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Drivers of Forest Cover Change and Indicators of Climate Change in Katimok Forest Reserve

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Abstract: *The conversion of forests into other land uses as well as unsustainable utilization of forest resources leads to a reduction in the area, quality and quantity of the forest cover and ecosystem services. Changes in forest cover as a result of the resource strain imposed on the ecosystem can significantly affect the local climate in terms of temperature and rainfall. This study was carried out to assess the drivers of forest cover change in Katimok forest and the impacts that the changes have had on the local climate in terms of temperature and rainfall. Household questionnaires, field observations and focus group discussions were used to identify the drivers of forest cover and to assess the perceptions of the community on whether there had been changes in forest cover and local climate since 1985. Climatic data was obtained from Katimok meteorological station. Descriptive and inferential statistics were used to analyze the social data and climatic data. The results indicated that agriculture and logging were perceived as the major drivers of forest cover change. The results from the climate data shows a slight increase in temperature trend from 1985-2012 with mean annual temperature range of +-1.44561. Similarly, the rainfall data shows an increasing trend, though not significantly. The study indicates that the observed forest degradation is as a result of observed anthropogenic activities in and around the forest. Therefore, there is need to develop stringent policy measures and appropriate strategies that can alter this unfavorable situation and lead to conservation of this ecosystem.*
Key Words: Climate Change, Forest Cover, Ecosystems, Degradation, Katimok Forest Reserve

1. Introduction

Land use is one of the major factors through which humans influence the environment. According to Intergovernmental Panel on Climate Change (IPCC) report on land use, land use change and forestry(LULUCF), when humans modify the environment through land use, certain environmental impacts such as; soil erosion, flooding, emission of greenhouse gases, and local climate change among other consequences occur. Overall, the world's forest ecosystems are estimated to store approximately 638 billion tons of carbon, which is more than the amount of carbon in the entire atmosphere (IPCC, 2000). Therefore, alteration of forests into agricultural land, grazing lands and settlements can affect climate on various scales ranging from local to international levels. This is because forests absorb carbon dioxide from the atmosphere and store some of the carbon throughout their lifetime. When a forest is cleared, its ability to store carbon is reduced and hence the carbon they had sequestered is emitted into the atmosphere causing global warming (Stiebert *et. al*., 2002).

In Africa, where there is high rates of poverty and population growth coupled with low agricultural production, expansion of agricultural lands remains the main cause of deforestation (Geist & Lambin, 2002). Kenya has a total of about 1.64 million ha of gazetted forestland and about 100,000 ha of trust lands (Matiru, 1999). The country's closed canopy forests are concentrated in the moist central highlands where the human population and agricultural production are also pervasive (Wass 2000). In the semi-arid region, closed canopy forests are mainly found on isolated hills and along riverbeds. Forest degradation and destruction in Kenya has been on the rise. It is estimated that between the years 1995 and 1999, an entire 44,502.77 hectares of forest land were formally degazetted and cleared (Matiru 1999).

According to Harrison (2010), the main drivers behind the degradation of forest ecosystems are pressures from the growing human population and rising rates of consumption. Kinyanjui & Karachi (2013) observed that between 1990s and early 2000, huge sections of the Mau Forest Complex were excised to resettle the forest dwelling communities, communities from other counties and the landless rural poor. They noted that Eastern Mau was reduced from 65,000 to 25,000 hectares. In general, the outcome of increased population densities appears to depend on economic opportunities available to rural people, agricultural systems, and access to markets for timber and non-timber products, as well as for other forms of production (Mythili & Shylajan, 2009).

While the loss of forest cover through agricultural expansion and clearing for settlement as well as overexploitation of forest resources is thought largely to be the outcome of a rapid population growth and high rates of poverty, there are other more serious underlying issues such as poor government policies, corruption, inadequate information and lack of education and property rights (Geist & Lambin, 2002).Weak institutional capacity and poor enforcement of forest laws have also been identified by Ochieng (2013) as major underlying drivers of forest cover change in Kenya. Shackleton*et al*. (2008) cites that, in arid and semi-arid areas, climate change, and particularly change in rainfall patterns, is a key driver of forest cover change. In their view, fluctuations and variations in rainfall patterns disrupt the normal functioning of the ecosystem hence the delivery of a range of forest ecosystem services. While this is the case, they further argue that climate change can be aggravated by human induced activities and this increases the frequency of extreme events such as high temperatures thereby high evapo-transpiration and overall decline in rainfall resulting to loss of forest plant diversity (Shackleton *et al.,* 2008).

In Kenya, approximately 14 million tons of carbon dioxide is released annually mainly as a result of changing the forests into other land uses. However, Kenya is now working toward achieving and maintaining a forest cover of 10% of the country's land area. This has been well articulated in Article 69 of the country's Constitution. Healthy forests absorb tremendous amounts of carbon dioxide, which is essential for human and environmental health. Forest cover change due to conversion to various land uses such as agriculture, logging and settlement has reduced the capacity of the forests to act as carbon sinks. Nevertheless, Kenya has developed a national REDD+ strategy, an international initiative aimed at reducing deforestation consequently increasing the absorption of carbon from the atmosphere (Global Canopy Programme, 2016).

The various regions of Kenya and the world as a whole generally experience the same drivers of degradation, but on closer examination, the underlying drivers differ in nature and even intensity. Human's ability to coexist with the ecosystems and sustainably utilize them has an influence on the peoples living conditions. An underlying cause for the deterioration of the ecosystems services is that the values of these services have not been taken into account in decision making. The international study on the economics of ecosystems and biodiversity (TEEB, 2010), has pointed out that increasing information and raising awareness on the importance of ecosystem services is of great importance to the local communities and decision makers. Katimok Forest in Baringo County is an ecosystem that has been subjected to several human induced pressures and this has led to change in forest cover and eventually change in local climate, specifically rainfall and temperature aspects. This study aimed at assessing the driving forces of forest cover change and the trend of local climate in Katimok Forest Reserve.

2. Materials and Methods

2.1 Description of Study Area

Katimok Forest Reserve, Gazetted 1949, is a forest in Baringo County, Kenya. It lies at an altitude of 2162 meters and between Latitude of 0°35'55.82" and Longitude: 35°47'26.52". The forest is under the management of Baringo County Government and protected by the Kenya Forest Service. It is the largest block of the current Kabarnet Forest which consists of thirteen blocks as shown in Table 1;

Table 1: Kabarnet Forest Blocks

Block	Size (ha)
Katimok Forest	1 956.59
Saimo Forest	750.9
Tarambas Hill Forest	483.8
Morop Forest	212.6
Kimeto Forest	210.4
Mosegem Forest	202.7
Sokta Hill Forest	163.9
Pemwai Forest	117.7
Chebartigon Forest	103.3
Ketwan Forest	46.6
Cherial Forest	42.5
Kabiok Forest	14.2
Tutwoin Forest	12.1

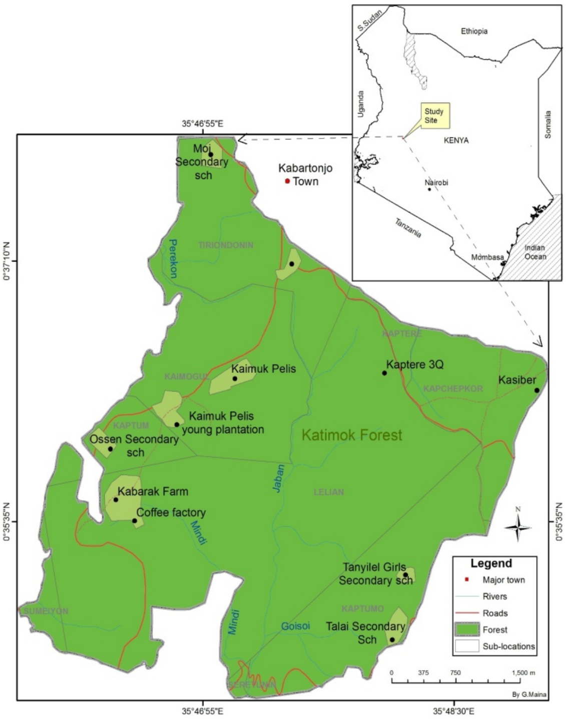

Figure 1: Map of study area (Katimok Forest Reserve)

A larger portion of the forest is composed of indigenous trees including. *Syzygium guineense, Olea africana, Prunus africana, Vitex keniensis* and the endangered *Osyris tenuifolia* among other tree species. Exotic plantations, such as *Eucalyptus saligna, Cupressus lucitanica, Pinus patula* and *Grevillea robusta* also make up the forest and they were established as early as 1970s on lands which became vacant after the eviction of illegal settlers. The forest is also home to wild animals and birds which include; colobus monkey, olive baboon, cape hare, common quail, helmeted guinea fowl and gazelles among others.

Agriculture is the backbone of the forest surrounding community. This is especially because the soils and the climate of the region are conducive for crop and livestock production. The area receives an annual rainfall of about 1000-1500mm and temperatures ranging from a minimum of 10^0C and a maximum of 30^0C. This coupled with fertile soils make the forest surrounding populations practice production of different varieties of crops such as maize, sorghum, millet and beans among other crops. In addition, rearing of goats, sheep, cattle, and bee keeping are other common economic activities in the area. Furthermore, the poverty level of the area is at 58.5% and as such, the communities surrounding the forest are largely dependent on the forests ecosystem services such as honey, wild fruits, construction material, fuel wood, agricultural land, water, traditional ceremonies and fodder among other benefits, for their livelihood. There are four major streams flowing through the forest and they are Goisoi, Mindi, Jaban and Perekon streams.

2.2 Data

Focus group discussions (FGDs) and household questionnaires were employed to identify and assess the drivers of forest cover change and indicators of climate change in the area. Further, observation checklist was used to get a greater picture of the status of the forest and any economic activities taking place within and around the forest. The pressures on the forest e.g. felling of trees, livestock grazing, firewood collection etc. were recorded. Data regarding the rainfall patterns was obtained from the Katimok forest weather station, and that of temperature patterns was obtained from the Kenya Meteorological Department. The data of both temperature and rainfall were from the years 1985 to 2015 which enabled analysis of how these climate attributes have been changing over the last three decades. Descriptive and inferential statistics were used to analyze the data.

3. Results and Discussion

3.1 Forest Cover Change and its Driving Forces

Based on observations and the Focus Group Discussions held, it is evident that the forest cover has changed in terms of size and density. According to the FGDs, the size of the forest has greatly reduced since 1985. These findings are in agreement with those of Stiebert et al. (2002) who indicated that at independence, Kenya's forest cover stood at 11% but it has reduced to 7%. In their view, the causes of this reduction in forest cover are diverse and constitute both direct and indirect drivers.

According to the FGDs, one of the factors that have contributed to the decrease in forest size is the encroachment of the forest boundaries by Saw millers. Their presence in the area has also indirectly contributed to loss of forest cover since illegal loggers have a ready market for their products. Individual encroachment by local leaders is another factor that has greatly contributed to change in forest cover as gathered from the FGD. The respondents indicated that local prominent politicians and businessmen had acquired forest lands illegally through corrupt dealings and that this had majorly reduced the size of the forest since they acquired large tracts of forest land. There was also clearing of the forests to pave way for infrastructural developments such as the establishment of health facilities, schools and administration centers like Ossen High School, a factor that led to the decrease in the size of the forest. The encroachments by local leaders and infrastructural developments eventually led to the degazettment of the forest in 1989 to enable the institutions and the persons legally own the forestland. This greatly reduced the forest cover in terms of size eventually reducing the forest's ecosystem services. These findings are in agreement with those of Stiebert et al (2002) who found out that degazettement of forest lands, corruption and ineffective enforcement capacity are underlying causes of forest cover reduction.

According to the household survey results, conversion into agricultural land was the leading driver of forest degradation as indicated by 50% of the respondents. This was followed by logging with 41.9%, and charcoal production and extraction of fuel wood with 4.5% and 3.6% respectively. Agricultural expansion was also mentioned in the FGDs as one of the major driving forces of forest cover change. There has been the introduction of the Plantation Establishment and Livelihood Improvement Scheme (PELIS) system which allows the community to farm on the forestland as they tend to young trees until they reach a certain growth level. This has encouraged the community to expand their agricultural activities into the forestland which has negatively impacted on the forest cover. The density of the forest, as observed and as gathered from the FGDs, has also reduced. One of the factors contributing to this reduction in forest density is selective logging and timber extraction. There is high demand for timber for local infrastructure developments such as building of houses and fencing, and there is also ready market for the timber products in the area which motivates the residents to take part in illicit timber extraction. Even though some of the loggers are licensed, there is over felling of trees and poaching of valuable tree species, the most preferred being *Osyris lanceolata* Hochst & Steud.

Overgrazing is another factor mentioned in the FGD. The residents rear cattle, goats and sheep in their farms, and due to shortage of fodder during the dry seasons, the forest offers an alternative foraging land for these livestock. Moreover, some residents have small farms which cannot cater for both crop farming and livestock grazing, so their animals graze in the forest all year round and this greatly affects the density of the forest. Firewood collection also contributes to loss of forest cover as this is the common source of energy for coking in the community. Charcoal production is also practiced as an economic activity in the area and certain selected indigenous trees are felled for this purpose contributing to forest density reduction. Some of the main causes of forest cover change as indicated by Geist and Lambini (2002) are conversion into agricultural land, unsustainable charcoal production, demand for fuel wood and logging.

All these human activities have greatly reduced the forest cover which in turn has interfered with the normal functioning of the ecosystem. Forests play a major role in combating climate change through carbon sequestration and therefore, a reduction in Katimok forest cover means changes in local climate in terms of seasonality, temperature and rainfall patterns.

3.2 Change in Local Climate

Climate is a phenomenon with many variables such as humidity, temperature, rainfall, among many other measurements that can be used to describe climate. In this study, temperature and rainfall data are used as indicators of local climate change since 1985 to 2015. The findings are illustrated in line and bar graphs.

3.3 Rainfall Trend

Regarding the rainfall trend, majority (77.1%) of the interviewed households had experienced a decrease, 8.6% an increase and the rest 14.3% had no idea. Unfortunately, the rainfall data obtained from the forest's meteorological station indicates an increasing trend, in the annual rainfall, although not significantly as shown in Figure 2. However, the data shows fluctuating rainfall pattern with the lowest rainfall recorded in 1991 and 2009 and the highest peak observed in 2010 and 2012. It is worth noting that, the area has been receiving fluctuating rainfall amounts. This observation concurs with the UNDP climate change profile for Kenya report which notes that there are no significant variation in rainfall amounts received in various parts of Kenya since 1960 (Lizcano et al., 2008). The FGD respondents of this study are also of the opinion that the rainfall amounts have become unpredictable during the recent decades. The dry periods have become longer and frequent causing shrinkage of rivers and when it does rain, it is severe, bringing about floods and erosion.

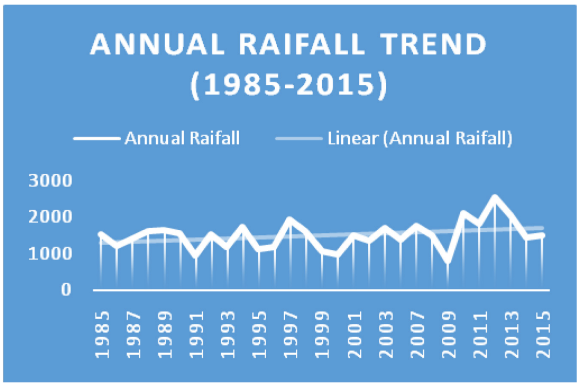

Figure 2: Katimok Annual Rainfall Trend

Figure 3 shows the seasonal rainfall cycle of the study area calculated from rainfall data 1985- 2015. In this graph, two wettest months are observed, July with a mean seasonal rainfall of 207.64 mm followed closely by April with a mean seasonal rainfall of 207.28mm. In Kenya, there are two wet seasons, long rains season (March-June) and short rains (October-December). This graph indicates that there is a change in climate since July and August which are supposed to record lower rainfalls are peaking. According to the household survey, majority of the respondents (83.6%) indicated that the seasonality had become unpredictable. Similarly, the FGDs participants were of the same opinion, noting that this phenomenon had completely altered their cropping cycle. These findings are in concurrence with the UNDP climate change profile for Kenya report which notes that the onset, duration and amount of rainfalls vary from year to year (Lizcano et al., 2008).

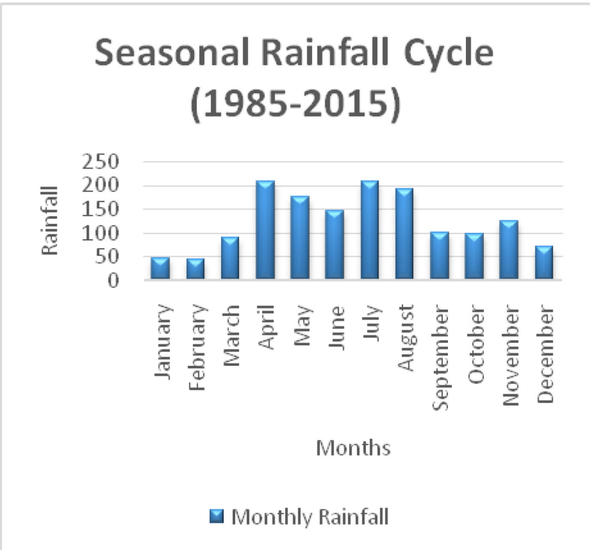

Figure 3: Katimok Seasonal Rainfall Cycle (1985-2015)

Figure 4 shows the long rains season (March-June) rainfall amounts for the different years. The patterns are seen to be inconsistent and the trends decreasing over time. This shows that there is change in climate since the rainfall amounts should be consistent for the different months rather than varying. This would have resulted in an unchanging trend over the years. Moreover, the decreasing trend means that the wet season is now receiving low rainfall amounts hence change in seasonality.

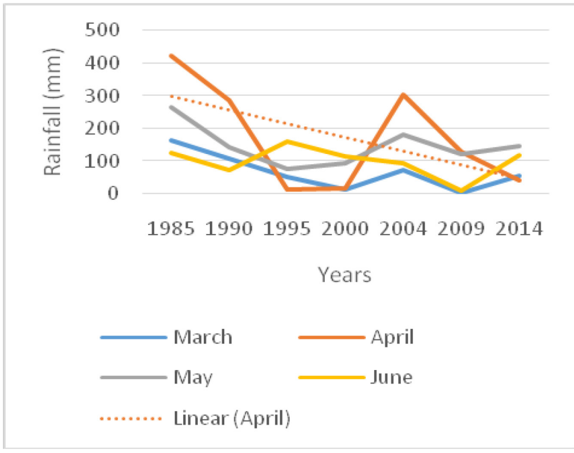

Figure 4: Katimok Long Rains Wet Season Trend for Selected Years

Similarly, the short rains period (Figure 5) indicates a fluctuating pattern for the different years. First, it shows an increasing trend which means that there is a gradual increase in rainfall amounts during the short rains season. Again, the pattern is not consistent for the different time periods.

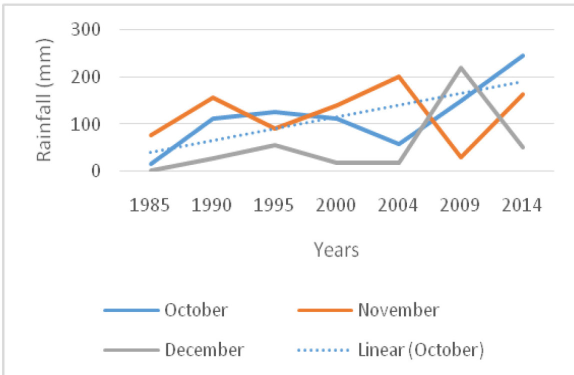

Figure 5: Katimok Short Rains Wet Season Trend for Selected Years

A comparison of the graphs of long rains and short rains wet season as shown in Figures 6 and 7 depicts a clear difference between the two seasons. A slight decline in rainfall during the long rainy season and a rainfall increase during the short rainy season is observed. This is an indication of a changing climate. The respondents of the study indicated that the rainfall patterns had become erratic and there had been a change in seasonality which affects the time of planting and harvesting of their crops. These findings corresponds with those of Lykens & Liebmann (2012), which also indicated that the trends of rainfall in the Rift Valley region showed a small decrease in the long rains and an increase during the short rains season.

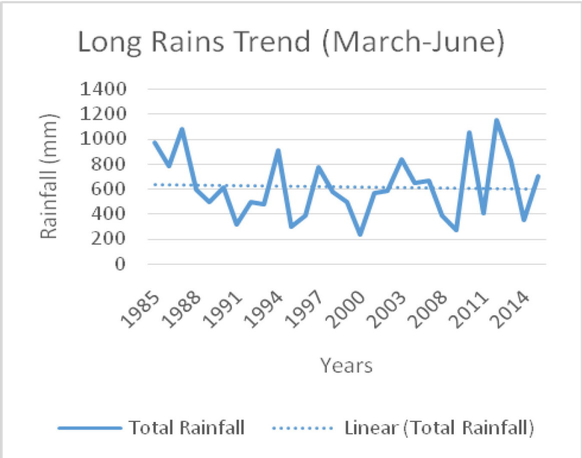

Figure 6: Katimok Long Rains Trend (1985-2015)

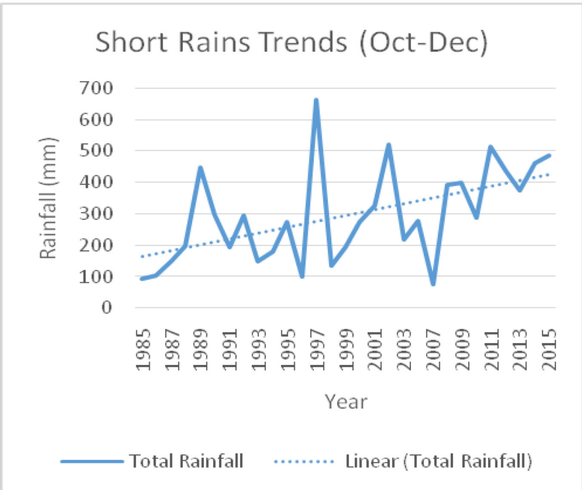

Figure 7: Katimok Short Rains Trend (1985-2015)

3.4 Temperature Trend

The temperature data indicates a rising trend of temperatures as shown in Figure 8. This increase in temperature is an indicator of climate change (warming). This is consistent with what was gathered in the FGDs as the respondents indicated that the temperatures had increased in the area. Majority (76.9%) of the household respondents also reported to have experienced increasing temperatures in the last few decades. According to Figure 8, the highest temperatures were recorded 2009 with annual average temperatures of 25.59 degrees Celsius, and the lowest temperatures were recorded in 1989 with an average annual temperatures of 24.14 degrees Celsius.

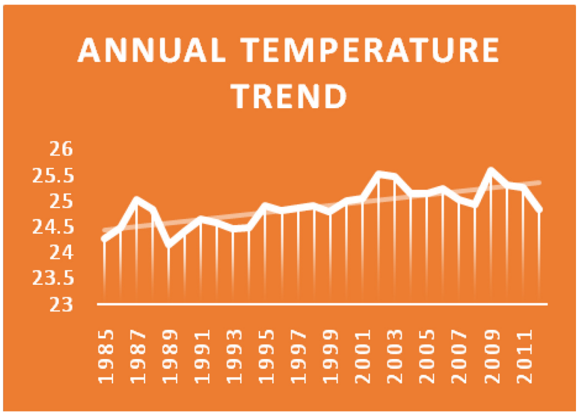

Figure 8: Annual Temperature Trend (1985-2012)

The annual temperature range of change in the maximum and minimum mean annual temperature is +-1.44561. This concurs with the findings of UNDP Climate Change Profile for Kenya which also note that the mean annual temperatures in Kenya have risen by about 1.0^{0}C. The change in average temperatures between the years 1989 and 2009 gives a clear picture of the warming trend in the area.

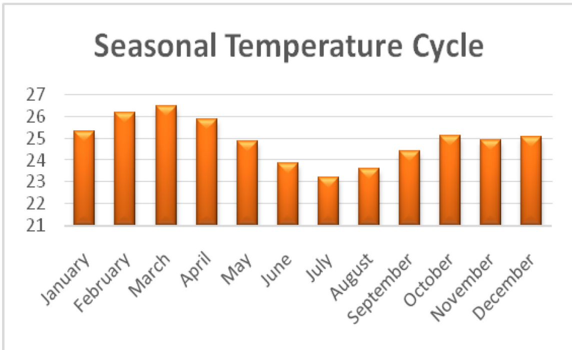

Figure 9: Seasonal Temperature Cycle (1985-2012)

Figure 9 shows the seasonal temperature cycle of the study area calculated from the average monthly temperature data 1985- 2012. In this graph, it is observed that February, March and April are the hottest months while June, July and August are the coolest months. It is also observed that there is little temperature variations between these hottest and coolest months with the range between March (26.48^{0}C) and July (23.2^{0}C), which are the hottest and coolest months respectively, being 3.28 degrees Celsius. These findings are in agreement with those of the UNDPs Climate Change Profile for Kenya which note that temperatures in Kenya have slight fluctuations throughout the year but drop in the coolest months of June, July, August and September (Lizcano Et al., 2008).

3.5 Traditional Climate Change Indicators

Local knowledge has long been used by communities to predict climate change based on its impacts on the ecosystems. The results of the sampled respondents indicate that there has been a change in climate over the last 30 years, more so in terms of temperature, rainfall and seasonality. Most respondents noted that there has been a change in seasonality, in that it has become unpredictable. The temperatures have also risen according to 45% of the respondents and the rainfall has become inconsistent according to 56% of the respondents. Some of the local indicators that the community uses to determine change in climate are described below.

Invasive Species

Change in climate can alter vital components of natural systems such as rainfall, temperature, and land cover and this can facilitate the spread of invasive species. According to the focus group discussions, there has been a shift in ecological zones and tree species that used to grow in the lowlands are now found in the highland areas, for example *Balanites aegyptiaca*, *Acacia tortilis and Euphorbia candelabrum*.

Spread of Diseases

Climate change and shift in ecological conditions has supported the spread of diseases such as malaria and Rift Valley Fever. The FGD participants noted that malaria was not common in the area as there were no mosquitoes to transmit the disease, but nowadays mosquitoes have invaded the area and this is an indicator that climate has changed. The participants also noted that there was re-emergence of Rift Valley Fever, a disease that is attributed to unusually long rains indicating a change in climate.

Change in Planting and Harvesting Seasons

The FGD participants observed that, in the olden times, planting seasons used to be the same every year usually at the beginning of long rains. March to April. They used to follow a particular pattern, but nowadays planting and harvesting seasons have become unpredictable.

Mist and Fog Spells

Based on the FGDs, the participants indicated that mist and fog spells which used to be so common especially during the rainy and cold seasons have become rare these days, and when they appear, they are at unusual times. This is clearly an indicator of climate change.

4. Conclusion

Forest cover change due to human activities that has led to deforestation and degradation is an environmental concern in Katimok area. Two major anthropogenic activities that have resulted in the decline of Katimok forest cover are conversion to agricultural land and logging. Areas that were once covered with dense forest lands in the early 1980s have been turned into farmlands and build-up areas. The degazettment of the forest in 1989 to allow for human settlement and infrastructural developments further reduced the forest land from its original size.

From the results, it is also clear that the climate of the area has changed. There has been a slight increase of temperatures as indicated in the results, and this has led to shrinkage of rivers. The results also show that the rainfall patterns have become erratic. Sometimes it rains too much causing floods and at other times there is no rain at all. This unpredictability in the rainfall patterns has affected the cropping cycles of the farmers leading to losses. Change in climate has also been manifested by the change in the planting seasons, the appearance of invasive species and the emergence of diseases associated with extreme weather conditions. Therefore, this information is important to relevant forest management authorities in order for them to develop stringent policy measures and appropriate strategies that can alter this unfavorable situation and lead to conservation of this ecosystem. The following recommendations are reached at based on the findings and conclusions from this study;

1. The forest cover change that has occurred is as a result of overexploitation of forest resources, therefore, economic empowerment of the communities surrounding the forest needs to be carried out so that the residents can explore other avenues of income generation

2. To mitigate changes in local climate and achieve a positive trend in forest cover, the

communities should be encouraged to plant trees on their farmlands (10%), especially gravellier and croton which grow fast, and where possible establish private forests to avoid overdependence on forest resources.

5. Acknowledgements

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