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Rainfall Variability Effects on Pastoral Pasture Availability in Turkana Central Sub-County, Kenya

D. C. Moso[1*], G. M. Ogendi[1], S. M. Makindi[1] and G. M. Maina[1]

[1]Department of Environmental Science, Egerton University, P.O.Box 536-20115, Egerton, Kenya.

Authors' contributions

This work was carried out in collaboration between all authors. Author DCM designed the study, collected data, performed statistical analysis and wrote the first draft. Authors GMO and SMM helped in designing the study and managed the analyses of the study. Author GMM generated Normalized Difference Vegetation Index maps. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study was conducted to analyse rainfall variability and assess its effects on pasture availability, over the period 1983 to 2014.
Study Design: The study employed causal research design, in order to highlight the changes in pasture availability in response to rainfall variability.
Place and Duration of Study: The study was conducted in Turkana Central Sub-County, between June 2014 and December 2014.
Methodology: Landsat images for the years 1984, 2002 and 2014 were obtained. Meteorological rainfall data for the period 1983 to 2014 was acquired. Focus group discussions were held with village elders and key informants from Livestock Department. Data was processed and analysed using descriptive statistics and Geographic Information Systems softwares, to generate Normalized Difference Vegetation Index values.
Results: The study findings revealed that the significant pastures were tree leaves and shrubs, *Acacia tortilis* being the most abundant tree species in the study area. It was also established that the amount of rainfall received in Turkana Central varied annually, displaying a general trend of 160.7 mm increase over the thirty-two years. Consequently, pasture availability increased; the mean Normalized Difference Vegetation Index value in the year 1984 was 0.262, whereas it was

**Corresponding author: E-mail: daisymoso@gmail.com, mosodaisy@yahoo.com;*

0.377 in the year 2014. However, with the reduction of the drought cycle from 10 to 2 years, pasture scarcity had become more severe in the recent past.
Conclusion: Increasing amount and variability in rainfall led to increase in pastures. However, unlike in the past, severe pasture scarcity is experienced during droughts, which are becoming more recurrent, intense and prolonged.

Keywords: Rainfall variability; climate variability; pastoralism; pasture availability; vegetation; Turkana Kenya.

1. INTRODUCTION

Pastoral systems provide an important source of livelihood to many people in the world. About 40 million people, almost half of them being African pastoralists, depend almost entirely on livestock for their livelihoods [1]. Rangeland productivity is mainly determined by rainfall. Rainfall is very important for pastoral systems as it determines the distribution, amount and quality of pasture [2]. However, over the years climate variability, particularly rainfall variability, has negatively affected the ability of local ecosystems to meet the ever increasing demand for feed resources for livestock; sustainability of pastoral systems has been facing a lot of challenges in Africa, especially in terms of availability of adequate animal feed resources [3]. When successive rainy seasons fail, there is insufficient regeneration of grazing land, and areas under pastures reduce.

Inter-annual variability of rainfall has been increasing globally [4]. In addition, large regional differences exist in rainfall variability [5]. In some regions, different climate models project different trends in wet and dry extremes, while in other regions the models show clear trends of either wetness or dryness [6]. Scenarios for summer rainfall in the Sahel region vary by as much as +/- 20% [7]. In Kenya, rainfall variability is increasing: rainfalls have become irregular and unpredictable, and downpour is more intense when it rains [8]. A general decline in the amount of rainfall has been observed during the long rains season (March to May); frequent and prolonged droughts are experienced during this season [8]. On the other hand, more rains have been received during September to February, extending the short rains season (usually October to December) into a previously hot and dry period of January and February [8].

Nomadic pastoralism, based on the subsistence-based exploitation of shifting, grazing and browsing opportunities is central to the economy of Turkana. Livestock forms an integral part of the communities' social and spiritual life. In addition to providing life-sustaining products (such as milk, blood, meat, hides, skins and ghee), goats, sheep, cattle and camels are used as payment of bride price and in local rituals. Notwithstanding, during the past 20 years or more, the survival of nomadic pastoralism as a traditional subsistence-based livelihood strategy in Turkana has been increasingly threatened by persistent droughts and low rainfall [9]. Consequently, droughts now cause significant humanitarian problems and localized degradation of natural resources [9].

The Intergovernmental Panel on Climate Change (IPCC) has made numerous documentations on global rainfall trends. However, knowledge of changes in climate extremes is sparse, particularly for Africa [6]. Moreover, the sign of changes in mean precipitation in many parts of Africa varies across climate models [10]. Prolonged episodes of droughts and floods in Turkana Central, which have in part been attributed to climate variability and declared national disasters in Kenya, have greatly contributed to food insecurity and frequent inter-ethnic and clan conflicts over natural resources in the region. Consequently, it was crucial that the regional effects of rainfall variability on livelihoods be assessed; pasture availability, which is crucial for sustainability of the major source of livelihood in the region, is highly dependent on rainfall. It is against this backdrop that this study sought to provide regional data on rainfall trends, for the period 1983 to 2014, and consequently assess the effects of rainfall variability on pasture availability in the region. The study findings are meant to aid in the prediction of especially droughts and thus enhance preparedness and ultimately sustainability of pastoral livelihoods within the region.

2. METHODOLOGY

2.1 Description of the Study Area

Turkana Central Sub-County is located in north western Kenya within Turkana County, which

borders Uganda to the west, South Sudan to the north and Ethiopia to the north-east. It is a 5,269 km^2 arid and semi-arid region to the west of Lake Turkana, within the Great Rift Valley. The area borders the following constituencies: Turkana North to the north; Turkana West to the north-west; Loima to the west; Turkana South to the south; and Turkana East to the south-east.

The area lies at an altitude of about 523 m to the west, and then falls to 369 m to the shores of Lake Turkana in the east [11]. The main geological features characterizing the area are volcanic and sedimentary rocks. Other topographical features consist of plateaus, low lying plains with isolated hill ranges, minor scarps, foot slopes, footbridges, seasonal rivers, River Turkwel and Lake Turkana [11]. Lake Turkana, located at about 3° N and 36° E, is the largest desert lake in the world, the largest lake in eastern Rift Valley, the fourth largest lake by volume in Africa and the most saline in East Africa [12].

Turkana Central experiences a hot and dry climate. Temperatures in the region are between 24℃ and 38℃, with a mean of 30℃ [13]. The average precipitation ranges from 121 mm in the east to over 540 mm in the northwest [9]. Rainfall, though erratic and unpredictable, mainly occurs in two seasons. The long rains normally occur between March and July, with a peak in April. On the other hand, the short rains fall from October to December, with a lesser peak in November or December [9]. The western parts and areas of higher elevation in the region receive more rainfall. The drier the area, the more unreliable the rain is [11].

A map of the study area is illustrated below:-

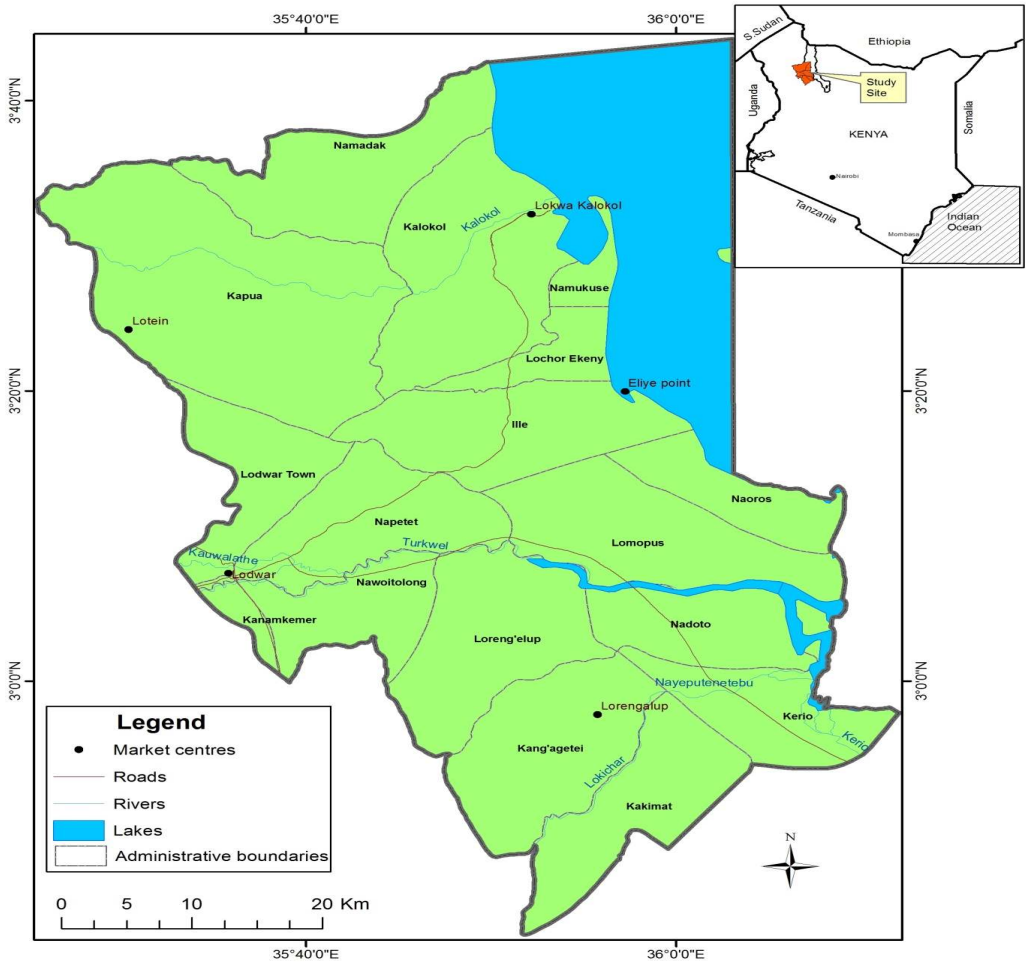

Fig. 1. Map of Kenya (inset) showing the location of Turkana Central Sub-County

2.2 Study Methods

Causal research design was used to describe the cause-effect relationship between rainfall variability and pasture availability. Direct observation and taxonomic identification were employed to identify the various vegetation species within Turkana Central. In addition, secondary data on the flora of the study area was obtained from published sources. Focus group discussions were held with village elders and key informants from Department of Livestock whose jurisdiction covers the region. Remotely-sensed Landsat satellite images covering the study area were also acquired for the years 1984, 2002 and 2014. Normalized Difference Vegetation Index (NDVI) values of the maps were then processed to compare the level of greenness for the three years. Secondary data on monthly rainfall, from the year 1983 to 2014, for Lodwar station was also obtained from Lodwar Meteorological Department. Descriptive statistics were then used to compute averages of rainfall amounts for period 1983-1998 and 1999-2014. Additionally, means for NDVI values representing vegetation were computed. Ultimately, the direction of change for both vegetation availability and rainfall amount was compared to assess the changes in pasture availability in response to rainfall variability.

3. RESULTS AND DISCUSSION

3.1 Rainfall Variability

With climate variability and change experienced in East Africa, the rainfall patterns are no longer predictable regarding timing and levels [14]. The amount of rainfall received in Turkana Central varied annually, displaying a general trend of 160.7 mm increase over the thirty-two years, calculated basing on the trend line's equation ($y = 5.0208x + 109.73$) in Fig. 2. To substantiate the fact that rainfall amount received increased, the mean rainfall for Turkana Central was 159.8 mm from 1983-1998, while in the consecutive 16 years the mean was 225.4 mm. In general, the mean rainfall over the thirty-two years was 192.6 mm. The lowest annual rainfall, 38.9 mm, was recorded in the year 2000, while the highest value recorded in the year 2012 was 421.4 mm. Nonetheless, village elders felt that the amount of rainfall received had decreased over the years.

Generally, unlike during the period 1983-1998, more rainfall was received from the year 1999 to 2014, especially during the short rains season. During the long rains season (March to May), the sum of the monthly averages was 80.2 mm and 107.7 mm for the period 1983-1998 and 1999-2014, respectively. During the short rains season (October to December), the sum of the monthly averages was 25.6 mm and 60.7 mm for the period 1983-1998 and 1999-2014, respectively. Notably, higher rainfall amounts were received in March, May and August to December in the first half of the period under study than from the year 1999 (Fig. 3).

3.2 Pasture Availability

Pasture, forests and medicinal plants are critical resources upon which people in Northern Kenya and other dry areas in the country depend, with women and youth playing key roles in natural resource management though older men have control over most resources [15]. Vegetation in Turkana Central consists of shrub savannah, trees, thickets and herbaceous vegetation; evergreen and semideciduous woodlands are found along Turkwel and Kerio Rivers [16]. Shrubs and trees leaves were the two most important pastures for the pastoralists' livestock, as stated by Livestock Department personnel. Some of these tree and shrub species that were identified and observed are listed in Table 1; *Acacia tortilis* being the most abundant tree species.

According to village elders, pasture availability had decreased in Turkana Central Sub-County over the three decades. In agreement, Ehrhart states that millions of people currently live a lifestyle that is centred on the search for the increasingly scarce pasture in the Horn of Africa [17]. When pastoralists lose their livelihoods, through loss of access to pastures, they become destitute and conflicts over resources arise [18]. However, computed Normalized Difference Vegetation Index (NDVI) values for three Landsat images revealed an increase in the level of greenness in the region over the years. Very low values of NDVI (0.1 and below) correspond to barren areas of rock, sand or snow; moderate positive values, approximately 0.2 to 0.4, represent shrub and grassland, while values approaching 1 indicate temperate and tropical rainforests [19]. Thus, means for NDVI values representing vegetation were computed. In the year 1984 and 2002, the mean NDVI values were 0.262 and 0.278, respectively, which correspond to gradually increasing shrub and grassland vegetation over the period. The mean

NDVI value computed for the year 2014, 0.377, indicates denser shrub and grassland vegetation than that in the former two years. The increase in vegetation can be partly attributed to the aggressive invasion of the plant species indigenous to Mexico, *Prosopis juliflora,* which was introduced to Lodwar after being introduced to Kenya in the 1980s [20]. This species has overwhelmed the region's grasslands by shutting out other species through interlinking canopies; it has displaced indigenous species from the banks of River Turkwel [ibid]. During the study, it was observed that the banks of both seasonal and perennial rivers, especially Kauwalathe and Turkwel Rivers, had high densities of *Prosopis juliflora*. Yet, according to Turkana Central Livestock Department officers, the leaves of the tree are very bitter and its pods too sugary; ideally, the species is not fit for livestock consumption. Nonetheless, livestock feed on this species. Figs. 4, 5 and 6 give a clear pictorial illustration of the changes in vegetation in Turkana Central over the years.

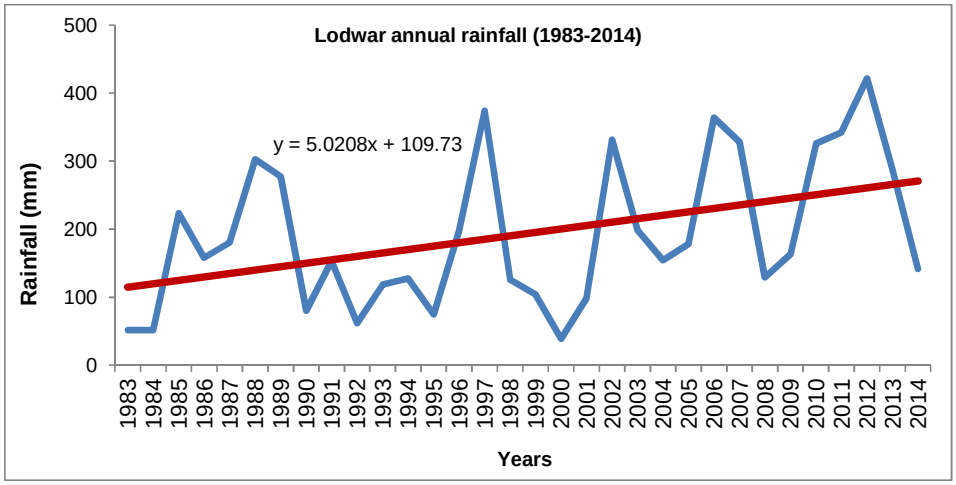

Fig. 2. Graph showing annual rainfall totals for 1983-2014 for Lodwar, Turkana Central Sub-County

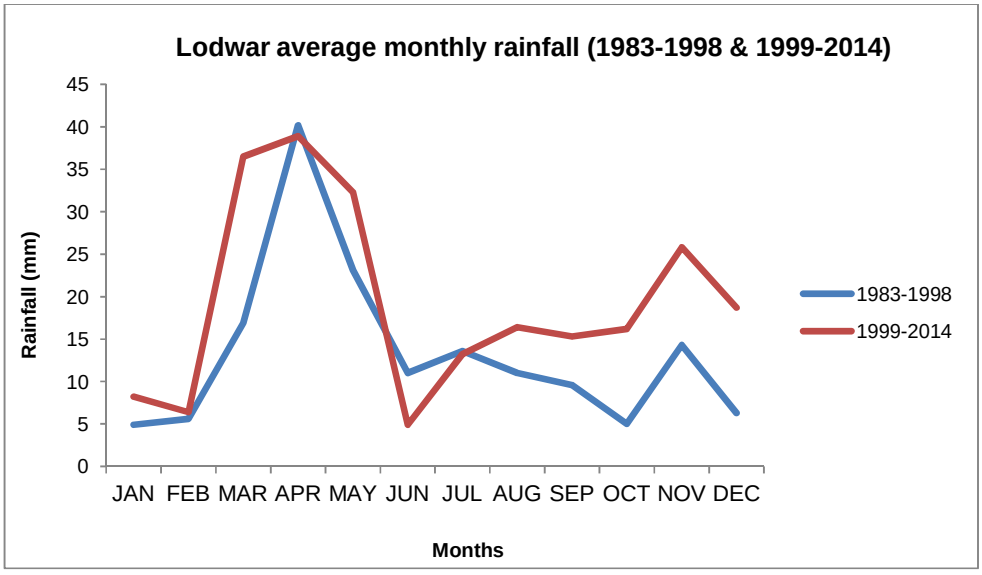

Fig. 3. Graphs showing average monthly rainfall for 1983-1998 and 1999-2014 for Lodwar, Turkana Central

Table 1. Pasture tree and shrub species in Turkana Central Sub-County

Turkana name	Scientific name	Common English/Swahili name
Ewoi/Etir	*Acacia tortilis*	Umbrella thorn
Esanyanait	*Acacia elatior*	River acacia
Edurukoit	*Acacia albida*	Apple-ring acacia
Ekunoit	*Acacia senegal*	Gum arabic
Ebei	*Balanites orbicularis*	Mbamba ngoma
Elamach	*Balanites pedicellaris*	Small green thorn
Eroronyit	*Balanites aegyptiaca*	Desert date
Epat	*Grewia bicolor*	False brandy bush
Engomo	*Grewia tenax*	White cross-berry
Ekalale	*Zizyphus mauritiana*	Jujube
Ereng	*Cadaba farinosa*	Herd's boy fruit
Ekurichanait	*Delonix elata*	Creamy peacock flower
Esekon	*Salvadora persica*	Toothbrush tree
Edapal	*Dobera glabra*	Mkupa
Erdung	*Boscia coriacea*	Shepherd's tree
Echoke	*Ficus sycomorus*	Sycamore fig
Esajait	*Lawsonia inermis*	Henna tree
Edome	*Cordia sinensis*	Grey-leaved saucer berry
Epeduru	*Tamarindus indica*	Tamarind
Emeyan	*Berchemia discolor*	Brown ivory/Wild almond
Eterai	*Prosopis chilensis*	Chilean mesquite
Eterai	*Prosopis juliflora*	Mexican thorn

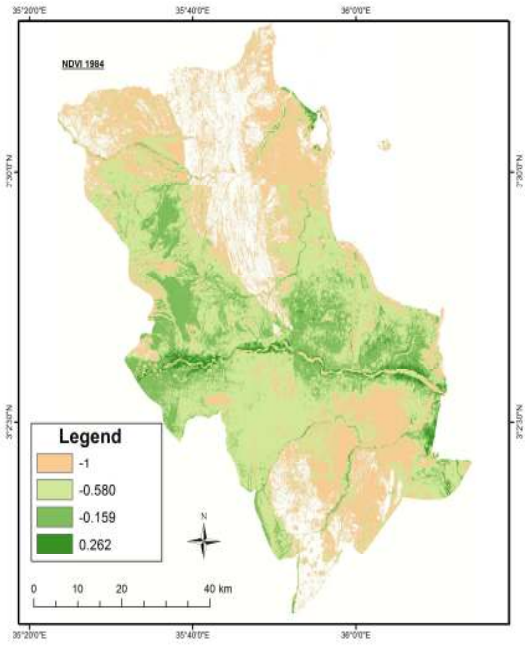

Fig. 4. NDVI map for Turkana Central Sub-County for September, 1984

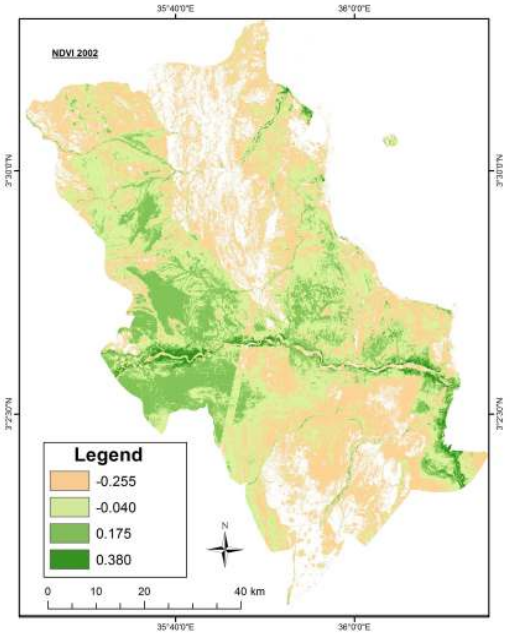

Fig. 5. NDVI map for Turkana Central Sub-County for September, 2002

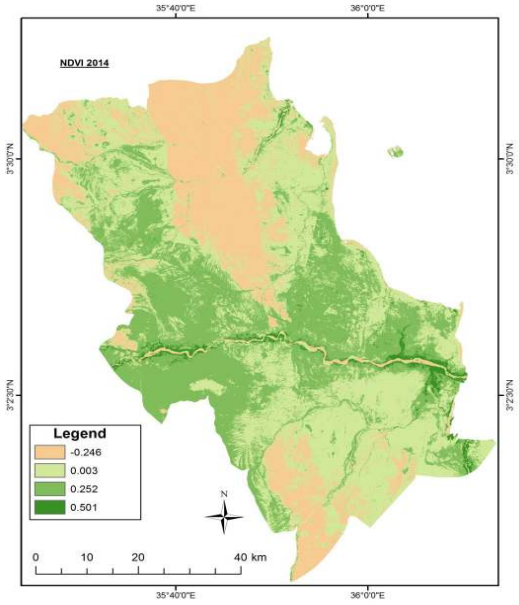

Fig. 6. NDVI map for Turkana Central Sub-County for September, 2014

3.3 Rainfall Variability - Pasture Availability Relationship

Factually, as the amount of rainfall received increased, pasture availability increased in Turkana Central Sub-County during the period 1983 to 2014. Both phenomena displayed positive changes. Village elders' perception of decrease in rainfall amounts and ultimately pasture availability can be attributed to the increasing frequency and severity of droughts. In a similar study conducted in Garissa County in Kenya, 67% of the respondents indicated that increasing poor rainfall patterns resulted in a significant decline in pasture availability, greatly affecting livestock productivity in the region [21]. In Kenya, droughts are the most significant and widespread manifestation of climate variability perceived by the indigenous communities, since they affect natural resources-based production systems like pastoralism [14]. The drought cycle in East Africa appears to be contracting sharply: rains used to fail every nine or ten years, then the cycle went down to five years and now the region is experiencing drought every two or three years [22]. Turkana Central Livestock Department personnel corroborated that before 1990 the drought cycle of Turkana Central was predictable; after every 10 years there was a severe drought. However, between 1990 and 2014, the droughts became spontaneous, occurring after every 2 years. Village elders added that heavy rainfall intervals had increased resulting in severe droughts, unlike in the past. In 2009, Central Turkana experienced one of the worst droughts to ever hit the region, resulting in massive deaths of livestock and thus significantly undermining livelihoods [23].

Changes in the frequency or magnitude of disturbance and covariance between perturbing factors, such as precipitation, may cause inevitable and irreversible vegetation changes [24]. Climate variability and change in the recent past has led to recurrent droughts, leading to water shortage and disruption of the vegetation cycle, thus causing a crisis for Turkana pastoralists [11]. The village elders confirmed that recurrent and severe droughts had a negative effect on pasture availability; grass virtually dried out during the dry seasons. Pastoralist communities from Kotido in north-eastern Uganda add that successive poor rains have led to shrinking of pastures in the region; they explain that the long rains that used to occur between March and August are now beginning as late as May [25]. According to Turkana Central Livestock Department personnel, a major drought in 2004 and 2005 resulted in migration of livestock from Turkana Central to Uganda, where there was sufficient forage. After sometime, conflicts arose over the water and pasture resources, forcing the Kenyan pastoralists to return. Since there was very little forage and water, both cattle and small stock were starved, got weak and eventually died. Consequently, there was food insecurity. For instance, the 1984 drought resulted in introduction of yellow maize in Turkana; that was the year relief emergency began. In addition, the Turkana Central Livestock Department personnel stated that the recurrent droughts led to migration of livestock to insecure areas in other regions of Turkana County; no-man-go zones (Turkana South and Loima). These regions usually had pastures because there was neither human nor livestock population. These are border points between the Turkana and Pokot communities.

On the other hand, floods occurring during the rainy season had minimal effects, as they were confined to areas along river courses. Though the 1997/1998 El Niño was severe, the Turkana Central Livestock Department personnel stated that it was beneficial to the Turkana community: there were adequate pastures for livestock. However, the personnel further explained that livestock were drowned and swept away in 2006

and 2007 when Rivers Turkwel and Kauwalathe flooded their banks.

4. CONCLUSION

Pasture availability increased as rainfall amounts and variability increased in Turkana Central, Kenya, over the period 1983 to 2014. Computed Normalized Difference Vegetation Index (NDVI) values for Landsat images revealed a higher increase in the level of greenness in the year 2014, when compared to 2002, than in the year 2002, when compared to 1984. Shrubs and tree leaves were the two most important pastures for the pastoralists' livestock, with *Acacia tortilis* being the most abundant tree species. More rainfall was received, especially during the short rains season, from the year 1999 to 2014 than from 1983 to 1998. Notwithstanding, unlike in the past, severe scarcity of pasture was experienced during droughts in the recent past. This was attributed to the increase in frequency and severity of droughts over the years; the drought cycle had significantly reduced. This resulted to migration by pastoralists and their animals to as far as Uganda, in search of pastures. Floods were confined to areas along river courses, and thus had minimal effects on pastoralism.

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COMPETING INTERESTS

The funding organization and institution had no subjective influence that would introduce bias to the study.

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