

DROUGHT RISK AND VULNERABILITY ASSESSMENT; A CASE STUDY OF BARINGO COUNTY, KENYA

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Abstract

This study was undertaken in arid and semi arid county of Baringo which is prone to perennial droughts, with the majority of its population affected by the recurrent droughts and high poverty levels. The primary objective of this research is to assess population vulnerability, drought risk and rainfall performance during the drought period. The drought assessment was based on known drought periods, of 2009. Meteorological validation using NOAA-AVRHR data was used to determine the rainfall variation over the long term average. The data were obtained from NOAA-Advanced Very High Resolution Radiometer (AVHRR), was processed with ESRI-GIS software. The population vulnerability was processed using poverty rates, population density and livelihoods. An analytical hierarchy process criterion was used in determining vulnerability using the three socioeconomic variables. The drought assessment was determined using the normalized difference drought Index (NDDI) a combination of the normalized difference vegetation index (NDVI) and the normalized difference water index (NDWI). The results show that the poverty prevalence is high in marginal and pastoral livelihoods. Approximately 27.87% of the marginal livelihood and 25.62% pastoral livelihood are highly vulnerable. The livelihood drought risk analysis indicates that 49.58% of the marginal livelihood and 46.43% of pastoral livelihood to be at risk due to drought hazard. In conclusion, marginal, pastoral and agro-pastoral livelihoods are under serious drought risk with its population capacities undermined by high poverty rates, in this respect government should promote poverty reduction projects and improved markets infrastructure and access.

Key words: Vulnerability, livelihood, drought risk, poverty, NDWI, NDVI, NDDI

1.0 Introduction

Kenya is a drought prone country because of its eco-climatic conditions. The country contains few high potential climate regions of regular annual rainfall average of above 2000mm. Approximately 80% of Kenya's land mass are arid and semi Arid characterized by average annual rainfall of between, 200mm to 500mm per year, and are prone to harsh weather conditions, Serigne, (2006). Approximately 70% of Kenya's land mass are affected by drought; this covers parts of the Rift Valley, North Eastern, Eastern province and Coast Province, UNDP, (2006).

Approximately 75% of Kenya's population, earns its living from rain-fed agriculture and due to the vast areas prone to drought, Kenya's vulnerability to food insecurity is the highest among the majority of pastoralist and small scale agriculturalist in arid and semi arid lands of the country, UNDP, (2006). Drought is a naturally occurring phenomenon that exists when precipitation recorded is significantly below normal recorded levels causing a serious hydrological imbalance that affects land resource production systems, UNEP and GOK, (2000). Wilhite, (2005) observed that, drought accumulates slowly over a considerable period of time making it not easy to determine its starting and ending point. The hazard is characterized by its onset, termination, severity and frequency, Tychon *et al*, (2007). Wilhite and Glantz, (1985) observed over 150 drought definitions in an effort to categorize drought and generally classify them into four main types, i.e. socio economic, meteorological, agricultural, and hydrological drought. Balint, *et al* (2011) attempted to contextualize drought definition for the greater horn of Africa and observed drought to be a natural phenomenon, in a period where unfavourable weather conditions persist leading to scarcity of fresh water. This definition seemed to agree with the earlier definition put forward in Murad, *et al*, (2011), UNEP, and GOK, (2000). They defined drought as a hazard situation that results from a deficiency of precipitation from expected long-term normal, stretched out over a long period.

The applied remote sensing indices for drought assessment are the normalized difference vegetation index (NDVI), normalized difference water index (NDWI) and the normalized difference drought index, which is a combination of NDVI and NDWI. The previous studies such as in Tucker, (1980) found NDVI to be useful in drought assessment.

Thomas, *et al*, (2004) observed that, NDVI despite its capability in drought assessment is its limited capability in estimating vegetation water condition is affected by other variables. Thomas, *et al*, (2004), summarized the limitations of using NDVI as ; different plant species have their own relationship of chlorophyll content and vegetation water condition, and a decrease in chlorophyll content does not imply a decrease in vegetation water condition, whereas a decrease in vegetation water condition does not involve a reduction in chlorophyll content.

To enhance the information obtained from the index, the index must be applied jointly with another indicator that gives more information on precipitation and soil moisture to determine the vegetation response in case of drought investigations as observed in Gao, *et al*, (1996), JRC (2011). NDWI has been used to observe and monitor the moisture conditions of vegetation canopies, Xiao *et al* (2002), and has been tested as drought indicator (GU, *et al*, (2007) and found that the values exhibited a quicker response to drought condition than NDVI. As NDWI is very efficient in the area of stress because it is sensitive to soil moisture content, vegetation cover and leaf moisture content, Tychon *et al*, (2007). Some of the noted weaknesses of NDWI are in its susceptibility to soil background effects on the partial vegetation cover. Drought and water stress are not the only factors that can cause a reduction in the NDWI values or anomalies. The Change in land cover or pest and diseases can also be responsible for such variations of the signal, Gao *et al* (1996).

Normalized Difference Drought Index (NDDI) combines information from both the NDWI and NDVI data derived from the satellite data as in GU, *et al*, (2007). NDDI is found to be more responsive and have more extensive dynamic range values than a simple NDVI and NDWI differencing through drought periods, (Mongkolsawat *et al*, 2009). The observations by Mongkolsawat *et al*, (2009) finds that NDVI and NDWI values decreases with decreasing slope gradient of cumulative rainfall while the rapid increase of NDDI values during the dry months of the years, thus more sensitive to water content than NDVI and making it better index for drought identification. The studies by GU, *et al*, (2007) over the great plains of the United States, found that NDDI had a stronger response to summer drought conditions than a simple difference between NDVI and NDWI and is therefore more sensitive indicator of drought in grass land than NDVI alone. The NDDI in this research was taken up for drought hazard which was used in with vulnerability product, obtained by combination of socioeconomic variables to determine the drought risk in the study area.

Drought risk is a function of vulnerability and drought hazard. The simplified, standard formula for assessing the risk posed by natural hazards is ($Risk = Hazard \times Vulnerability$) highlights that a highly vulnerable sector can be impacted significantly by even a moderate hazard, Shahid & Behrawan, (2008). Stone and Potgieter, (2008) observed that, drought risk is a product of climatic hazard and vulnerability of farming or cropping practices whereas vulnerability can be as a result of land use management practices. Vulnerability assessment is a very important tool for decision-making processes. Senbeta, (2009), observed that vulnerability assessment informs decision makers and facilitates their decision-making processes.

Vulnerability according to the Colorado Water Conservation Board, (CWCB S, 2010) is a condition resulting from social, economic, and environmental factors or processes, which increases susceptibility of agricultural systems to the impact of drought hazard. Vulnerability assessment in context of Baringo County will be assessed based on socioeconomic and environmental indicators such as livelihoods, poverty index and population density. The conflicts experienced by the inhabitants of the northeastern parts of Baringo, mostly the land based and cattle rustling, further exacerbate the population vulnerability. The conflicts most often affect livelihood, though the communities involved have since developed coping mechanisms of migration to the safer places as they wait for matters to take root.

Baringo County in Kenya is in arid and semi arid lands of the Rift valley province of Kenya, it experiences frequent droughts, and drought related losses like any other county situated in the northern regions of Kenya. The livelihoods Baringo County is primarily pastoral, agro-pastoral, mixed and marginal farming livelihood. The population is experiencing varying levels of vulnerability based on their vulnerability to drought hazard. The livelihoods however are exposed to drought differently due to limited choices. A previous study by Hahn's, *et al*, 2009 found that, families who engage in one form of livelihood activity such as farming or livestock keeping only are more vulnerable than those who engaged in various livelihood activities for such as mixed farming, or agro-pastorals. This means that only

one form of livelihood leaves the people more exposed, as their coping capacities are limited.

The primary objectives of this research is to evaluate the population vulnerability using a combination of socioeconomic variables such as poverty rates, population densities and livelihoods and to derive drought risk using the vulnerability and drought hazard experienced in 2009 with verification of the drought situation using the rainfall performance for the drought year against its long term mean average.

The existing vulnerability assessment method is complex and time consuming as it uses multiple indicators from various stakeholders which takes time to assemble hence making it not a reactive tool for vulnerability and drought risk assessment. This research considers the basic socioeconomic variables such as poverty index, population density and livelihood to determine the vulnerability and the use of Geo- information tools to assess drought and its risk.

2.0 Methodology

Baringo county is characterized by desert shrubs with drier thorny acacia trees and thorny bushes with small patches of grassland, with temperate forests and evergreen forests composed of semi deciduous bushes and wooded grassland towards the south, (Homewood *et al.*, 1987). The mean annual zonal rainfall averages between 450 mm to 900 mm to the semi-arid, 800 to 1400 mm in the semi-humid, 1000 to 1600 to the sub- humid zones and 1100 to 2700, (Odada *et al.*, 2006), with lowland daily mean temperature varies from 15°C to 35°C (Johansson and Svensson, 2002). The county population is 555,561 with 60,995 living in urban and poverty rate of 57.4%. (KNBS, 2010). The main livelihood in the study area is made up of the pastoral, agro-pastoral, mixed farming, and marginal farming. The map in Figure 1 shows the geographical location of the study area in Kenya.

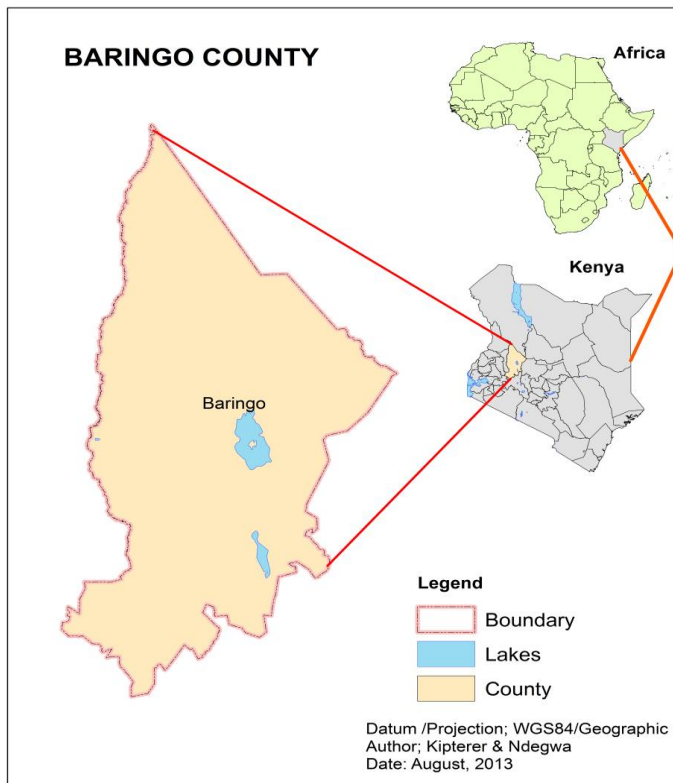


Figure 1: study area

The data used in this research are summarised in Table 1 with the details of products, sources, access link, formats and its spatial resolutions and their frequencies.

Table 1: Data sources

Data products	Source	Resolution/frequency	Format	An access link
NDVI	SPOT -VGT	1km*1km/dekadal	GeoTiff	
NDWI	SPOT-VGT	1km*1km/dekadal	GeoTiff	
Poverty Index	KIHBS, 2005/6	Admin level 4	Vector	www.knbs.or.ke
Population Density	KNBS, 2009	Admin level 4	Vector	www.knbs.or.ke
Rainfall	NOAA-AVHRR	8km * 8km/decadal/day	WINDSP	http://earlywarning.usgs.gov
Admin files	RCMRD	County levels	Vector	RCMRD, Nairobi.

The research methodology is summarized framework in Figure 2.

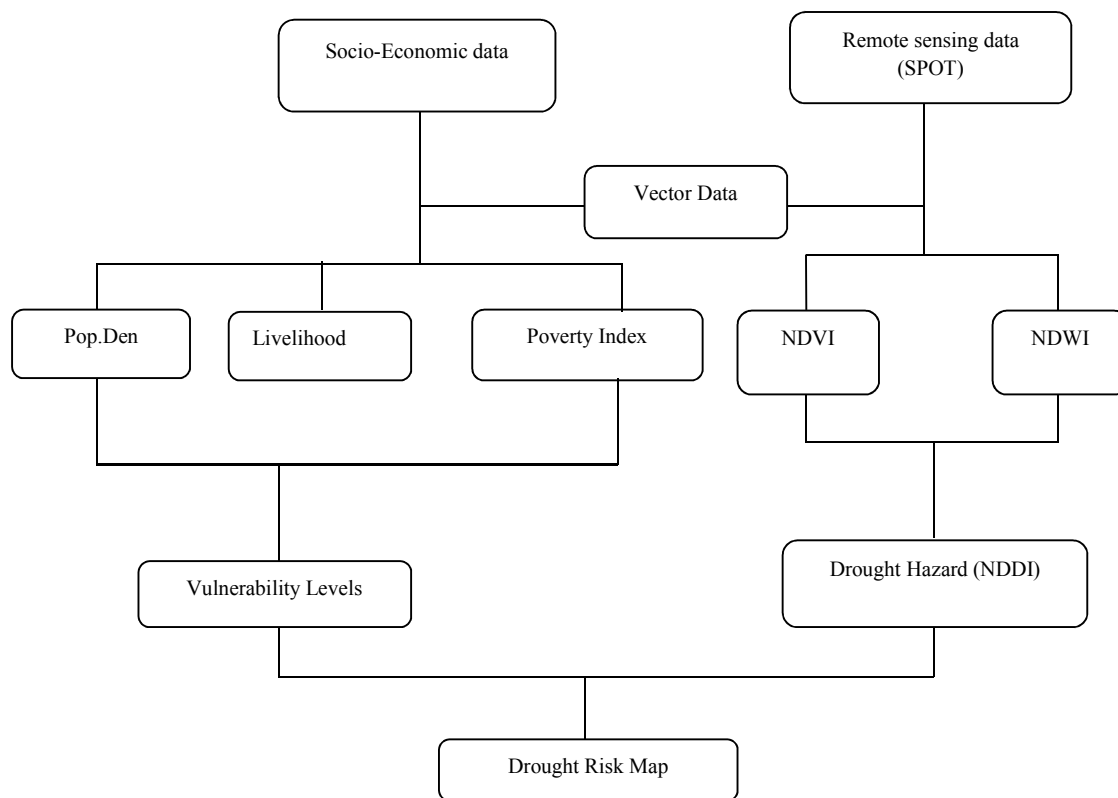


Figure 2: Research Framework

Note:

Pop.Den = Population Density; NDDI = Normalized Difference drought Index; NDWI = Normalized difference water Index; NDVI = Normalized difference vegetation index; SPOT = Satellite Pour l'Observation de la Terre= (French)

The research methodology as summarized in the framework in Figure 2 involves three main steps i.e vulnerability drought hazard and drought risk assessment. Vulnerability in this framework is determined by a combination of socioeconomic variables, whereas the drought hazard is achieved by use of remote sensing variables and the drought risk is a product of vulnerability and the drought hazard. The vulnerability levels used socioeconomic data. The input variables used are; Livelihoods, Poverty rates and Population density in a geographic Information system is weighted sum analysis. Analytical hierarchy process (AHP) was applied to determine the weights a variable contributes into

the vulnerability assessment. The weights subjected to AHP was sourced from expert’s opinion working in the study area and those who are conversant with the subject. The livelihood is a means by which households obtain and maintain access to the resources necessary to ensure their immediate and long-term survival (USAID, 2005). Geographical aspects such as climate, soil, topography among others and marketing or trade aspects such as roads proximities to urban centres define a livelihood zone map, which affects consumption by households. Livelihood dynamics such as livelihood recovery in an event of hazard affects the population vulnerability.

The poverty ratings by the Kenya National Bureau of statistics uses the foster-Greer-Thorbecke (FGT), a measure of poverty within an economy that combines information on the extent of poverty as measured by the headcount ratio with the intensity of poverty measured by the total poverty gap. This information provides an indicative measure of population purchasing power parity, and the poor the persons are the vulnerable they may be to the hazards. Population density is the number of persons per square kilometre. The location administrative level data was obtained from Kenya national bureau of statistics. This input variable is very important in determining the population vulnerability to hazard. The vulnerability product was derived using equation 1 below.

Vulnerability = **(W)** Poverty Index + **(W)** Livelihood + **(W)** Population density; **(1)** Where; W stands for Weights.

Normalized Difference Drought Index (NDDI) has been used in drought assessment. NDDI combines information from both the normalized difference water index (NDWI) and normalized difference vegetation index (NDVI). Equations 2, 3 and 4 below show how these remote sensing products are derived.

$$NDVI = (NIR - R) / (NIR + R), \text{ (Tucker, 1980) (2) where, NIR; Near Infra-red, R is red}$$

$$NDWI = (R - SWIR) / (R + SWIR) \text{ (Gao, et al, 1996) (3) , where SWIR; Short wave Infra red and R is red}$$

$$NDDI = (NDVI - NDWI) / (NDVI + NDWI) \text{ Gu et al, 2007 (4)}$$

The drought risk assessment obtained by combining the drought hazard with the vulnerability generated using the socioeconomic data in a geographic information format using the conventional risk assessment methods as shown in equation (5)

$$\text{Risk} = \text{Hazard (drought)} \times \text{Vulnerability (Degree of exposure) (5)}$$

The risk of assessment in this context is drought risk, under drought hazard and degrees of population exposure.

3.0 Results

The results indicate that, The rainfall performance was consistently below normal long term average with false start at the beginning of each season, i.e. March and August. Poverty rates among the Pastoral, Agro-pastoral and Marginal livelihood is high. The livelihood vulnerabilities in in this livelihoods are equally high with the least vulnerable being the mixed farming livelihood. Drought was found to be very severe in the northern and eastern parts of the area with pastoral and marginal livelihoods more affected.

The rainfall performed poorly throughout the agronomic seasons and the entire year with its thresholds falling excessively below the climatological average of 1981 to 2012. The graph in figure 3 summarized the overall rainfall performance in the period. Study area.

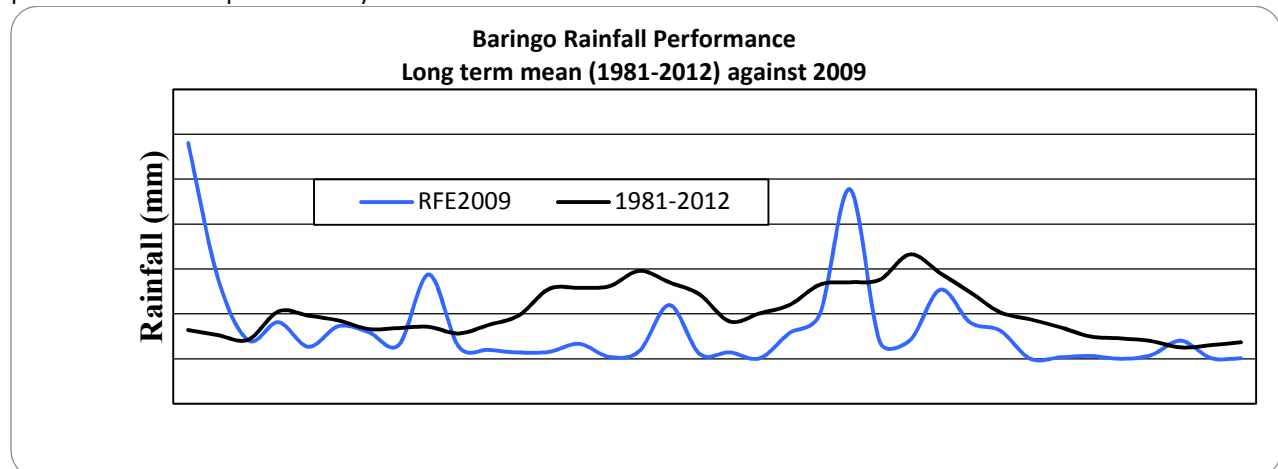


Figure 3: Rainfall performance

The rainfall onset on third dekad of march for the long rains season started late and declined below the normal in the first dekad of April. The second season started very well in the second decade and again declined below the long term normal. The failed rains exacerbated the dry spell, this implied that the areas was affected by the drought.

The poverty rates according to the The Foster-Greer-Thorbecke, a measure of poverty within an economy that combines information on the extent of poverty as measured by the headcount ratio with the intensity of poverty measured by the total poverty gap is summarized in Table 2.

Table 2: Livelihood poverty rates

Poverty levels/index	Livelihood analysis			
	Pastoral	Agro-Pastoral	Marginal	Mixed
Very Low (0.289-0.371)	7.67%	13.76%	8.25%	26.55%
Low (0.372-0.447)	22.80%	30.57%	14.63%	46.06%
Moderate (0.448-0.49)	8.23%	25.87%	13.00%	17.43%
High (0.50-0.59)	21.77%	12.51%	49.68%	5.17%
Very High (0.60-0.734)	39.53%	17.29%	14.44%	4.80%

The poverty rates were classified into five main classes, i.e., very low, low, high and very high poverty rates. The low poverty rates in the study area ranges between (0.29 to 0.371) at very low classification and (0.372 to 0.447) at low poverty rates while moderate rates are (0.448 to 0.49) and high at (0.50 to 0.59) and very high at (0.60 to 0.734) The livelihood analysis within the same poverty rates (0.49-0.734) indicate that 64.12% of the marginal, 61.3% of Pastoral , 29.8% of agro-pastoral and 9.9% of mixed of the population live in this poverty levels.

The population vulnerability to hazards based on their capacities in the county is 20.45% on higher scale, 50.51% moderate and 29.03% on low vulnerability. The specific livelihood vulnerabilities are at 44.78% for marginal farming livelihood, 31.33% agree-pastoral and 17.03% for pastoral livelihood. The population in pastoral livelihood is less vulnerable due to their coping mechanisms and their low population densities. Table 3 below shows the vulnerability levels in the livelihoods.

Table 3: Livelihood vulnerability

Levels	Percentages of the vulnerabilities			
	Pastoral	Agro-pastoral	Marginal	Mixed
Not/ Very Low Vulnerability	0.03%	0.12%	1.57%	18.69%
Low Vulnerability	27.66%	28.10%	37.07%	8.14%
Moderately Vulnerable	55.27%	40.45%	16.58%	69.26%
Highly Vulnerable	14.53%	9.34%	25.45%	3.53%
Extremely Vulnerable	2.50%	21.99%	19.33%	0.37%

Remote sensing image analysis of drought hazard assessment in the livelihoods as summarized in Figure 4.

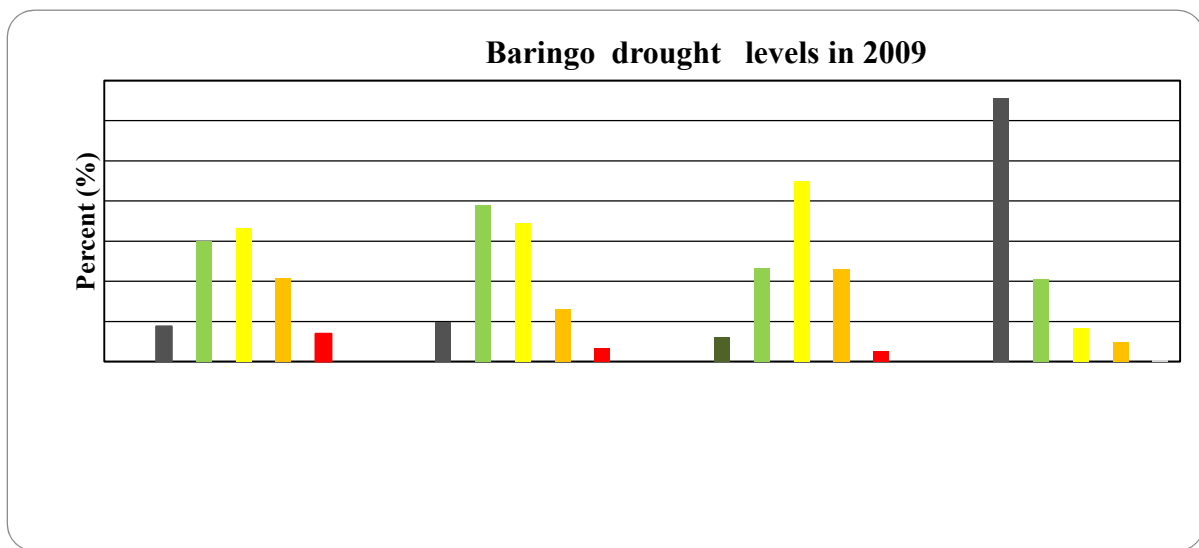


Figure 4: drought hazard

About 27.87% of the pastoral and 25.62% of the marginal farming livelihoods was severely affected by the 2009 drought whereas 16.43% of the Agro-pastoral and 5.36% of the mixed farming was severely affected. The results implied that the worst drought hit livelihood zones was pastoral and marginal farming livelihood zone.

The maps presented in Figures, 5,6 and 7 shows the socioeconomic indicator layers that were combined to determine the vulnerability of the county.

Figure 6: population density

Figure 7: Livelihood zones

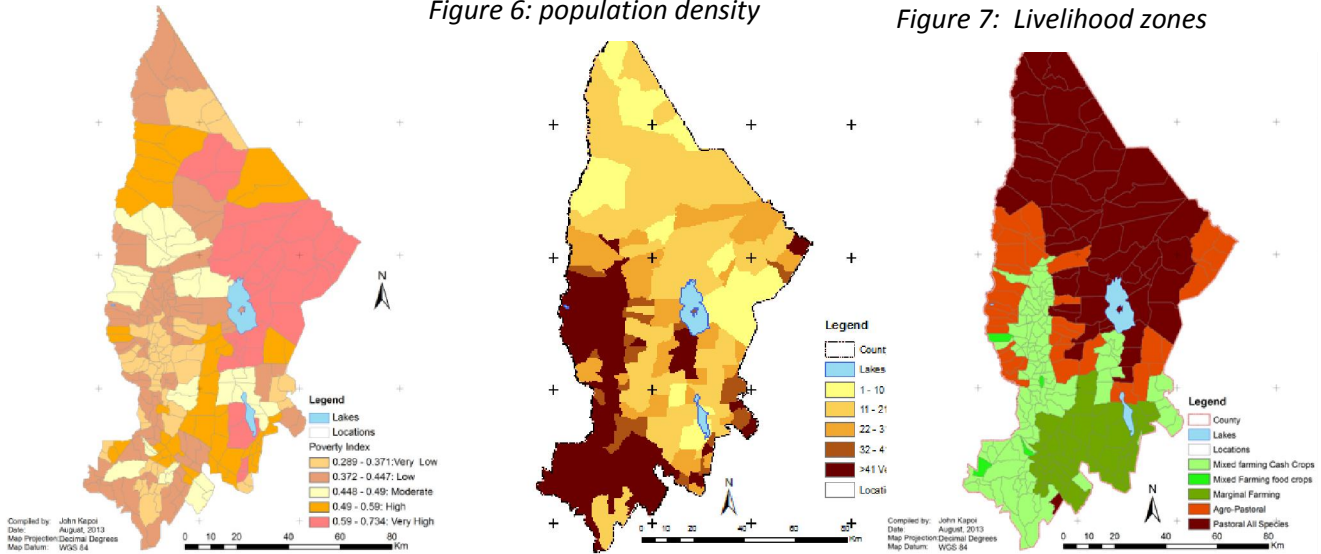


Figure 5: Poverty rates

The poverty rates were classified into five main classes as follows class 1; (0.289-0.371), 2; (0.372-0.447), 3; (0.448-0.49), 4; (0.50-0.590) and 5; (0.60-0.734) as shown in Figure 5. Table 3 shows the summary of the livelihood poverty rates according to the five main classes. The poverty rates in the eastern parts of the study area are high. The poor eastern parts are dominated by pastoral and agro-pastoral forms of livelihood refer to Figure 7 on livelihood zones. The southern parts which are dominated by a marginal form of livelihood as shown in figure 7, are relatively on high scale of poverty rating of (0.50-0.59).

The population density was manually classified into five classes with the very low class 1 (1-10) persons per square kilometre, low, 1 (11-21), medium 3, (22-31), high 4 (32-41) and very high (>42). The population density is very high (class 5) in southern and western parts of the county and around Lake Baringo, the largest lake in the study area. The highest population density is concentrated on the mixed farming and some parts of Agro-pastoral livelihood zones, as summarized in figure 6 above.

The livelihood was reclassified into five main classes, i.e., pastoral, agro-pastoral, marginal farming, mixed farming with cash crop and mixed farming with food crops as shown in Figure 7. The northern and eastern parts of the study area that is dominated by Pastoral and Agro-pastoral livelihood is characterized by low population densities as shown in Figure 6 (population densities) and with high poverty rates as shown in Figure 5 (poverty rates). The proportions upon classifications puts pastoral livelihood at 49.6%, 17.4% agro-pastoral, 12.9% marginal farming and 20.1% is mixed farming of both food and cash crops. The classification shows that, the county is dominated by pastoral and agro-pastoral which constitutes 67% making it the major livelihoods supporting the study area economy.

Figure 8: Vulnerability

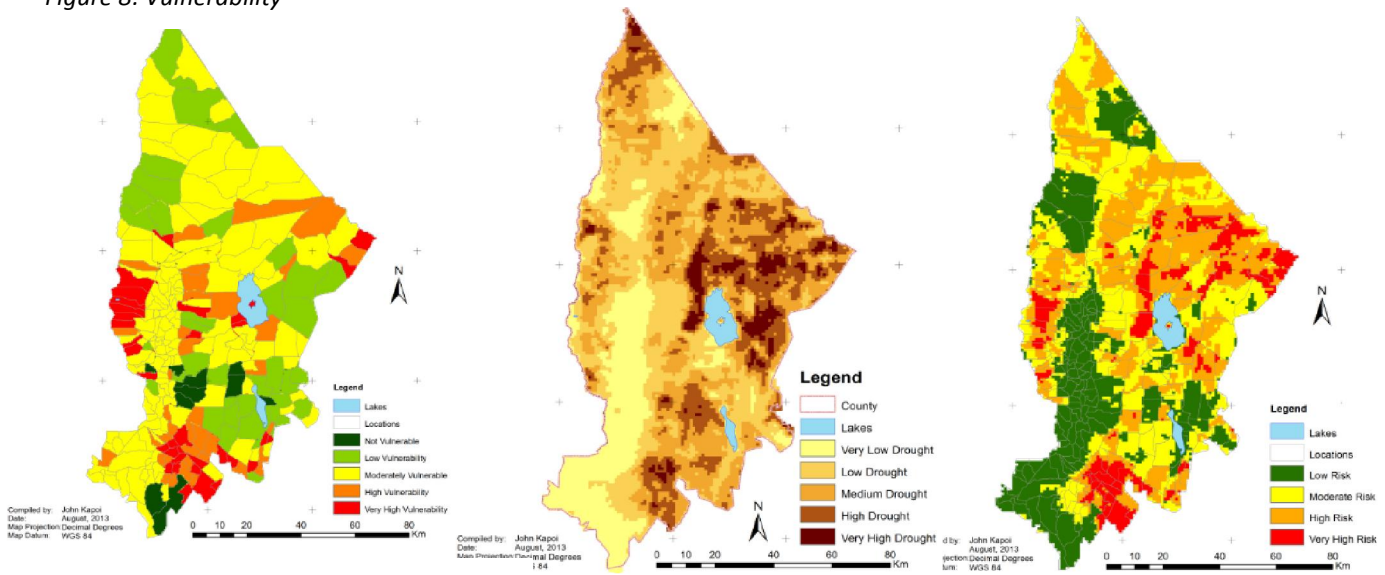


Figure 10: Drought Risk

The drought risk (Figure 10), was determined by a combination of the drought hazard (Figure 9) and the population vulnerability levels (Figure 8). In Pastoral livelihood, about 8.78% and 29.99% of the livelihood are on very low or no drought to low drought respectively with 33.36% to moderate and 20.9% and 6.97% on high and severe translating to 27.87% on highly severe drought thresholds. The marginal livelihood indicates that 6.16% and 23.35% are on no drought and low drought thresholds respectively and 44.87% moderately severe with 23.07% and 2.55% on high and severe threshold respectively. This indicates that 25.62% of the livelihood are highly affected by the drought.

About 9.93% and 39.03% in agro-pastoral livelihood is in no drought and low drought levels by 34.62% in moderately thresholds while 13.10% and 3.33% in highly and severe drought levels. In mixed livelihood zone 65.58% and 20.62% falls in no drought and low drought respectively and 8.45% on the moderate levels with 4.95% and 0.41% on high and severe levels.

The results indicate that large parts of pastoral (27.87%) and marginal farming (25.62%) livelihood is severely affected by drought. The livelihood that is least affected by the 2009 drought as indicated in these results is mixed farming where 5.36% of the livelihood are in high and severe drought thresholds. The analysis of vulnerability analysis indicates that the most highly vulnerable livelihood is marginal farming livelihood. 44.78% of the livelihood are highly vulnerable, 16.58% moderately vulnerable and 38.64% are on low and very low vulnerability making it very difficult to predict the most affected households.

About 31.33% in agro-pastoral livelihood is highly vulnerable with 40.45% and 28.22% moderately and very low to low vulnerability. Pastoral livelihood proportions indicate that 17.03% is highly vulnerable, 55.27% moderately vulnerable and 27.69% lies in low to very low vulnerability. The least vulnerable livelihood in the study area is mixed farming where 3.9% is highly vulnerable with 69.26% under moderate and 26.83% in low and very low vulnerability. Figure 8 shows the map of the vulnerability levels in the study area.

The drought risk results are summarized in the graph in Figure 11 below where each livelihood drought risk is represented with its proportion.

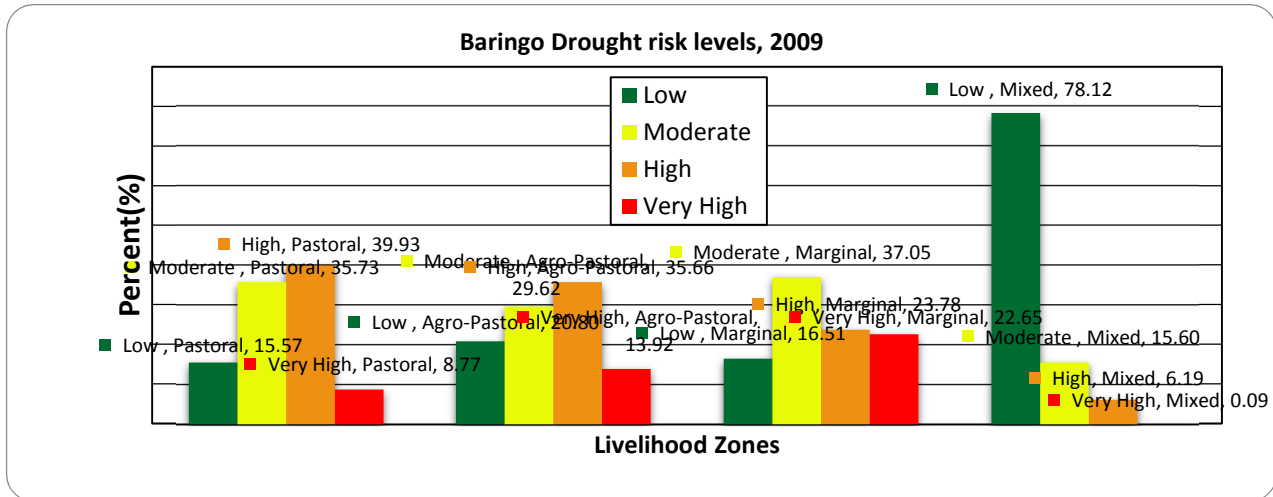


Figure 11: Livelihood drought risk levels

The drought risk assessment indicates that 30.44% of the study area were under severe drought risk. The livelihood analysis indicates that 49.58% of the marginal, 48.7% pastoral, 46.43% agro-pastoral and 6.2% of the mixed farming livelihood land mass was at very high drought risk.

4.0 Conclusion

Marginal, pastoral and agro-pastoral livelihoods are under serious drought risk with its population capacities undermined by high poverty rates. The populations in Agro-pastoral and marginal farming livelihoods are worst affected by drought despite the fact that the agro-pastoral have a number of alternatives, they are still undermined by the population densities and higher poverty rates. The study also puts the eastern and northern parts of the county to be higher at drought risk with high population vulnerability levels.

The government should promote poverty eradication projects in the area that aims at improved market access and infrastructures such as road networks, enhanced agriculture based services that targets agricultural production through support in breeding for pastoral, farm input subsidies (fertilizers, seeds, farm chemicals and farm mechanization especially in cultivation) to marginal, mixed and agro-pastoral communities.

The socio-economic aspects that exacerbate the population vulnerabilities in the livelihoods such as the resource based conflicts on land, water and pasture and the literacy rates has been linked by various studies to be of concern in vulnerability assessment, future research on vulnerability assessment should put this into consideration.

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