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Analysis of spatial variability in rainfall trends in Baringo County, Kenya

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This study assessed actual rainfall trends and variability in Baringo County. The objective of the study was to determine whether there were variations in rainfall trends by agro ecological zones. Meteorological rainfall data for the period 1981 to 2010 from three distinct agro-ecological zones covering highland (LH 2), low land (IL 6) and midland (LM 5) was used. The choice of rainfall stations was informed by agro-ecological zones and percentage of missing data. Data were analyzed on annual and monthly basis. Trend analysis and coefficient of variation was used to analyze actual trends and rainfall variability. Trend analysis showed year to year variability in rainfall. The trends were by agro-ecological zones. Annual rainfall in LM5 and IL6 showed decreasing trends while in LH2, it showed increasing trend. IL6 and LH2 exhibits a very high coefficient of variation for annual rainfall (CV > 30%), indicating high rainfall variability. Increasing awareness of climate variability and development of mitigation options will be necessary response strategies in Baringo County.

Key words: Rainfall trends, rainfall variability, trend analysis, Baringo County.

INTRODUCTION

Climate Change and Climate Variability are two important characteristics of climate. Climate change has emerged as one of the defining scientific, political and socioeconomic issues of the twenty-first century. IPCC (2014) describes climate change as a change in the state of the climate that can be identified by changes that persists for an extended period, usually decades or longer. Although an area's climate is always changing, the changes do not usually occur on a time scale that is immediately obvious to people. Weather changes can be observed from day to day but slight climate changes are not as readily detectable. Climate takes the following elements into account, the most important of which are: Air temperature and humidity, type and amount of cloudiness and precipitation (e. g. rainfall), air pressure, and wind speed and direction. FAO (2007) describes climate variability refers to variations in the mean state and other climate statistics such as standard deviations, and the occurrence of extremes among others on all temporal and spatial scales beyond those of individual

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weather events. Variability may result from natural internal processes within the climate system (internal variability) or from variations in natural or anthropogenic external forces (external variability). Every year in a specific time period, the climate of a location is different. Some years have below average rainfall, some have average or above average rainfall.

Climate, with particular reference to rainfall, is known to be changing worldwide (Chaponniere and Smokhtin, 2006). Rainfall exhibits notable spatial and temporal variability in Africa (Hulme et al., 2005). Inter-annual rainfall variability is large for the most part of the continent and, forsome regions; multi-decadal variability is also large. The water supply is highly variable in Africa and dry or wet spells can range from months to decades. Inter-annual rainfall variability in Africa is influenced by several factors: El Nino Southern Oscillation (ENSO), Inter-Tropical Convergence Zone (ITCZ), topography, urbanization and global warming (Matondo, 2010). The annual rainfall cycle in East Africa is influenced by the movement of the Inter-Tropical Convergence Zone (ITCZ), which migrates between 15°S and 15°N between January and July respectively, and by the monsoon circulation. The monsoonal winds of the ITCZ are the major source of moisture flux in countries like Kenya, for example Ogallo (1992). These rainy seasons occur during the transitions between the winter and summer monsoons, when air in both hemispheres converge near the equator (Hastenrath et al., 2004). Eastern Africa's diverse topography also contributes to the high spatial variance in seasonal distribution of rainfall. The "short rains" have shown more inter annual variability than the "long rains" despite the larger amounts of rainfall received in March, April and May (Black et al., 2002; Clark et al., 2003; Hastenrath et al., 1993). Projections in East Africa suggest that increasing temperatures due to climate change will increase rainfall by 5 to 20% from December to February, and decrease rainfall by 5 to 10% from June to August by 2050 (IPCC, 2007; Hulme et al., 2001). Rainfall in Kenya is variable and annual variations follow El Niño and La Niña episodes (Parry et al., 2012). Some regions experience frequent droughts during the long rainy season while others experience severe floods during the short rains (RoK, 2013).

Climate change affect rainfall distribution and weather patterns (Taylor et al., 2012). Long term fluctuations in rainfall distribution pattern around the world have been linked to the effects of climate change (Scott, 2004). Climate change has altered not only the overall magnitude of rainfall but also its seasonal distribution and inter-annual variability worldwide (Easterling, 2000; Trenberth et al., 2007; Zeng et al., 1999). Such changes in the rainfall regimes will be most intensely felt in arid and semiarid regions where water availability and timing are key factors controlling biogeochemical cycles (Zeng et al., 1999). Developing countries, Arid and Semi-Arid Lands (ASALs) and the poor in society are the most vulnerable and likely to be hit hardest by climate change due to their low adaptive capacity (Boko et al., 2007; IPCC, 2007b). Poverty determines vulnerability through several mechanisms, principally in access to resources to allow coping with extreme weather events and through marginalization from decision making and social security (Kelly and Adger, 2000). The existing developmental challenges such as endemic poverty, complex governance and institutional dimensions; limited access to capital, including markets, infrastructure and technology; ecosystem degradation; and complex disasters and conflicts have contributed to Africa's weak adaptive capacity (Boko et al., 2007). Although arid and semi-arid regions are already climatically stressed with high temperatures, low rainfall and long dry seasons, they are often thought of as being particularly vulnerable to climate change (ACDI, 2016).

Approximately 80% of Kenya's land mass is arid and semi-Arid (ASAL) characterized by average annual rainfall of between, 200 to 500 mm per year, and is prone to harsh weather conditions according to Serigne (2006). Some areas in the northwest and east receive only 200 mm per year (NCEA, 2015). Kenya has a population estimated at 38.6 million (RoK, 2010). Over two thirds of the country is classed as ASALs (Orindi et al., 2007), and these areas are home to approximately 30% (~12 million) of Kenya's people, a third of Kenya's population (UNDP, 2016). The principal climatic hazard in the ASALs is drought. Most of the droughts exhibit such characteristics as false and late onset of the rains, pronounced breaks during the rainy season, and early cessation of the rains, leading to drastic alterations in the pattern of seasonal rainfall distribution (Jones and Thornton, 2003; Lobell and Burke, 2010; Nyoro et al., 2007). Baringo County in mid-west Kenya is predominantly arid and semi-arid lands.

While Kenya, like countries in other parts of the world, have considerable experience in dealing with climate variability, climate change is likely to present them with new and tougher challenges. Consequently, the country needs to adopt new strategies to cope with new situations. The current technologies and approach especially in water are unlikely to be adequate to meet projected demands, and increased climate variability will be an additional stress (IPCC, 2001). Consequently, the country needs to adopt new strategies to cope with new situations. The current technologies and approach especially in water are unlikely to be adequate to meet projected demands, and increased climate variability will be an additional stress (IPCC, 2001). The present study sought to analyze rainfall variability with specific focus on annual trends, rainfall amount and distribution of rainfall. The analysis aims at quantifying the magnitude of variation in Baringo County. This information shall be used to relate the implication of rainfall variability on water access at household level. Characterizing rainfall

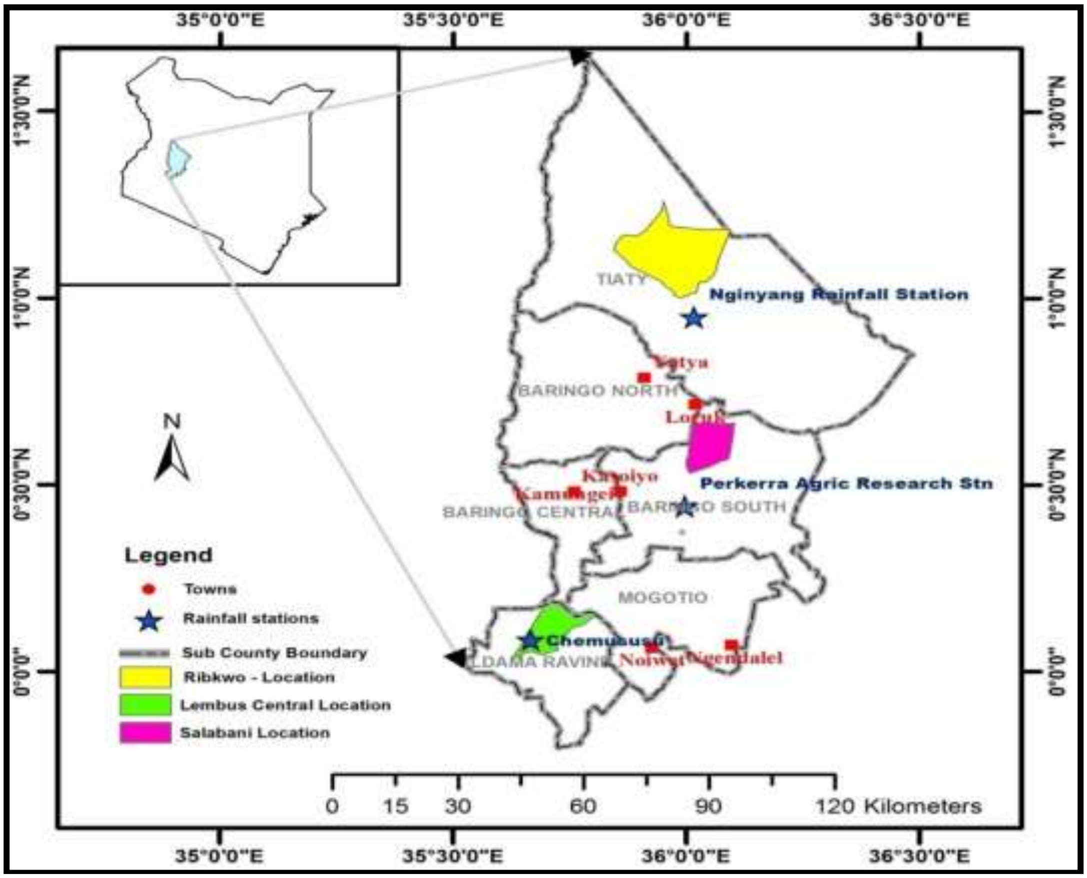

Figure 1. Geographical location of the study area in Kenya.

variability is of great importance to rural households not only in Baringo County but also in other parts of Kenya that have the same climatic conditions.

MATERIALS AND METHODS

Study area

This study was conducted using meteorological data records from Nginyang, Chemususu and Perkerra stations, located in Baringo County Northwestern part of Kenya. Geographically, Baringo is situated between Latitudes 00^{o} 13^{l} South and 1^{o} 40^{l} North and Longitudes: 35^{o} 36^{l} and 36^{o} 30^{l} East (Figure 1). The County is cut across by the Equator at the southern part. According to the 2009 Kenya population and Housing census results, Baringo's human population stood at 555,561 people (KNBS, 2010). This figure is projected to increase by about 5% in the next census. Baringo County covers a range of climatic zones, from semi-arid (zone iv), arid (zone v), and very arid (zone vi) through semi-humid (zone iii) and sub-humid (zone ii), to a small portion in the humid zone (zone 1). The mean annual rainfalls in these zones are 450 to 900 mm (semi-arid), 800 to 1,400 mm (semi-humid), 1,000 to 1,600 mm (sub-humid) and 1,100 to 2,700 mm (humid). The mean annual potential evaporation amounts for these areas are 1,650 to 2,300 mm (semi-arid), 1,450 to 2,200 mm (semi-humid), 1,300 to 2,100 mm (sub-humid), and 1,200 to 2,000 mm (humid) (Odada et al., 2006). Baringo County is divided into three major agro-ecological zones namely the highlands, midlands and lowlands and the following sub- zones: UH 1, UH 2, LH 2, LH 3, UM 3, UM 4, UM 5, LM 4, LM 5, LM 6 and IL 6 (RoK, 2013).

The choice of rainfall stations for this study was informed by agro-ecological zones (Jaetzold et al., 2007) and percentage of missing data (less than 10% for any given year as required by the World Meteorological Organization). Thus, the selected rainfall stations were Nginyang (IL6), Salabani (LM5) and Lembus Central (LH2) and each had a data set of over 20 years and it is fairly a representation of the entire Baringo homogenous climatological zone identified by RoK (2013). This study relied on secondary data sources. The data was obtained from Kenya Meteorological Department. Daily rainfall data was collected for three stations: Perkerra, Chemususu and Nginyang to represent agro-ecological zones LM5, LH2 and IL6 respectively. The data collected from LH2 and IL6 was for the period 1981 to 2010 while the data collected from LM5 was for the period 1981 to 2008 because there was no sufficient data. Nonetheless, the data was within the above 25-year threshold required for a climatological analysis (Atheru, 1999).

Data analysis

To show rainfall variability, this study carried out a trend analysis. The year-to-year variation of annual rainfall over the studied agro-

Table 1. Summary of rainfall variables for the study sites.

Agro-ecological zone	Rainfall (mm)	Annual
IL6	Minimum	99.6
	Maximum	1517.7
	Mean	792.81
	Coefficient of variation	0.45
LH2	Minimum	353.8
	Maximum	6471.4
	Mean	2209.13
	Coefficient of Variation	0.70
LM5	Minimum	237.6
	Maximum	926.8
	Mean	576.1
	Coefficient of Variation	0.33

ecological zones was analysed. Results of the values were cumulatively added to each other for the period of record and plotted to achieve long-term trends of annual rainfall. The mean annual rainfall for the three agro ecological zones LM 5, IL 6 and LH 2 was calculated. To show rainfall variability, a coefficient of variation (CV), defined as the ratio of standard deviation to the mean, was also calculated for rainfall amount for each station. The correlation coefficient is a measure that assesses the degree to which two variables' movements are associated (Abdi, 2009).

RESULTS AND DISCUSSION

The mean annual rainfall for agro ecological zones LM 5, IL 6 and LH 2 was 616.9, 792.81 and 2209.13, respectively. According to the performed analysis (Table 1), maximum annual rainfall (1517.7 mm) was observed in the year 2010 in Nginyang station while in Chemususu station, maximum annual rainfall (6471.4 mm) was observed in the year 2005. For Perkerra station, maximum annual rainfall (926.8 mm) was observed in the year 2007. The minimum annual rainfall (99.6 mm) was observed in the year 2000 in Nginyang station while in Chemususu station, minimum annual rainfall (353.8 mm) was observed in the year 1984. The lowest annual rainfall (237.6 mm) recorded in Perkerra station also was in 2002. The findings concur with those of Opiyo et al. (2014) who observed the lowest annual rainfall (54.2 mm) in 1984 in Lodwar, Turkana County. The lowest rainfalls recorded in the same year (1984) in the two agro ecological zones may be linked to the1983 to 1985 droughts which afflicted Africa's dry lands. There was a failure of Kenya's 'long rains' in April to May of 1984 (ODI, 1987).

The coefficients of variation for annual rainfall amount for IL 6 (Nginyang station) is 0.45 while LM 5 (Perkerra station) stands at 0.33.LH 2 (Chemususu station) exhibits a very high coefficient of variation for annual rainfall amount (0.70) (Table 1). According to Araya and Stroosnijder (2011), a coefficient of variation greater than 0.30 is an indicator of large rainfall variability. This variability in rainfall in Baringo may be linked to the 1982, 1994 and 2007 El Nino rains that characterized the average annual rainfall in Kenya (GoK, 2000). Amissah et al. (2002) in Kenya also found that annual rainfall increased during El Nino events compared with neutral years and that highland sites had the highest rainfall variability between El Nino events than lowland sites. Shisanya et al. (2011) also reported above normal rainfall during short rains season than preceding long rains season rainfall in ASALs of Kenya during El Nino years. Links between El Nino and climate variability have also been suggested by other studies (Anyah Semazzi, 2007; Ngongondo, 2006).

According to the results of the trend analysis (Figure 2), rainfall in AEZ IL6 (Nginyang rainfall station) of Baringo County has been on the decrease over the period of study. The years 1982, 1994 and 1997 recorded highest amount of rainfall while the years 1996, 1999, 2000 and 2009 recorded the lowest amount. Rainfall in the years 1996, 1999, 2000 and 2009 decreased at the rates of -1.4, -1.2, -1.9 and -1.1 per annum respectively. The findings concur with those of Jenny and Svensson (2002) who observed a similar pattern in Baringo lowands. Kansiime et al. (2013) also observed a decreasing trend of total annual rainfall for low lying areas in Uganda. However, according to Arthur et al. (2002), sites in the highland wet ecoregion of Kenya had the greatest decrease in annual rainfall than lowland and midland.

The results of the trend analysis (Figure 3) show that rainfall in AEZ LH 2 (Chemususu station) Baringo County depicted increasing trends over the period of study. The years 1983, 1984, 1991 and 1993 depicted highest

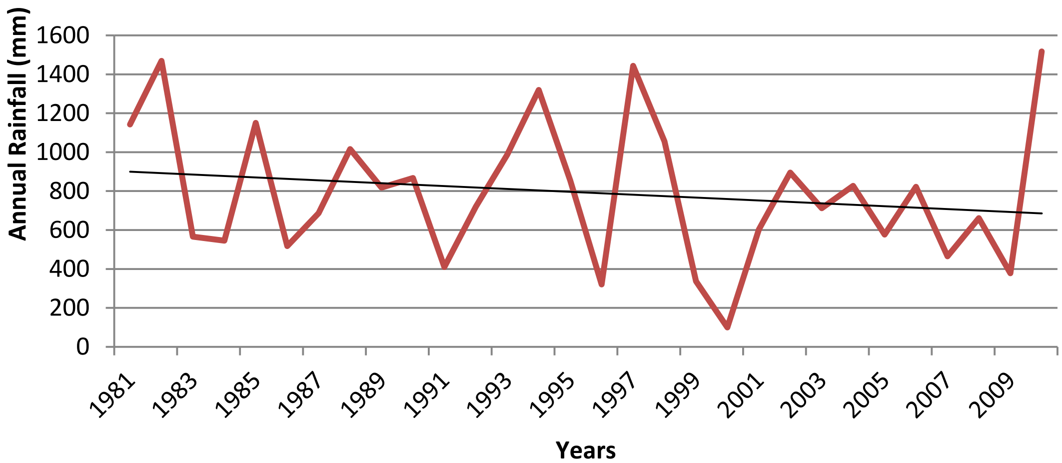

Figure 2. Trends in annual total rainfall for lowland.

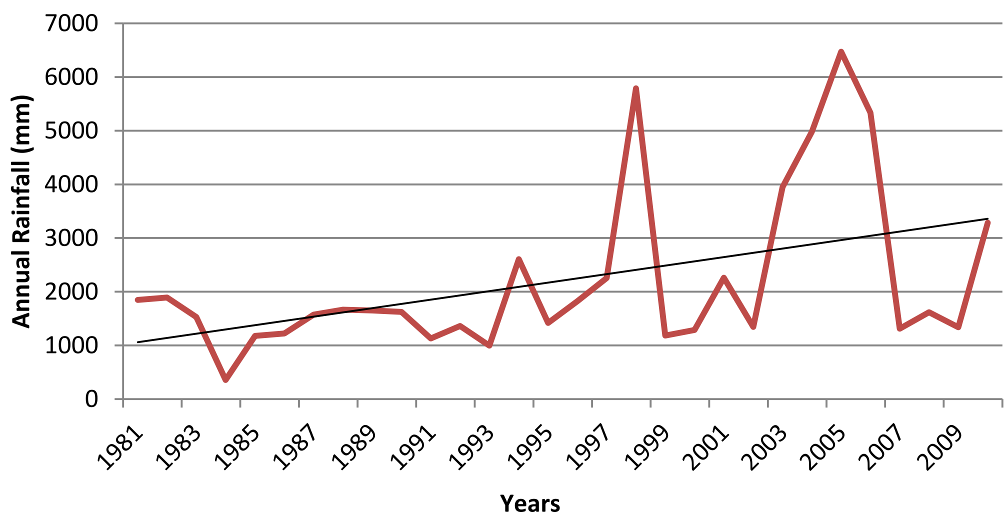

Figure 3. Trends in annual total rainfall for highland.

negative decreasing trends while the years 1998, 2003, 2004, 2005 and 2006 depicted highest positive increasing trends. The results are in line with those of Kansiime et al. (2013) in Uganda who observed an increasing trend of total annual rainfall for highland areas. Basalirwa (1995) also predicted an increase of approximately 10 to 20% in rainfall for high ground areas, and more drying conditions for low lying areas of Uganda.

At AEZ LM5 (Perkerra rainfall station), the results of the trend analysis (Figure 4) show that there was a decrease in rainfall over the period of study. The year 2007 depicted highest increasing trend. A noticeable decrease of rainfall was observed in the years 1984, 2002, 2002 and 2004 while the other years showed a fluctuating decreasing and increasing scenarios which were not noticeable. The findings concur with those of Jenny and Svensson (2002) who observed a similar pattern in the same station in Baringo. Arthur (2002) also observed a decrease in annual rainfall in midland sites of Kenya. However, Kansiime et al. (2013) in Uganda observed an increasing trend of total annual rainfall for mid lying areas.

Trend analysis performed on annual scale to examine if there are patterns in the data at this scale showed varied results. Rainfall showed year to year variability in the amount and distribution. The data also revealed wide variation in rainfall trends by agro-ecological zones. This is a common finding from other studies on actual rainfall trends and variability such as in Lower Eastern Kenya (Omoyo et al., 2015), Eastern Uganda (Shisanya et al.,

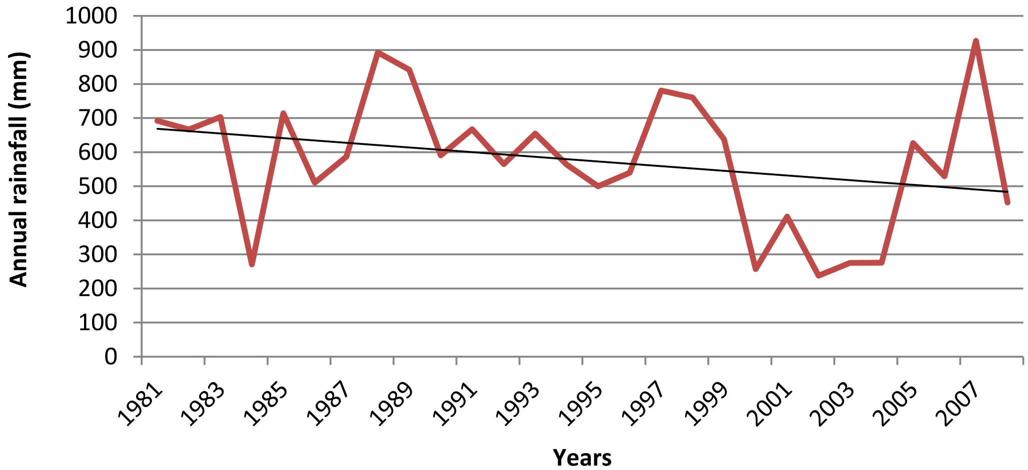

Figure 4. Trends in annual total rainfall for midland.

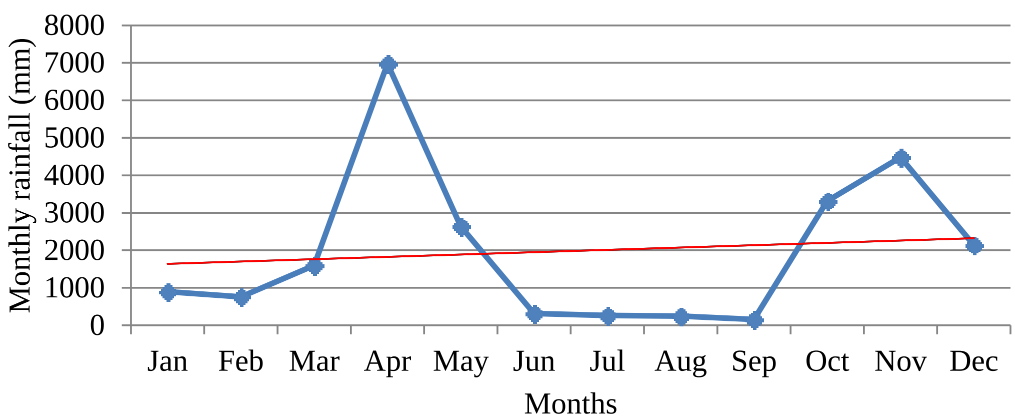

Figure 5. Monthly rainfall trend from 1981 to 2010 for Nginyang.

2011), semi-arid central Tanzania (Slegers, 2008), Ethiopia (Tilahun, 2006) and Sudano-Sahelian regions (Sivakumar, 1991). Graphical visualization of annual rainfall data in the studied agro-ecological zones presented in Figures 2 to 4 shows that there is an observed increasing trend of total annual rainfall for Baringo highland and a decreasing trend for Baringo lowland. Baringo midland also showed a decreasing trend. This variation in rainfall amounts among the three agro-ecological zones may be attributed to variations in altitude and land use intensity in the specific locations.

Monthly rainfall trends

According to the performed analysis on monthly rainfall trend, the highest monthly rainfall was observed during the month of April in the three agro-ecological zones. The maximum monthly rainfall was 6,981, 9,861.7 and 2,572.6 mm for IL6 (Nginyang), LM5 (Chemususu) and LH2 (Perkerra) stations respectively. The lowest rainfall monthly totals were recorded during the month of January in Chemususu (1508.7 mm) and Perkerra (575.2 mm) stations while in Nginyang, it was recorded during the month of September and this was 156.5 mm. The monthly rainfall in the three agro-ecological zones had a mixture of increasing and decreasing trends. Figures 5 to 7 illustrate monthly total rainfall trend pattern for the three agro ecological zones of Baringo County.The highest monthly rainfall recorded in the month of April in Baringo may be attributed to long rains that occur in April to August.

Conclusion

The study examined rainfall variability in Baringo County by providing trends since the 1980’s, coefficient of

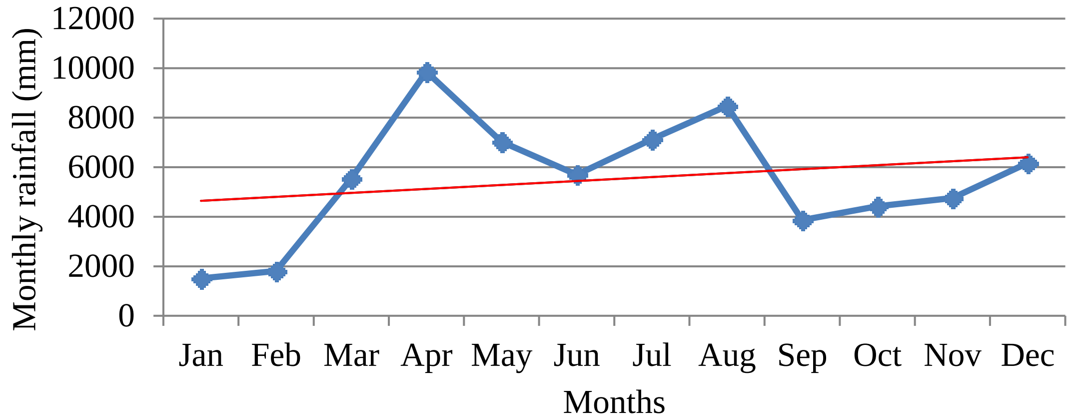

Figure 6. Monthly rainfall trend from 1981 to 2010 for Chemususu.

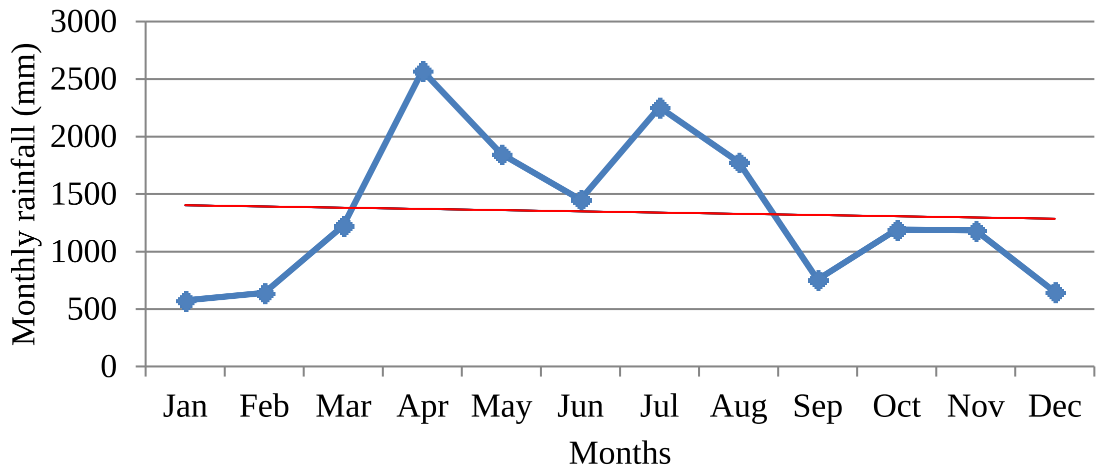

Figure 7. Monthly rainfall trend from 1981 to 2008 for Perkerra.

variation and mean rainfall amount. The findings of this study have established that rainfall is variable as demonstrated by inter-annual variability. Total annual rainfall also varied among the three Agro-ecological zones. Annual rainfall in LH2 (Lembus central) showed a positive trend whereas in LM5 (Salabani) and IL6 (Ribkwo), it showed negative trends. Nearly all the years in IL6 showed below normal mean rainfall. This is attributed to increasein extremes of rainfall on the annual scale such as high intensity rainfall and droughts thus affecting the variability. Variations in amount of rainfall by agro-ecological zones are attributed to variations in altitude and land use intensity in the specific locations. High land areas showed increasing amounts and higher variability in rainfall as opposed to low lying areas which showed decreasing amounts and less variability within and between the years. There is climate variability in Baringo which in the long term would constitute climate change. This has huge implications on hydrological systems and water resources. The study has confirmed that the arid and semi arid lands (ASALs) suffer from significant climate variability which has huge implications on water resources. The constraints posed by climate variability on water resources range from pronounced seasonality of rainfall to severe and recurrent droughts. Generally, extreme climatic events and mean value of rainfall influence water resources that are mainly rain-fed. Thus, to counter the adverse effects of climate change, there is a need for increase in awareness of climate change and development of appropriate mitigation measures. Local and national governments need to be proactively involved in local, national and global efforts to adapt to and mitigate climate change impacts. This is particularly important in ASALs where the impact of climate change is more severe than in humid lands, yet adaptation and mitigation capabilities in these areas are weak.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ABBREVIATIONS

ACDI, African Climate and Development Initiative; **ASAL,** Arid and Semi-Arid Lands; **FAO,** Food and Agriculture Organization**;** **IL6,** Inner Lowland 6; **IPCC,** Intergovernmental Panel on Climate Change; **KNBS,** Kenya National Bureau of Statistics; **LH2,** Lower Highland 2; **LM5,** lower Midland 5; **ODI,** Overseas Development Institute; **RoK,** Republic of Kenya; **UNDP,** United Nations Development Programme.

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