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EFFECTS OF DROUGHT DYNAMICS ON VEGETATION COVER IN MARIGAT SUB-COUNTY, BARINGO COUNTY, KENYA

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Abstract- Drought is a norm rather than exception in Marigat Sub-County, Baringo County in Kenya where it adversely affects vegetation and water resources which are key resource for pastoralism. However, the effects vary depending on the dynamic of each drought event. This study sought to establish the drought dynamics in in Marigat Sub-County and how the dynamics affect vegetation cover in the County. A sample size of 368 households from a total study population of 9,160 households was selected for the survey alongside meteorological datasheets, remotely-sensed images, hydrological datasheets and maps. Droughts were frequent in Marigat Sub-County occurring once in every two years. The intensity the droughts ranged from 0.1 to 57.8 percent below the long-term mean. Whereas some droughts were on off events, majority occurred in runs with the longest lasting for up to 5 years (2000-2004). Vegetation cover was severely affected when droughts were prolonged and intense and vice versa. Bare grounds devoid of vegetation cover were common during prolonged and intense droughts as it was experienced during the 2000 La Nina drought (NDVI value of-0.07). As the inhabitants strived to cope with the effects of droughts, they turned into their immediate environment exploiting the available resources. This led to destruction of vegetation cover through activities such as overgrazing on wetlands and forested areas, charcoal burning and clearing of vegetation to allow crop farming. Thus with the increasing drought frequency, duration and intensity, if the environmental degradation remains unchecked Marigat Sub-County will become a desert devoid of vegetation.

Index Terms- Droughts, Drought Frequency, Drought Duration, Drought Intensity, NDVI, Vegetation cover

I. INTRODUCTION

Drought is a natural phenomenon that exists when precipitation is significantly below 500-650mm affecting land resource production systems (UNEP, 1998; Ngaira, 2005). They occur in all climates but more predominant in the drylands. However, droughts vary in their mode of occurrence in terms of duration, intensity and frequency affecting land cover at varied magnitudes (http://www.isws.illinois.edu/hilites/drought, 2011). In Australia for instance, the 1958 lasted for 10 years ending in 1968(Lake, 2011) while in the southern and eastern parts of Australia a 12-year drought ravaged the country between 1996 and 2008 (Kogan et al., 2012). The frequency and intensity of droughts are increasing in a number of regions in the world (Owrangi, et al., 2011). However, the intensity vary from one drought to the other with some occurring rapidly but short lived while others develop slowly but persist for a long time (Smith, 2011). In Russia the 2010 drought was severe not only covering vast areas but also led to serious damages to the environment (Kogan et al., 2012).

Droughts trigger major changes in vegetation cover and their adverse impacts depend on their intensity, duration, frequency and severity. Eldridge et al (2011) observed that vegetation composition in the arid and semi-arid grasslands and savannahs of the world has been changing. Droughts are among the major contributors of these changes (Parolin, 2010). According to Owen (2008) a 15-month drought between 2002 and 2003 across Arizona and New Mexico led to loss of Ponderosa pine and Pinon-juniper ecosystem with over 90 percent of Pinon trees being lost. Godfree et al (2011) observed that the 2006-2007 extreme drought in Southeastern Australia led to destruction of temperate grasslands resulting in decline of grassland species. Africa, like other continents, has been experiencing droughts of varied characteristics with diverse effects on vegetation cover. Between 1970 and 2006 droughts accounted for 20% of the natural disasters affecting over 80% of the entire African population (Huho and Mugalavai, 2010). According to Murungaru (2003) the severity and frequency of droughts in Kenya, for instance, seems to be increasing over time. In the ASALs of northern Kenya, the frequency has increased from once in every 10 years in the 1970s; once in every 5 years in the 1980s; once in every 2 to 3 years in the 1990's and now annually since the year 2000 (Howden, 2009). Massive loss of vegetation cover have been experienced during the 1979-80 and 1991-2011 severe droughts in Turkana District (Terrence, 2010; Huho and Ngaira, 2011), the 2003-2006 and the 2008-2009 droughts in Laikipia County (Http:// www.acted.org/en/kenya, 2013, Terrence, 2010).

II. OBJECTIVES OF THE STUDY

The study was guided by the following objectives:
1) To establish drought dynamics in Marigat Sub-County
2) To examine the effects of drought frequency, intensity and duration on vegetation cover in Marigat Sub-County

III. STUDY AREA AND METHODOLOGY

Data for the study was collected from Marigat Sub-County which covers an area of 1,346 square kilometers and has a population of 41,780 persons comprising of 20,826 males and 20,954 females in 9,160 households. A total number of 368 households were interviewed. The population density is 53 persons per square kilometer. The sub-county is divided into 11 locations (Figure 1). Rainfall is about 50 percent reliable while the variability is very high. The annual mean minimum and maximum temperatures range from 16 to 18 °C and 25 to 30 °C respectively. Data was largely collected through the use of questionnaires, interviews and observation. Rainfall data obtained from Kenya Agricultural Research Institute (KARI) - Perkerra Meteorological Station was used to analyze drought years as well as drought duration and intensity. The remotely sensed data was analyzed using ERDAS IMAGINE Version 2011 and ArcMap Version 10.1 softwares and was used to monitor the vegetation cover. Normalized drought vegetation index (NDVI) was used to indicate the level of vegetation greenness or availability of pasture.

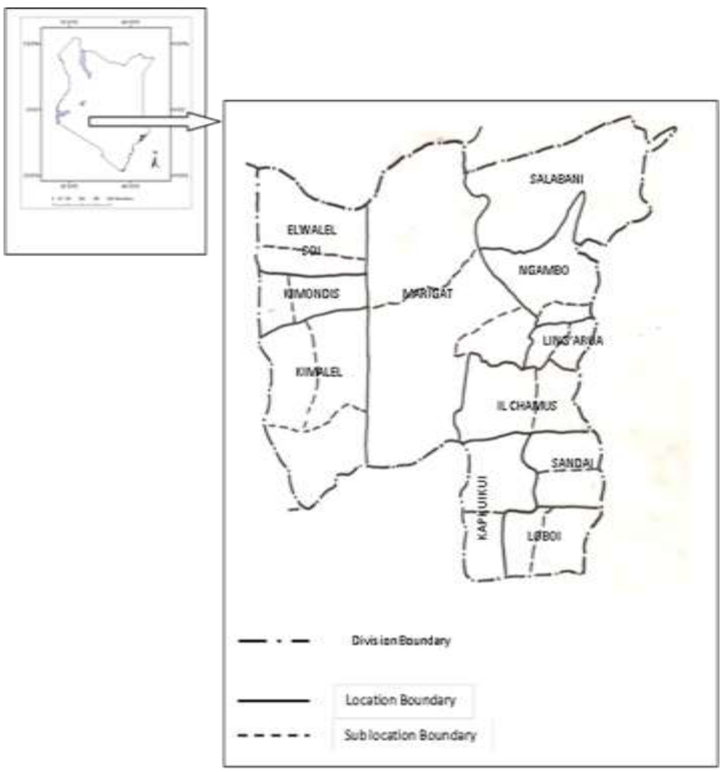


Figure 1: Study area

IV. RESULTS AND DISCUSSION

A. Drought Characteristics

Drought dynamics were assessed based on the following drought characteristics: occurrence and frequency, duration and intensity.

Drought Occurrence and Frequency

The study used 33 years annual rainfall data for a period between 1980 and 2012 to depict droughts years. Years with annual amount of rainfall below calculated long term mean of 563.7mm for the period under study were considered as drought years. As a result, Marigat Sub-County recorded 18 droughts which occurred in 1980, 1984, 1986, 1992, 1994, 1995, 1996, 2000, 2001, 2002, 2003, 2004, 2006, 2008, 2009, 2010, 2011 and 2012 (Table 1). Analysis of rainfall data in Table 1 revealed an increase in droughts frequency of occurrence. During the 1980-1989 decade, 3 out of 10 years (30%) were drought years. The frequency rose to 4 in every 10 years (40%) in 1990s and 8 out of 10 years (80%) in 2000s. The 1980s droughts occurred in 1980, 1984 and 1986, the 1990s droughts occurred in 1992, 1994, 1995 and 1996 while in the 2000s drought occurred in all years except 2005 and 2007. The observation was in agreement with Howden (2009) who notes that the frequency of droughts in northern Kenya have now become an annual phenomenon in the 2000s. The frequency was once in every 10 years in 1970s, once in every 5 years in 1980s, once in every 2-3 years in 1990s. Similar increasing drought frequency has been observed in most dry lands of the world. In eastern parts of Ethiopia for instance, droughts occurred once in every 2 years in the 1990s and almost on an annual basis in 2000s (Mekuria, 2012).

Table 1: Drought and Non-drought years in Marigat Sub-County (1980 – 2012) (Source: KARI Perkerra Meteorological Station, 2014)

Year	Total annual amount of rainfall (mm)	Drought/Non drought event
1980	427.5	Drought
1981	692.1	Non drought
1982	666.7	Non drought
1983	703.3	Non drought
1984	270.5	Drought
1985	714.4	Non drought
1986	510.6	Drought
1987	587.0	Non drought
1988	892.9	Non drought
1989	842.0	Non drought
1990	590.5	Non drought
1991	667.5	Non drought
1992	562.0	Drought
1993	654.9	Non drought
1994	563.4	Drought
1995	500.1	Drought
1996	539.7	Drought
1997	780.8	Non drought
1998	760.4	Non drought
1999	637.6	Non drought
2000	256.9	Drought
2001	411.2	Drought
2002	237.6	Drought
2003	275.4	Drought
2004	275.8	Drought
2005	626.6	Non drought
2006	529.3	Drought
2007	926.8	Non drought
2008	452.4	Drought
2009	486.3	Drought
2010	550.7	Drought
2011	510.2	Drought
2012	496.1	Drought

Mean=563.7 mm

Drought Duration

Drought varied in duration from one drought event to the other. The drought durations ranged from 1 to 5 years over the period under study. Like the drought frequency, the duration has been increasing. In 1980s droughts occurred as one-off events. In 1990s the drought duration ranged from 1 to 3 years and up to 5 years in 2000s. A 3-year drought was experienced between 1994 and 1996 in the 1990s while a 5-year drought occurred between 2000 and 2004 in the 2000 decade (Table 2).

Table 2: Decadal drought duration (Source: Analyzed KARI - Perkerra Meteorological Station data, 2014)

Decade	Drought Year	Total annual amount of rainfall (mm)	Drought
1980	1980	427.5	Drought
	1984	270.5	Drought
	1986	510.6	Drought
1990	1992	562.0	Drought
	1994	563.4	Drought
	1995	500.1	
	1996	539.7	
2000	2000	256.9	Drought
	2001	411.2	
	2002	237.6	
	2003	275.4	
	2004	275.8	
	2006	529.3	Drought
	2008	452.4	Drought
	2009	486.3	
2010	2010	550.7	Drought
	2011	510.2	
	2012	496.1	

Long term mean rainfall from 1980-2012 = 563.7mm

Drought Intensity

Drought intensity was calculated using the following formula and the results indicated in Table 3

$$DI = \frac{X - \overline{X}}{\overline{X}} * 100\%$$

The negative sign for the calculated drought intensity indicates the percentage of total annual rainfall for a specific year below the calculated long term mean rainfall (Trotman et al, 2007).

Table 3: Drought intensity for the identified drought years (1980-2012) (Source: Analyzed KARI - Perkerra Meteorological Station data, 2014)

Drought Year	Total Annual amount of rainfall (mm)	$DI = \frac{X - \overline{X}}{\overline{X}} * 100\%$ Drought intensity (%)	% below the long term mean rainfall $DI = \frac{X - \overline{X}}{\overline{X}} * 100\%$
1980	427.5	-24.2	24.2
1984	270.5	-52.0	52.0
1986	510.6	-9.4	9.4
1992	562.0	-0.2	0.2
1994	563.4	-0.1	0.1
1995	500.1	-11.3	11.3
1996	539.7	-4.3	4.3
2000	256.9	-54.4	54.4
2001	411.2	-27.1	27.1
2002	237.6	-57.8	57.8
2003	275.4	-51.1	51.1
2004	275.8	-51.1	51.1
2006	529.3	-6.1	6.1
2008	452.4	-19.7	19.7
2009	486.3	-13.7	13.7
2010	550.7	-2.3	2.3
2011	510.2	-9.5	9.5
2012	496.1	-12.0	12.0

Long term mean rainfall from 1980-2012 = 563.7mm

Table 3 revealed that drought intensity in Marigat Sub-County ranged from 0.1 to 57.8 percent below the long term mean. This implies that droughts occurring in the same area vary in terms intensity. The greater the negative variations from the long term mean, the higher the drought intensity. In this case, the 1994 drought where annual rainfall was 0.1 percent below the long term mean was of lesser intensity compared to the 2002 drought where annual rainfall was 57.8 percent below the long term mean. Actually, the 2002 drought was the most intense drought in the study area for the period under the study. The 2002 drought was wide spread affecting others parts of the world. For instance, San Diego in California recorded 51.1 percent rainfall below the long term mean whereas Quad cities in the US recorded 59 percent rainfall below the long term mean in the year 2002 (Pidwirny, 2008). In Ethiopia, North Afar zones, the 2002 drought was considered the worst and intense in human memory even worse than 1984-1985 droughts due to combination of high loss of animals and yields (Mekuria, 2012).

B. Effects of Drought Dynamics on Vegetation Cover

Droughts triggered major changes on vegetation cover in the study area. The magnitude of the vegetation cover change depended on the dynamic of the drought as explained below.

Diminishing of Grasslands Pastures and Shrubs Cover

Different types of rangeland vegetation were affected differently by droughts of varying characteristics. Respondents reported that grasslands pastures (annual grasses) and shrubs had diminished in the study area. This was attributed to the sensitive nature of annual grasses and shrubs to varying drought characteristics compared to tree cover and wetland vegetation. Mwangi and Swallow (2005) asserts that the predominant annual grasses and shrubs of the 1980 and 1990 decades in Kimalel, Kimondis, Elwalel-Soi, Salabani, parts of Kapkuikui and Marigat Locations had declined tremendously. Overall, vast lands of the study area laid bare (devoid of vegetation) over the study period. This was attributed to the increasing drought frequency, duration and intensity. The severe and prolonged droughts that were experienced during the 2000-2009 decade led to increase in bare grounds in most rocky areas of Kimalel, Salabani, Kimondis and Elwalel-Soi Locations. This was triggered by drying up of vegetation following the 5-year drought that occurred from 2000 – 2004, and the 2-year drought that occurred from 2008 to 2009. The observations made by the respondents was supported by the analyzed NDVI data from Landsat satellite images (Table 4 and Figure 2) on the effects of droughts of varying characteristics on riverine vegetation along Lake Baringo shores. From the satellite images the areas with green color represents the vegetation.

Table 4: NDVI values and drought intensity (Source: Analyzed Meteorological Data, 2014 and http://glovis.usgs.gov)

Drought year	Mean NDVI values	Drought intensity (%) below long term mean
1984	0.03	52.0
1994	0.08	0.1
2000	-0.07	54.4

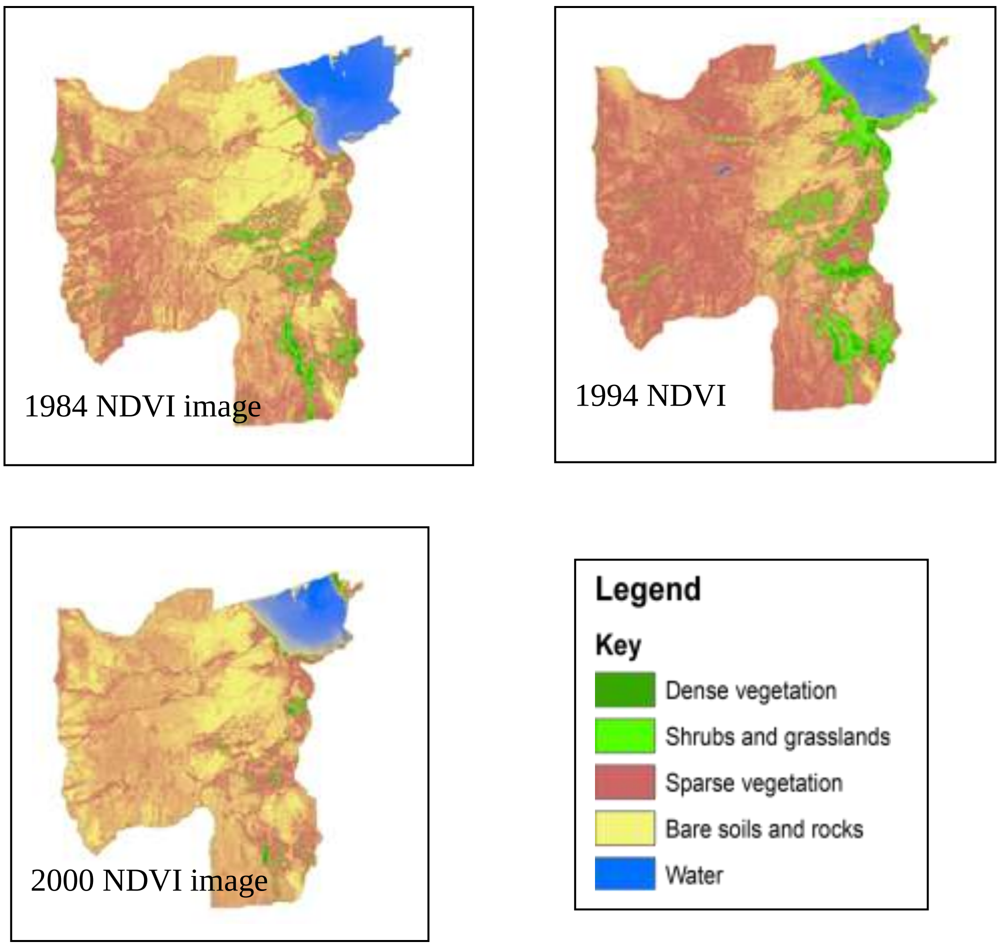


Figure 2: Vegetation cover for 1984, 1994 and 2000 droughts (Source: http://glovis.usgs.gov/, Downloaded on: 21/11/2014)

Table 4 and Figure 2 revealed that droughts of different intensities can drive significant changes on plant biomass in an area. When the drought intensity is low e.g. 0.1 for 1994, the mean NDVI value is high (0.08 for 1994). In such drought event, the study area had most of the area was covered with sparse vegetation (as indicated by the brown colour) and relatively higher concentration of shrubs and grassland vegetation (as indicated by the green colour) than when droughts are severe. When the intensity is higher, the NDVI value is low as it was during the 1984 and 2000 droughts. Vast areas were characterized by bare soils and rocks (indicated by diminishing green and brown colours and increase in yellow colour). The relationship between drought intensity and mean NDVI values could be explained by the fact that droughts with high intensity reduce the plant biomass, which has a high NDVI value, leaving bare soils and rocks with low NDVI values. The observation was in line with Travis (2006) findings in San Antonio region, Texas, who observed changes in NDVI images of 1999 and 2002. The mean NDVI values were noted to change from 0.195 in 1999, the year which recorded a drought of high intensity to 0.361 in 2002, the year with low drought intensity. The findings were also in line with Auken (2000) assertion that prolonged droughts experienced in the semi-arid of North America between 1987 and 1999 led to 54 percent decline of grasslands and 32 percent decline of shrub lands in the region respectively.

Reduction in Tree Cover

Reduction in tree cover was one of the most noted changes in vegetation cover. The most affected was the Acacia tree species, especially in the lowland parts of the sub-county which comprised of Marigat, Il-Chamus, Iling'arua and Ngambo Locations. Decline in tree cover was attributed to the extensive use of Acacia tree for charcoal burning as a coping strategy against droughts. The increasing number of charcoal bags (25-30 kg standard bag) sold form the sub-county indicated the high rates of tree felling (Figure 3). In addition the in migration by pastoralists from outside the sub-county during prolonged and severe droughts led to overgrazing in forested area (Table 5) resulting in destruction of trees. Grazing took place in Kaptich and Lpunyaki Forests in Marigat and Nga'mbo Locations respectively.

Table 5: Frequency of grazing in dry-season grazing fields in the study area (Source: Field Data, 2014)

Where livestock grazed during dry season	Frequency	Percent
Forests	46	13
Swamps	119	32
Along the riverine areas	106	29
Migrating to other areas	97	26
Total	**368**	**100.0**

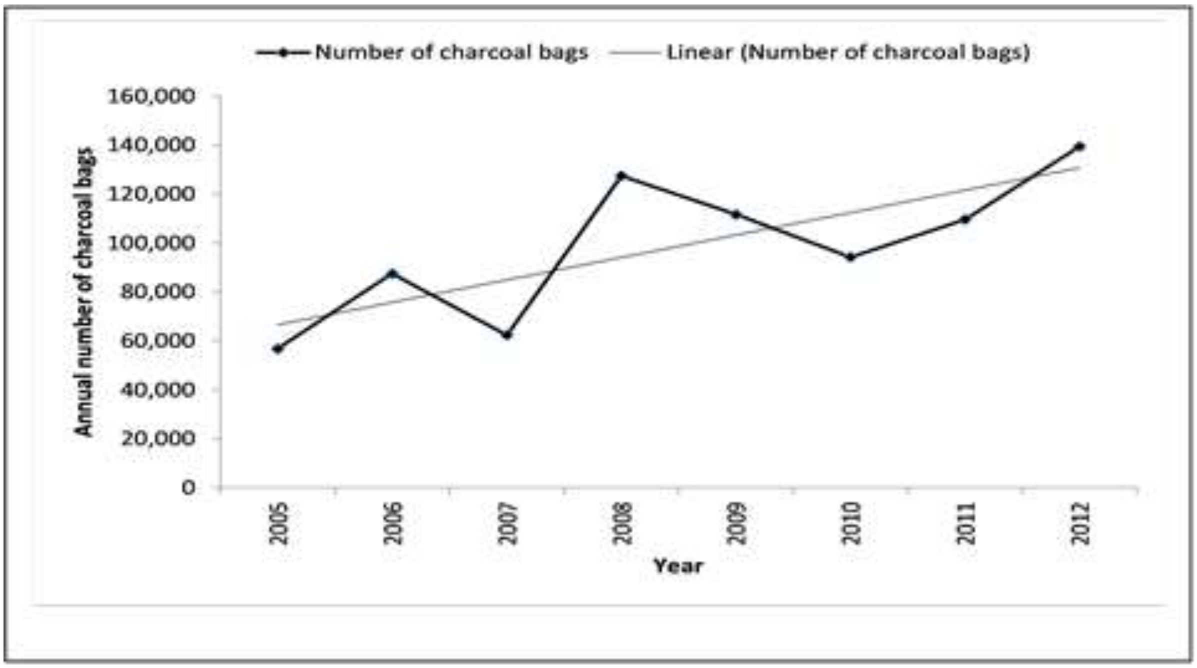
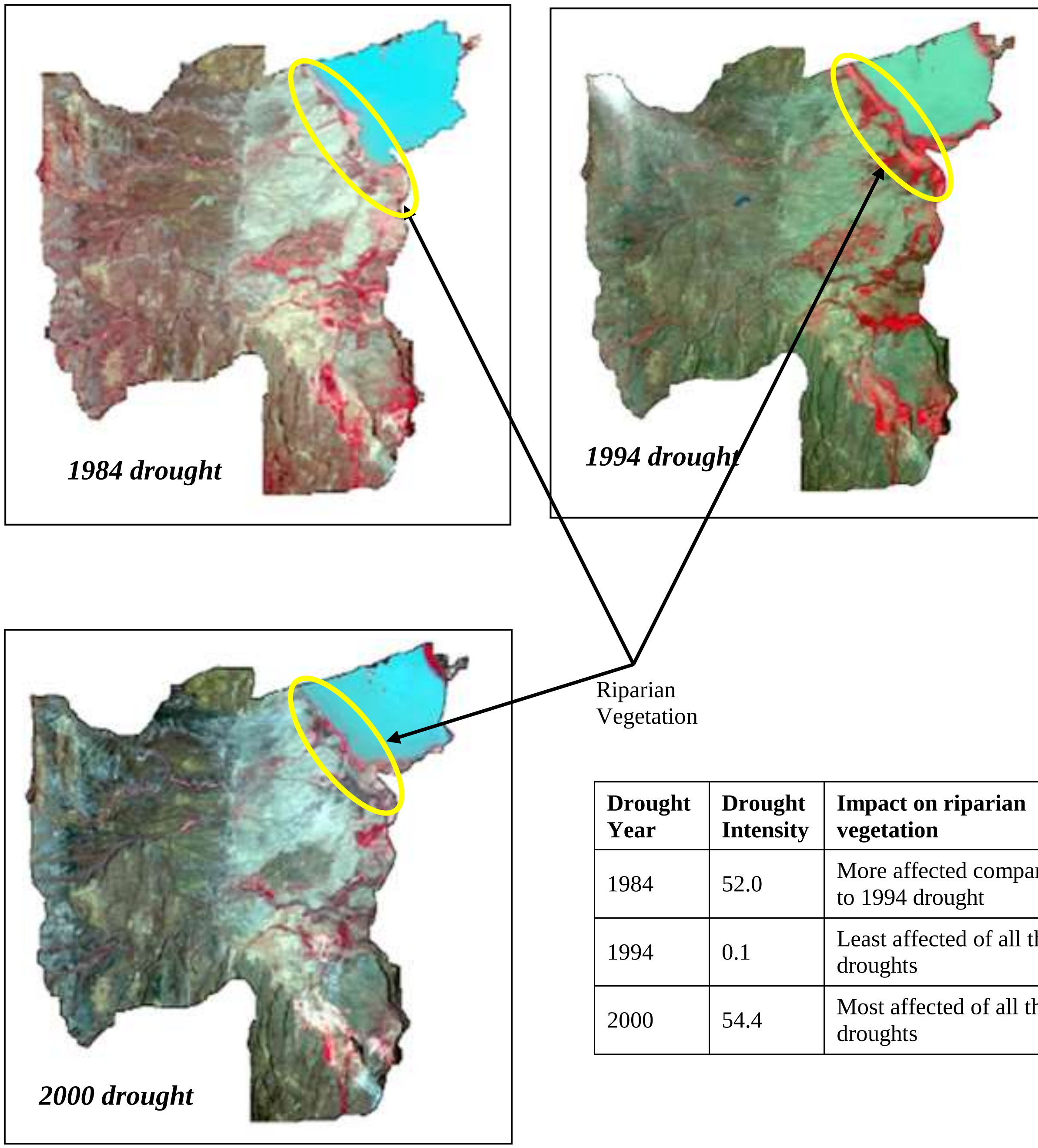


Figure 3: Increasing trend in number of charcoal bags produced in the study area (Source: field data, 2014)

Increase in charcoal production was attributed to the high number of inhabitants who engage in charcoal burning during drought periods. Savatia (2009) observes that over 70 percent of the pastoralists in the semi-arid areas of Northwestern Kenya engaged in charcoal burning and selling during the 2008 drought.

Destruction of Riparian Vegetation

The riparian (wetland and riverine) vegetation along Perkerra and Molo Rivers and wetland areas in Loboi and Marigat Locations were reported to have drastically reduced since the year 2000. The wetlands included Arabel and Perkerra Scheme in Marigat Location, Loboi Swamp in Loboi Location and Lake Baringo shores. The prolonged and intense droughts of the 2000 decade led to conversion of the wetland to farmland for agricultural purposes. About 80 percent of the respondents revealed that there was overgrazing on the wetland during the droughts. Table 4 indicates that 61 percent of the respondents grazed in the wetlands during prolonged and severe droughts and hence the rate of overgrazing increased with increasing drought intensity and duration. The analyzed NDVI data from Landsat satellite images revealed changes on riparian vegetation with varying drought characteristics as shown in Figure 4.



Drought Year	Drought Intensity	Impact on riparian vegetation
1984	52.0	More affected compared to 1994 drought
1994	0.1	Least affected of all the droughts
2000	54.4	Most affected of all the droughts

Figure 4: Riparian vegetation along Lake Baringo shores during droughts of varying intensities (Source: http://glovis.usgs.gov/, Downloaded on: 21/11/ 2014)

The NDVI data showed variations in amount of plant biomass during droughts of different intensities and durations. Droughts of high intensity resulted in low NDVI values compared to droughts of low intensity as shown in Table 5 and Figure 4. Depletion of wetland vegetation led to reduction in plant biomass. The study established that the low intensity drought of 1994 recorded a relatively higher amount of wetland vegetation (indicated by red colour) compared to the high intensity droughts of 1984 and 2000. The relatively similar amount of wetland vegetation cover during the 1984 and 2000 droughts can be explained by comparable drought intensities. The findings support other studies which indicate that depletion of riparian vegetation vary from year to year depending on drought characteristics (see Jacob, 2011; Urama & Ozor, 2010).

Change in Land Use Activity

Changes in land use had directly and indirectly affected vegetation cover. Land use had changed from predominantly pastoralism in the 1980s to agro-pastoralism in 2000s (Figure 5).

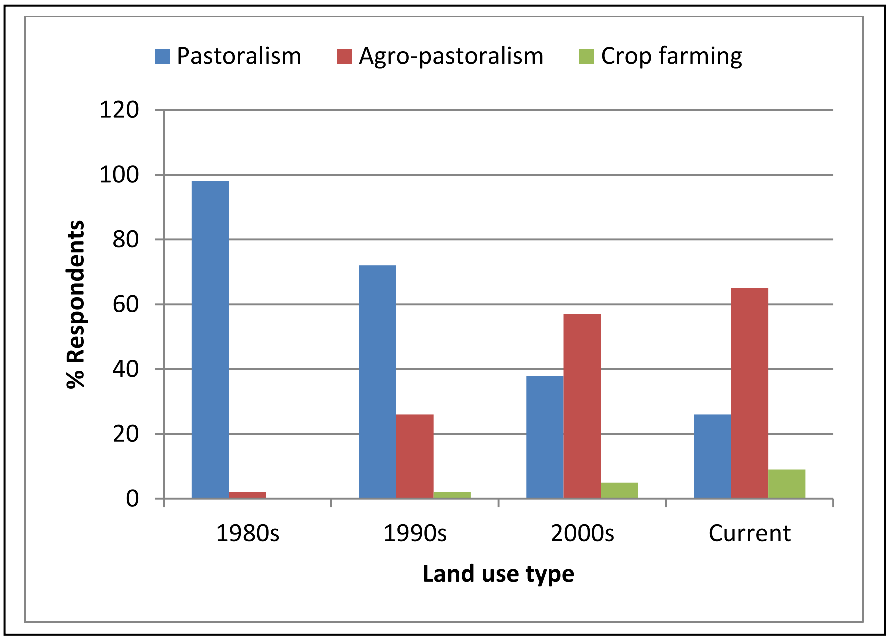


Figure 5: Changes in land use over the decades (Source: Field Data, 2014)

In 1980s, pastoralism predominated accounting for 98 percent of the household livelihood source. Only two percent of the households practiced agro-pastoralism. Household practicing pure crop farming emerged in 1990s accounting for 2 percent. In 2000s, agro-pastoralism predominated accounting for 57 percent of the households. Pastoralism and pure crop farming accounted for 38 and 5 percent respectively in 2000s. Currently about 65 percent of the households practice agro-pastoralism and about 10 percent practice pure crop farming. Pastoralism has been declining over the decades. This could be in response to the growing population and climate change i.e. increasing drought occurrences in the sub-county. The need for agricultural land has led to massive destruction of wetland vegetation and forest cover. As drought frequency, intensity and duration increases, the need for expansive land for cultivation increases. This acts a coping strategy where farmers maximize crop production by increasing the acreage under cultivation. These findings are consistent with those of Abdi et al., (2012) who also reported that population pressure and recurrent drought occurrences are the main driving forces of change in land use activity in the Semi-Arid of East Kordafan of Western Sudan. Studies by Kioko and Okello (2010) also associated climate change and population increase to the drastic changes in land use activity in the semi-arid rangeland of Southern Kenya.

V. CONCLUSIONS

Evidence indicates that droughts in Marigat Sub-County were becoming more frequent, prolonged and intense over the years. However, drought characteristics varied from one drought event to the other. Whereas all droughts affected vegetation cover, the magnitude of influence varied depending on drought dynamics. Frequent, prolonged and high intensity droughts had severe effect on vegetation cover compared to short-term and low intensity droughts. Droughts also caused changes in land use which directly or indirectly led to destruction of vegetation cover as people sought of agricultural land. With the increasing drought frequency and severity, if the environmental degradation remains unchecked Baringo County will become a desert devoid of vegetation.

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