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Assessment of Meteorological drought using Standardized Precipitation Index (SPI) in Kajiado County, Kenya

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ABSTRACT

Assessment of drought pattern is very important for risk management and climate change adaptation planning, especially in arid and semi arid lands (ASALs) where availability of water is a challenge. Meteorological drought is mostly the result of a decrease in precipitation in comparison with the mean value. The basis of drought indices is measuring the deviation of precipitation values from long-term mean, during a specific period of time. The standard precipitation index (SPI) can be used for indicating the associated temporal and spatial variations. This study assessed meteorological drought pattern in Kajiado County, Kenya in the last 4 decades (1970-2010) using SPI. Result shows that twenty (20) years have negative SPI values for the long rains (March-May), while twenty three (23) years have negative values for the short rains (October-December). The long rainy season recorded extreme drought in three years 1973, 1984 and 2000 with SPI values of (-2.48, -2.77 and -2.82) respectively. Also moderately dry season was recorded in 1976 with a SPI value of -1.13. The short rainy season recorded two years 1970 and 1981 of extreme drought with SPI values of (-2.33 and -2.18), respectively. The short rains also recorded one year of severe drought in 1975 with a SPI value of -1.53 and five years 1972, 1973, 1976, 1980 and 2005 of moderate drought with SPI values of (-1.14, -1.06, -1.13, -1.27 and -1.36), respectively. The year 2000 is the driest year recorded since 1970 with an SPI value of (-3.07). The results of this study are also relevant to climate change studies in the ASALs of Kenya. It will be useful in understanding the historic patterns and build future scenarios of drought for risk management and climate change adaptation planning.

Keywords: Meteorological drought, Standardized Precipitation Index, Arid and semi arid lands

Introduction

Drought is a considerable adverse climatic event for both ecosystems and human society. Based on Palmer (1965), drought is defined as a permanent and an unusual deficit of moisture. In this definition, “permanent” refers to the beginning times of drought until the end of the duration. Conceptually, drought is a recurrent feature of climate characterized by a noticeable and measurable reduction in precipitation over an extended period, resulting in a water shortage for some activities or some group (Opiyo, 2014). The decrease of precipitation is the principal cause of the origin of drought. This results in a reduction of storage volumes and fluxes involved in the hydrological cycle. Depending on the choice of variables of interest, drought is often classified into four types: meteorological, hydrological, agricultural, and socioeconomical droughts. Meteorological drought happens when dry weather patterns dominate an area.

Hydrological drought occurs when low water supply becomes evident, especially in streams, reservoirs, and groundwater levels, usually after many months of meteorological drought. Agricultural drought happens when crops become affected. And socioeconomic drought relates the supply and demand of various commodities to drought.

The impact of drought appears to have become more severe in recent years in Kenya, especially in the arid and semi arid lands (ASAL) (Funk *et al*., 2008). Most part of Kajiado county lies within the arid and semi-arid region and are highly susceptible to extreme climatic change such as drought. The arid and semi-arid lands have been identified as the most vulnerable areas to climate related risks in Kenya. Climate change, especially drought and dry spell has severe impacts on livestock production, small-holder agriculture and tourism, which are the dominant sources of livelihoods in ASALs. There is a strong link between climate and livelihoods in the ASALs and majorities of the population are heavily dependent on rainfall for the various land-use practices. As a result, rural livelihoods and food security in the ASALs of Kenya are highly vulnerable to climate variability (WWF, 2006).

Assessment of drought is one of the most important steps in risk management of drought analysis. Standardized Precipitation Index (SPI) is one of the methods commonly used to monitor drought and anomalously wet periods. It was introduced by McKee *et al*. (1993) with the purpose of assigning a single value to monthly rainfall that allows comparing the values across different climatic and geographic regions at a given period. SPI is calculated by dividing the difference between normalized seasonal rainfall and its long-term seasonal mean by standard deviation. The resulting SPI can then be used to compare precipitation across a region with different climates at a specific period (McKee *et al.*, 1993). Moreover, SPI can indicate wet conditions at a time scale and dryness at another time scale. A drought occurs when SPI is less than -1.0 and it ends when SPI becomes positive; the drought magnitude can be estimated by a factor of the standard deviation. The World Meteorological Organization (WMO) recommended SPI for drought monitoring (Wilhite, 1992). Kazem and Abdol (2011) used SPI to investigate drought over Iran and concluded that it was appropriate to quantify most of drought types, more importantly; he reported that SPI at 2-3 months time scale is more relevant for agricultural drought while 5-24 months relates to hydrological drought.

SPI is widely used for drought monitoring because of its simplicity; it only uses precipitation and is suitable for developing countries where temperature and soil data are not readily available. The second advantage of SPI is its temporal versatility; by allowing the use of different time scales, SPI is able to monitor any type of drought and is appropriate for analyzing drought dynamics. SPI is also standardized, this ensures the consistency of frequencies computed at any location; consequently, all SPI values are comparable across regions regardless their climatic differences.

This study used SPI to assess drought pattern in Kajiado county for the short and long rainy seasons. The result of this study will be useful for effective adaptation planning in the county.

Materials and methods

Study area

The study was conducted in Kajiado county in Kenya. Kajiado County is located in the

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southern tip of the former Rift valley province between longitudes 36°5 and 37°5 and latitudes 1°0 and 3°0 South (Amwata, 2013). It covers an area of 19,600Km^2 (CBS, 1981). Kajiado County is bordered by Tanzania to the south, Taita Taveta County to the east, Narok County to the west and Nakuru, Kiambu, Nairobi and Makueni Counties to the north. Kajiado County has two main rainy seasons: the long rainy season from March to May and the short rainy season from October to November. Analysis of rainfall for the two rainy seasons reveals that most areas receive 50 percent of annual rainfall during the March to May period and 30 percent during the October to December period (ROK, 2009).

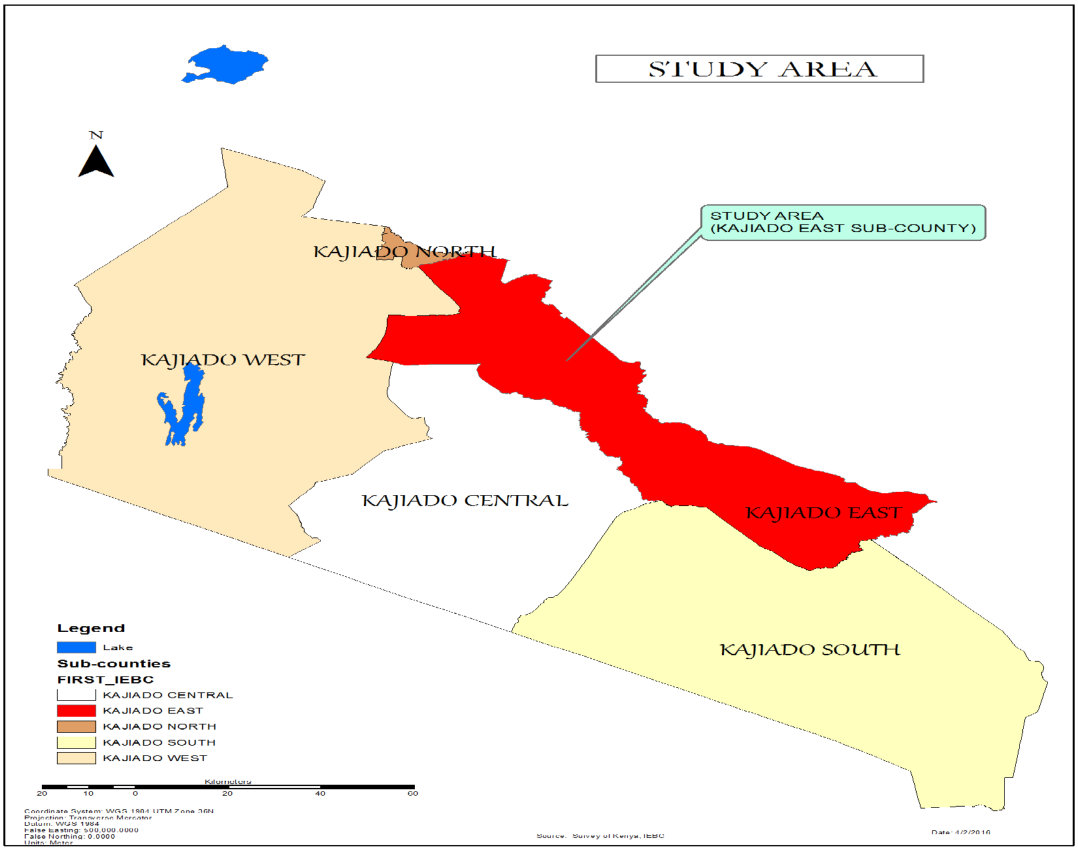

Figure 1: Map showing the study area in Kajiado County

Data collection and analysis

Rainfall data for Kajiado county was obtained from the Kenya Meteorological service (KMS) and used for this analysis. The rainfall data were analyzed for a period of 43years (1970-2013). The standardized precipitation index (SPI) was used to analyze drought severity in the study area between 1970 and 2013. SPI was designed to quantify precipitation deficit for multiple time scale (McKee *et al.*, 1993). The SPI is calculated by dividing the difference between normalized seasonal rainfall and its long-term seasonal mean by standard deviation as follows:

$$SPI = \frac{Xij - Xim}{SD}$$

Where *Xij* = Seasonal precipitation value at jth station

Xim = Long term seasonal mean precipitation

SD = Standard deviation

This study used the McKee *et al*. (1993) SPI classification system (Table 1) to define drought intensity resulting from the SPI.

Table 1: SPI classification used in this study

SPI values	Classification
2.0	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-.99 to .99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 and less	Extremely dry

Results and Discussion

Drought pattern in Kajiado County

The result of standardized precipitation index (SPI) values for the long rainy season (March-May) and the short rainy season (October to December) for a period of 43years (1970 - 2013) is presented in Table 2. A total of twenty (20) years have negative SPI values for the long rains, while twenty three (23) years have negative values for the short rains. The long rainy season recorded extreme drought in three years 1973, 1984 and 2000 with SPI values of -2.48, -2.77 and -2.82, respectively. Also moderately dry season was recorded in 1976 with a SPI value of -1.13. The short rainy season recorded two years 1970 and 1981 of extreme drought with SPI values of -2.33 and -2.18, respectively. The short rains also recorded one year of severe drought in 1975 with a SPI value of -1.53 and five years 1972, 1973, 1976, 1980 and 2005 of moderate drought with SPI values of -1.14, -1.06, -1.13, -1.27 and -1.36, respectively. The findings of this study agree with Camberlin and Philippon, (2002) who noted that the long rainy seasons are more reliable than the short ones in ASALs regions.

The result shows that six years (1971, 1972, 1973, 1975, 1976 and 1979) had negative SPI values between (1970 and 1979) for the long rains and six years (1970, 1972, 1973, 1975, 1976 and 1979) had negative SPI values between (1970 and 1979) for the short rains. Four years (1982, 1983, 1984 and 1978) of negative SPI values were recorded between 1980 and 1989 for the long rains and six years (1980, 1981, 1983, 1985, 1987 and 1988) of negative SPI values were recorded between 1980 and 1989 for the short rains. The result show that the year 1990 to 1999 recorded four years (1993, 1994, 1997 and 1999) of negative SPI values for the long rains, and also four years (1990, 1993, 1995, and 1996) of negative SPI values for the short rains between 1990 and 1999. The year 2000 to 2011 was the driest period reported in this study. Six (6) years (2000, 2004, 2007, 2008, 2009 and 2011) of negative SPI value were recorded for the long rains and seven (7) years (2000, 2003, 2004, 2005 2007, 2008 and 2010) were recorded for the short rains. Several studies (Mutai and Ward 2000; Wasonga *et al*., 2010; and Amwata 2013) have reported significant reduction in rainfall amounts especially during the short rainy season in the ASALs of Kenya. This report also confirms the findings from the Focus group discussions FGDs where discussants reported increase in drought events in the last 15years.

Table 2 Drought severity for the long rains (March to May) and short rains (October to December) in Kajiado County between 1970 and 2013

Long rains (March to May)			Short rains (October to November)		
Year	SPI	Drought Classification	Year	SPI	Drought Classification
1971	-0.40	Near normal	1970	-2.33	Extremely dry
1972	-0.19	Near normal	1972	-1.14	Moderately dry
1973	-2.48	Extremely dry	1973	-1.06	Moderately dry
1975	-0.02	Near normal	1975	-1.53	Severely dry
1976	-1.13	Moderately dry	1976	-1.13	Moderately dry
1979	-0.41	Near normal	1979	-0.61	Near normal
1982	-0.96	Near normal	1980	-1.27	Moderately dry
1983	-0.34	Near normal	1981	-2.18	Extremely dry
1984	-2.77	Extremely dry	1983	-0.77	Near normal
1987	-0.07	Near normal	1985	-0.45	Near normal
1993	-0.67	Near normal	1987	-0.50	Near normal
1994	-0.34	Near normal	1988	-0.53	Near normal
1997	-0.19	Near normal	1990	-0.04	Near normal
1999	-0.43	Near normal	1993	-0.38	Near normal
2000	-2.82	Extremely dry	1995	-0.40	Near normal
2004	-0.24	Near normal	1996	-0.45	Near normal
2007	-0.74	Near normal	2000	-0.3	Near normal
2008	-0.76	Near normal	2003	-0.02	Near normal
2009	-0.67	Near normal	2004	-0.09	Near normal
2011	-0.63	Near normal	2005	-1.36	Moderately dry
			2007	-0.8	Near normal
			2008	-0.1	Near normal
			2010	-0.03	Near normal

Source: Author’s compilation

Table 3 Annual drought severity (January to December) in Kajiado County between 1970 and 2013

Year	SPI	Drought classification
1971	-0.44	Near normal
1972	-0.72	Near normal
1973	-1.81	Near normal
1975	-1.24	Moderately dry
1976	-2.03	Severely dry
1980	-0.42	Near normal
1981	-0.95	Near normal
1983	-0.05	Near normal
1984	-1.48	Moderately dry
1985	-0.27	Near normal
1986	-0.51	Near Normal
1987	-0.15	Near normal
1994	-0.16	Near Normal
1996	-0.18	Near Normal
1999	-0.8	Near normal
2000	-3.07	Extremely dry
2003	-0.13	Near Normal
2004	-0.37	Near Normal
2007	-0.35	Near Normal
2008	-0.69	Near Normal
2011	-0.44	Near Normal

Source: Author's compilation

Results of annual drought severity from 1970-2013 (Table 3) show that a total of 21years has negative SPI values. The study area experienced severe and extreme drought in the year 1976 and 2000 with SPI values of -2.03 and -3.09, respectively; with the year 2000 being the driest year reported in this study. Six years (2000, 2003, 2004, 2007, 2008 and 2011) have negative SPI values between 2000 and 2011. The increasing severity and frequency of drought occurrence in Kajiado County is an indication that the region is getting drier reflecting the observed climate change in the ASALs of Kenya.

Seasonal decadal drought pattern in Kajiado County

It is important to understand seasonal variation in rainfall pattern for effective risk management and adaptation planning. This is particularly very important in farming and pastoral communities where their main sources of livelihood depend on rainfall. Kajiado county has two rainy seasons, the long rainy season, from March-May and the short rainy season 0ctober –November. The long rainy season is usually more reliable and useful to farmers and pastoralist. The amount and seasonal distribution of rainfall are crucial factors for understanding the spatial distribution of different ecological units (Herrero *et al.*, 2010; Opiyo 2014). Therefore, this study results could be of great importance to detecting climatic impacts on arid and semi-arid ecosystems in the region.

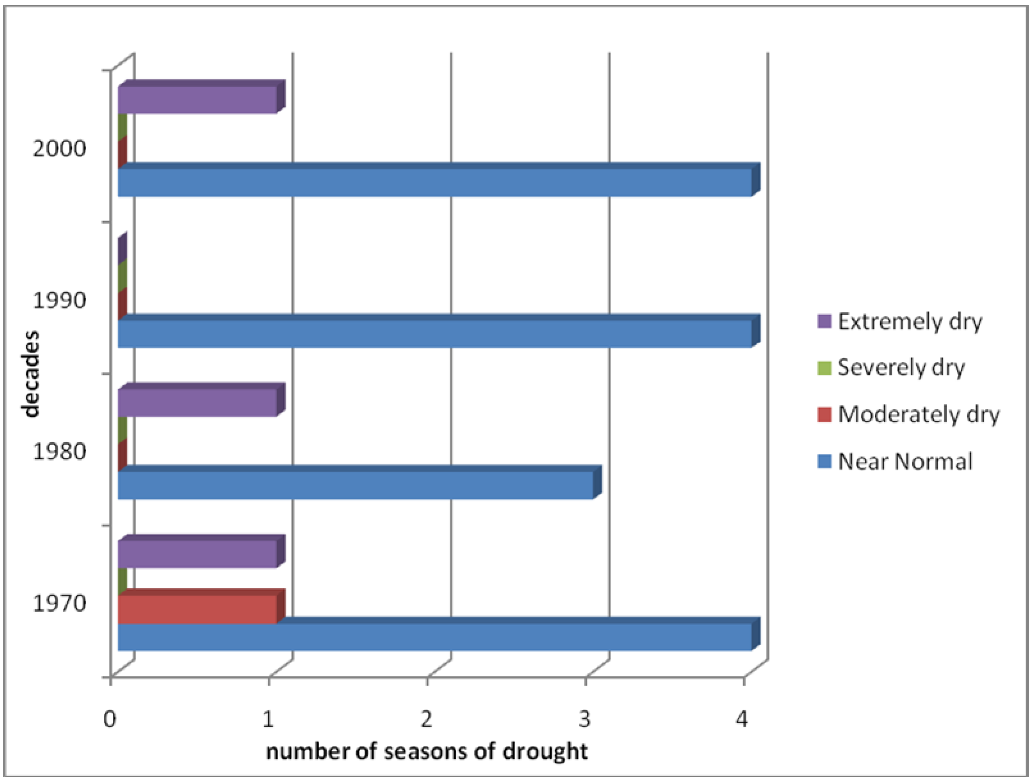

Figure 2: Decadal drought pattern for long rainy season

The result of decadal variation in SPI for the long rainy season (Figure 2) shows that the year 1970-1980 experienced 4 seasons of near normal rainfall with SPI (-99 -.99), 1 season of moderately dry precipitation with SPI (-1.0- -1.49) and 1 extremely dry season of SPI (-2 and less). The years between 1980 and 1990 shows that there were 3 seasons of near normal rainfall and 1 season of extreme rainfall. Between 1990-2000, the long rainy season in Kajiado county experienced 4 seasons of near normal precipitation. 2000-2010 shows 4 seasons of near normal rainfall and 1 extremely dry season. This result shows that 1970-1980 is the driest decade followed by 2000-2010. The year 1990-1999 has the least number of dry long rainy seasons. Generally, there is one season of extreme dryness per decade except for 1990s. This study corroborates the findings of Opiyo, (2014) who reported the similar years of drought for ASALs of Kenya.

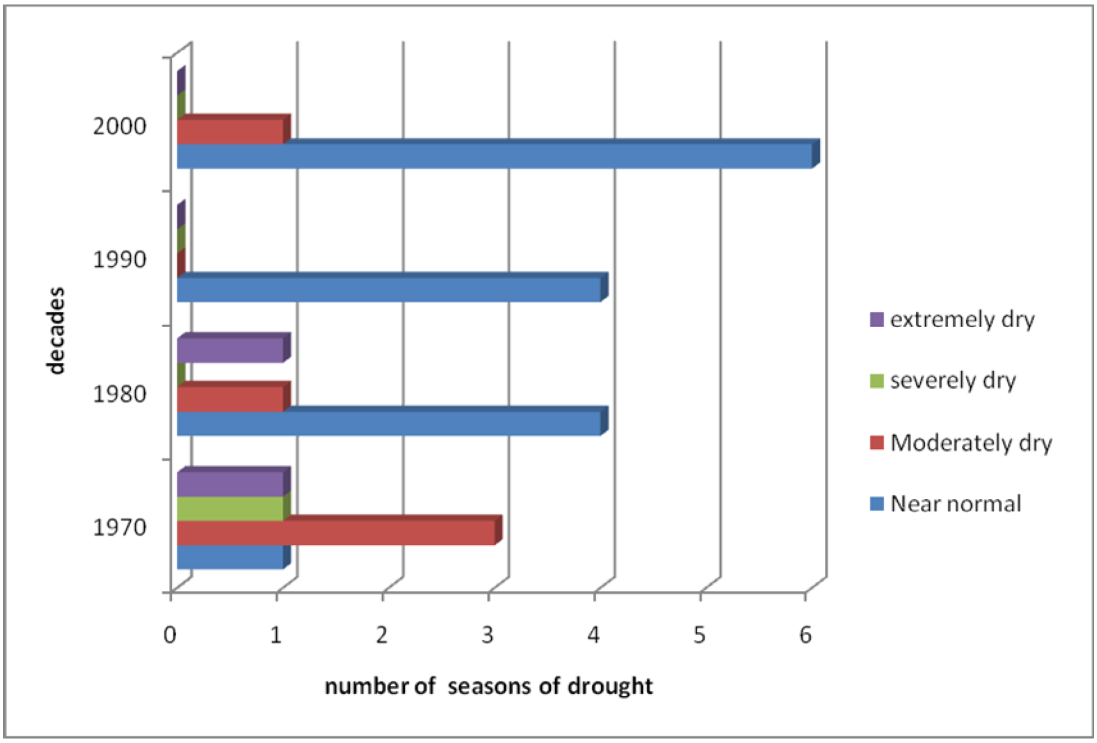

Figure 3: **Decadal drought pattern for short rainy season**

The result of the decadal variation in SPI for the short rains is presented in Figure 3. Generally, the result shows that the rains are very unpredictable with more years of dryness when compared to the long rains. This is the reason why farmers in ASALs of Kenya concentrate more on the long rains for production. Many studies (Brooks *et al*., 2005; Amwata 2013 and Opiyo 2014) reported that the short rains are getting more erratic in the ASALs of Kenya. The year 1970-1979 has 1 season of extreme dry rains for the short rains, 2 seasons of severely dry rains, 3 seasons of moderately dry rains and 1 season of near normal rains. This shows that 1970-1979 is the driest decade in the study period.

The years 1980-1989 has 1 year of extreme dryness, 1 years of moderate dryness and 4 years of near normal dryness. 1990-1999 shows 4 years of near normal rainfall while the year 2000-2010 has 1 year of moderately dry rainfall and 6 years of near normal rainfall. The year 2000-2010 has the highest number of years with negative SPI, this shows that there is an increase in dryness of ASALs in Kenya especially during the short rains. This observation agrees with the findings of Howden (2009) and Opiyo (2014) who reported a gradual reduction in rainfall in the ASAL of Kenya. The findings of this study show that the ASAL lands of Kenya are relatively dry with many years of negative SPI. Drought has been reported to have had far reaching consequences which include a decline in crop yield, increase in food prices, loss of income and decline in pasture availability. In general, recurrent drought impacts exacerbate the many existing challenges in ASALs of Kenya. There is a need for planned adaptation strategies to reduce impact of drought and dry spell on already vulnerable ASALs

Conclusion

This study examined seasonal drought patterns in Kajiado County, Kenya. The SPI has revealed many interesting results on the variability in the occurrence of meteorological drought in the arid and semi arid lands of Kenya. This study observes a drought pattern of one extreme drought per decade for the long rainy season. The short rainy seasons shows increase in negative SPI in recent decade. Comparison of drought frequency in different decades and ranking rainy seasons based on drought persistence are extremely important in understanding historic drought patterns and assessment of future risk. Increased drought frequency between years 2000 – 2010 for both the long and short rainy season observed in this study facilitates better preparedness and coping mechanisms. The SPI-based drought patterns can be integrated with agricultural and hydrological parameters for quantifying drought risk. The results of this study are also relevant to climate change studies in the ASALs of Kenya. It will be useful in understanding the historic patterns and build future scenarios of drought for risk management and climate change adaptation planning. Further research should include relating dryness patterns with pastoral systems, cropping pattern and crop production. Such an attempt will enable quantification of drought impact in economic terms.

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