indicated in Table 5 and Figure 7b, when forage over Rift Valley Ecozone was lagged by 30 days and correlated with decadal rains at M.S.W Meteorological Station, it yielded a correlation coefficient of 0.923, significant at 0.05 confidence levels, an indication of a very strong significant association between rainfall and forage levels over this ecozone. 30 days after onset, rainfalls at this station explained upto 92% of forage available over this ecozone and accounted for changes in forage performance to a magnitude of 85%, with a further increase in unit rainfall raising percentage forage level by a factor of 0.23 (Fig.7b). A generated regression line displayed a close to unity curve fitting showing that forage dynamics over the Rift Valley Ecozones were highly impacted upon by rainfall since other factors only accounted for 15% of forage available and 7.7% of changes in forage level. This is also evidenced by the scatter plots closely clustering around the regression line.

4.5.4. Seasonal Forage Response to Rainfall Variability

As depicted in Figure 8, at the onset of long rains over Central Kajiado in the last dekad of February, a 30-day lapse period in forage response occurs pushing forage onset by the same amount of time to the last dekad of the following month (March 21st – 31st). Similarly, as the rainfall peaks in the month of April, a corresponding peak in forage around Athi Kapiti Ecozone is realized later in the last dekad of May. A drop in mean rainfall amounts from 144.6mm in April to 113.3mm in May correspondingly led to an equal temporal (30days) forage decline from the last dekad of May to the last dekad of June. A further sharp drop in rainfalls from 113.3mm in May to its lowest mean of 10.5mm in July evidently impacted on forage levels from the last dekad of June through to the end of September.

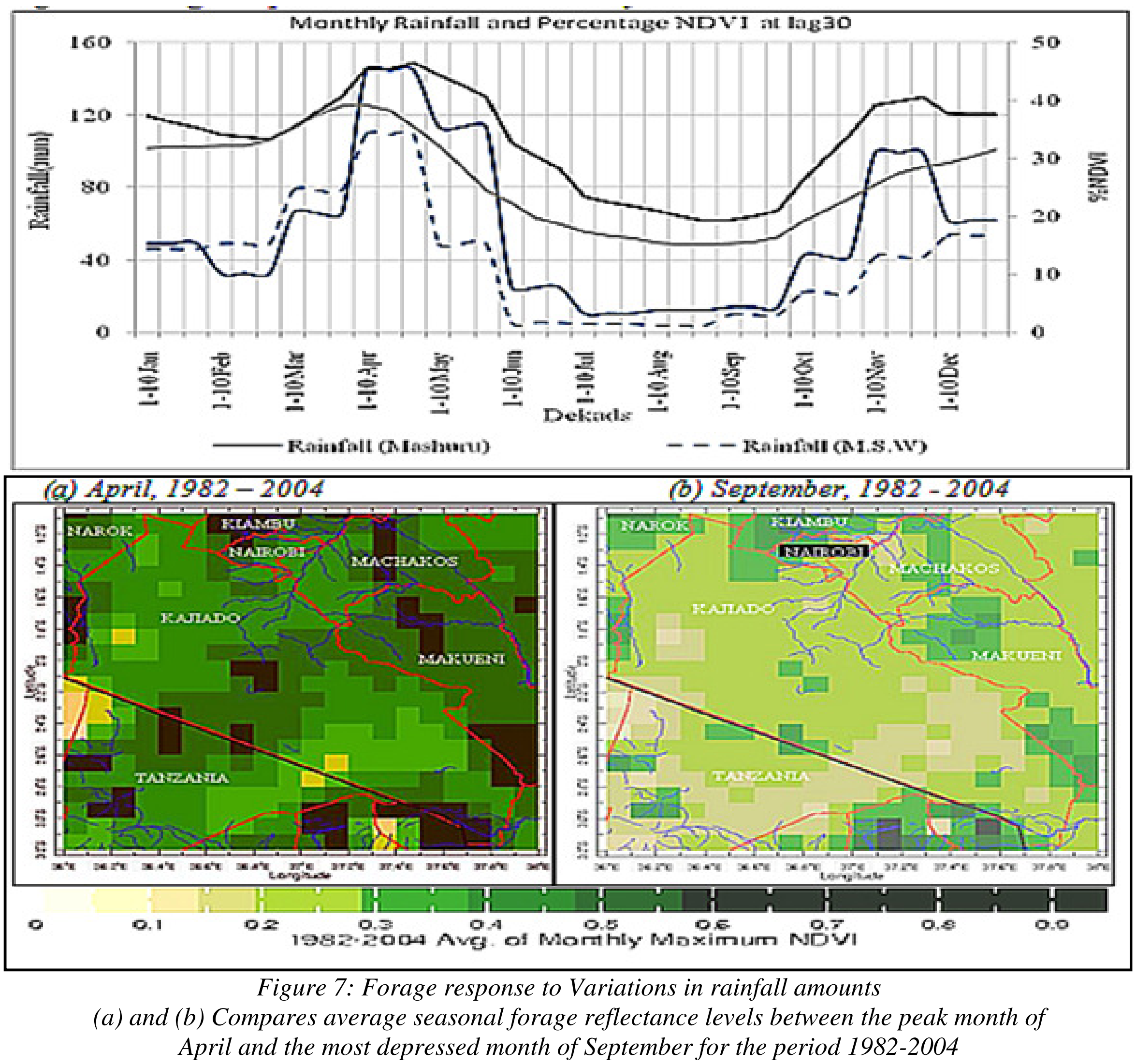

Figure 7: Forage response to Variations in rainfall amounts
(a) and (b) Compares average seasonal forage reflectance levels between the peak month of April and the most depressed month of September for the period 1982-2004

4.5.5. Inter-annual Forage Response to Rainfall Variability

As depicted in Figure 1, there was a responsive tendency by forage to fluctuations in rainfall over the 23 years' study period. The low rainfall amounts recorded in the years 1983, 1984 and 2000 were accountable for the bellow mean NDVI values of 0.29, 0.28 and 0.26 respectively registered over that period. A push to forage peaks in 1985, 1989, 1998, and 2001, were as a result of high rainfalls received in those years, a confirmation of findings by Jahnke 1982, that in low rainfall areas, fodder production is a function of annual rainfall.

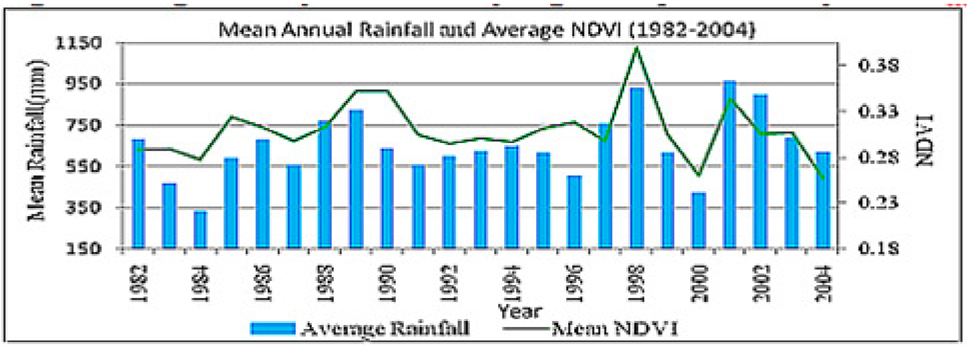

Figure 8: Average annual fluctuation in forage in response to rainfall over Kajiado County

In as much as rainfall accounted for forage performance in the area, it did not account for a constant climb in forage against annual decline in rainfall from an average total of 614.2mm and 502.6mm in 1995 and 1996 respectively (Figure 8). The good performance by forage over this period could be associated to management practices Klein and Roehrig (2006) or assertion by the same authors that in Kenya, rainy season can fail completely but even in the driest years some vegetation growth occurs.

5. Conclusions

Findings of this study showed that both inter-annual and seasonal rainfall variability is high in Kajiado County and as such the rainfalls were unreliable and unpredictable. Comparisons of C. Vs showed that there existed spatial rainfall variability to a tune of 5% while on a seasonal account the variability range was wider to a tune of between 5 to 15 percent. Rainfall had a direct and significantly high influence on forage performance. The high correlation coefficients over the two ecozones of Rift Valley (arround Lake Magadi) and Athi-Kapiti indicates that in arid and semiarid regions, NDVI correlates well with percentage vegetation cover, biomass, and biological productivity (Nicholson 1994).

It is however important to note that climate variability may not only be of negative impact as frequently reported; it also presents vast opportunities for pastoralists, so long as appropriate managerial practices are put in place. In as much as increasing and stable/less variable precipitation would be more beneficial to pastoralists, it is important to note that although pasture and ecosystems are more productive with more precipitation, lower precipitation may help reducing animal diseases that are quite significant for livestock.

6. References

i. Bekure S, P. N. de Leeuw, G.E. Grandin and P. J. H. Neate (1991). Maasai herding: An analysis of the livestock production system of Maasai pastoralists in eastern Kajiado District, Kenya. ILCA Systems Study 4. ILCA (International Livestock Centre for Africa), Addis Ababa, Ethiopia. 172 pp.

ii. Government of Kenya, National Coordinating Agency for Population and Development (2005), Kajiado District Strategic Plan 2005-2010; Ministry of Planning and Development, Republic of Kenya.

iii. Government of Kenya, Office of the Prime Minister, Ministry of State for Development of Northern Kenya and Other Arid Lands Resource Management, Kajiado District Annual Progress Report, July 2008-June 2009.

iv. Herrero, M., C. Ringler, J. van de Steeg, P. Thornton, T. Zhu, E. Bryan, A. Omolo, J. Koo and A. Notenbaert (2010). Climate variability and climate change and their impacts on Kenya's agricultural sector. Nairobi, Kenya. ILRI

v. Jahnke, H.E. (1983). Livestock Production Systems and Livestock Development in Tropical Africa. Kieler Wissenschaftsverlag Vauk, Kiel.

vi. Kenya Food Security Steering Group (2009)

vii. Klein, D., and Roehrig, J. (2006), How does vegetation respond to climate variability in a semi-humid West African in comparison to semi-arid East African environment?. University of Bonn

viii. Matherson F. J., (1966), Geology of the Kajiado Area; Republic of Kenya, Ministry of Natural Resources and Wildlife Geological Survey of Kenya, Report No. 79.

ix. Nicholson S. E, (1994): On the use of the normalized difference vegetation index as an indicator of rainfall. Global Precipitations and ClimateChange, NATO ASI Series 1, Vol. 26, Springer, 293–306.

x. Nicholson S. E, Tucker CJ, Ba MB (1998) Desertification, drought, and surface vegetation: an example from the West African Sahel. Bull Am Met Soc 79:815–829

xi. Nicholson, S. E, (1990): The need for a reappraisal of the question of large-scale desertification: Some arguments based on consideration of rainfall fluctuations. Report of the SAREC-Lund International Meeting on Desertification, December 1990, Lund, Sweden, 14pp.

xii. Pasture Network for Eastern and Southern Africa (PANESA), 1988 African forage plant genetic resources, evaluation of forage germplasm and extensive livestock production systems. Proceedings of the Third Workshop held at the International Conference Centre, Arusha, Tanzania, 27–30 April 1987. ILCA, Addis Ababa. pp. 260–268.

xiii. Zwaagstra, L., Z. Sharif, A. Wambile, J. de Leeuw, M.Y. Said, N. Johnson, J. Njuki, P. Ericksen, and M. Herrero (2010). An assessment of the response to the 2008/2009 drought in Kenya: A report to the European Union Delegation to the Republic of the Republic of Kenya. ILRI, (International Livestock Research Institute) Nairobi, Kenya, 108p

xiv. http://iridl.ldeo.columbia.edu/SOURCES/.USGS/.LandDAAC/.MODIS/.version_005/.WAF/.NDVI/