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Evaluation of the Nature of Drought Experienced in Makueni County, Kenya

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Abstract
Drought events remain a major threat to lives and livelihoods in sub-Saharan Africa (SSA) due to the high exposure and vulnerability of populations. In the last three decades, Kenya experienced high frequency of drought events. The frequency of drought is projected to increase in the future more so due to anthropogenic climate change whose impacts include erratic seasonal rainfall and increased frequency of extreme rainfall events such as drought. Droughts present extreme conditions of water scarcity which have adverse effects on the physical environment and water resource systems particularly for arid and semi arid regions. The design and implementation of drought mitigation and response strategies requires an understanding of the nature and impacts of drought. Previous mitigation measures have been done randomly without establishing the nature of drought , reason as to why drought in Makueni County whether major or minor has severe impacts on this community.Makueni County of, Kenya has suffered many severe and extreme drought conditions the nature and impacts of which have however remained unknown and undocumented. The objective of this study was to examine the nature of drought in Makueni over the last three decades. Secondary data comprising of rainfall records from Makindu, Mavindini and Kibwezi areas was used to compute a drought index. The standardised precipitation index SPI was used to identify the nature of drought occurring in the study area. The results revealed that Makueni County experienced three episodes of extreme meteorological droughts in the last three decades. In the same period, Hydrological drought persisted for over 8 years while over five extreme and severe Agricultural droughts were analysed in the study area. Though the drought conditions in the study area are pathetic, the residents of Makueni County seemingly did not fathom the nature of drought that they experienced. The findings of this study are anticipated to inform decision makers and development actors in Kenya, whose interest is to mitigate, and respond to drought on Kenyans lives, economy and development as a whole.

Introduction

Drought is a natural hazard and a threat to people’s livelihood and socio-economic development according to (UNISDR, 2007). It is caused by a combination of both climate hazard (the occurrence of deficits in rainfall) and societal vulnerability (the economic, social, and political characteristics that render livelihoods susceptible in the region influenced by the deficits) (UNISDR, 2007). The severity of the drought depends upon the degree of moisture deficiency, the duration, and the size of the affected area. Drought tends to occur less frequently than other hazards. However, when it does occur, it generally affects a broad region for seasons or years. This often results in a larger proportion of the population being affected than when other disasters occur. Globally, drought disasters account for less than 10 per cent of all disaster occurrences, but they account for nearly 40 per cent of all people affected by natural disasters Durey et.al.,(2005). The impact of drought varies regionally and over time. Over the years, disasters triggered by prolonged drought in Africa have affected millions of people and contributed to malnutrition, famine and loss of life (Durey et.al.2005).

Drought is defined as a long period of time in which the water available from rainfall and stored water is not enough to provide for the needs of users. It is not simply an acute shortage of water. In a technical sense, the term 'drought' can be applied in three ways, meteorological, hydrological and agricultural and socio-economic (Boken et.al 2005).

A meteorological drought is simply a prolonged period of below-average precipitation. It does not take into account the needs of users or the amount of stored water. A hydrological drought occurs when water reserves available in sources such as lakes, dams, aquifers and reservoirs, fall below the statistical average. Droughts of this nature can prevail even with substantial periods of precipitation, such as when increased water usage diminishes reserves. In recent years, periods of low rainfall coupled with expanding populations in major cities and towns have forced many populations to deal with hydrological drought. An agricultural drought arises when there is insufficient moisture for average crop production. In conjunction with low periods of rainfall, drought can be intensified in rural regions through poor soil quality and inefficient agricultural techniques.

There is little chance that the entire continent would suffer from drought at the same time. Some regions can be afflicted by severe drought, while other districts enjoy bountiful rain. Some droughts are short-lived, while others extend over a number of years. Several studies and reports (e.g Mukhala 2005; Mutie 1993; Durey et.al 2005; Dietz et.al 2004; FEWSNET 2011; Freeman, 2001; Karen et.al. 2003) observe that drought is frequent in Africa and can contribute to diminished food security on the continent.

Drought studies have received increasing attention throughout the world. This is because drought is a recurrent phenomenon whose occurrence causes serious social, economic and environmental impacts. With increasing human population and expanded land use practices into marginal lands, problems of land degradation and a heightened susceptibility to the adverse effects of drought are being experienced in several areas leading to serious impacts. Boken et al., (2005) notes that, besides the diverse socio economic and environmental impacts, drought is also associated with famines, poverty and undermines incentives for development in various parts of the world.

Kenya is a drought-prone country located in East Africa, with 80 percent of the territory covered by arid and semi-arid land where annual rainfall varies between 200-700 mm. Only about one-third of the total land area of Kenya is agriculturally productive, including the central highlands, coastal plains and the lake region, where rain-fed cultivation dominates (Wokabi, 1997). The other two-thirds have low, unreliable and poorly distributed rainfall. Periodical droughts are part of the climate system that affects Kenya. A recent survey by Bryan et al. (2011), covering the humid, temperate, semi-arid, and arid agro ecological zones of Kenya, found that more than 80 percent of all households interviewed had experienced drought over the last 5 years, regardless of agro ecological zone. Erratic rainfall affected 18-45 percent of households, depending on the districts, while hailstorms and floods were relatively uncommon (Bryan et al. 2011).

Like most places in sub-Saharan Africa, food shortages in Kenya are most often associated with drought (Verdin et al., 2005). In addition to the immediate impacts, drought often has long term consequences on people and their assets. It generally takes more than one season for farmers to recuperate from seasonal droughts, as resources, including seeds, are not available for the following, non-drought season. Hence, a good understanding of the nature of drought and occurrences is essential for taking proactive actions to mitigate adverse drought effects and for long-term policy making

Historical rainfall records are available at the Kenya Meteorological Department and are sufficiently reliable to profile drought conditions in Kenya. Records for the last three decades show that 'severe' and extreme drought conditions have occurred in Makueni County. Analysis of rainfall records have showed a marked decrease in precipitation levels in Makueni County indicating persistence of severe and extreme drought conditions during the study period. Continuous drought conditions were experience during the period 1990 to 2011 causing severe negative impacts among communities.

Apparently, the nature and impacts of these droughts in Makueni County have been assessed using indicators of biological and physical nature such as withering of crops, emancipation of livestock, dry water points, vegetation loss and hence reduced forage for livestock among others..

These methods although are useful in revealing the physical aspects of drought conditions, they only indicate the impacts associated with the drought and fall short of indicating the actual drought conditions with respect to scientific aspect of water scarcity, , which would otherwise enable effective response. In this respect therefore assessment based on these methods have been of little practical use to the local communities who bear the brunt of the drought. A comprehensive quantified assessment of the nature of drought in Makueni over the last three decades is not available (UCCS 2008), yet it is one of the areas in Kenya experiencing recurrent drought. This study utilized monthly rainfall data to assess the nature of droughts in and to understand the physical characteristics of drought and related impacts in Makueni County over the last three decades.

Materials and Methods

This study was carried out in Makueni County of Kenya. The study area is located in the arid and semi arid regions of the country. The area lies between Latitude 00° 03' and 3° 00' and Longitudes 36°45' degrees 39°12' (Figure 1). The area receives rains twice a year, with the main rains season occurring in October to December and the lesser rains season occurring in March to May. The annual rainfall ranges from 500 mm in the low moorland areas to 1500 mm in the sub-humid hilltops. The seasonal rainfall is highly variable, erratic and unreliable.

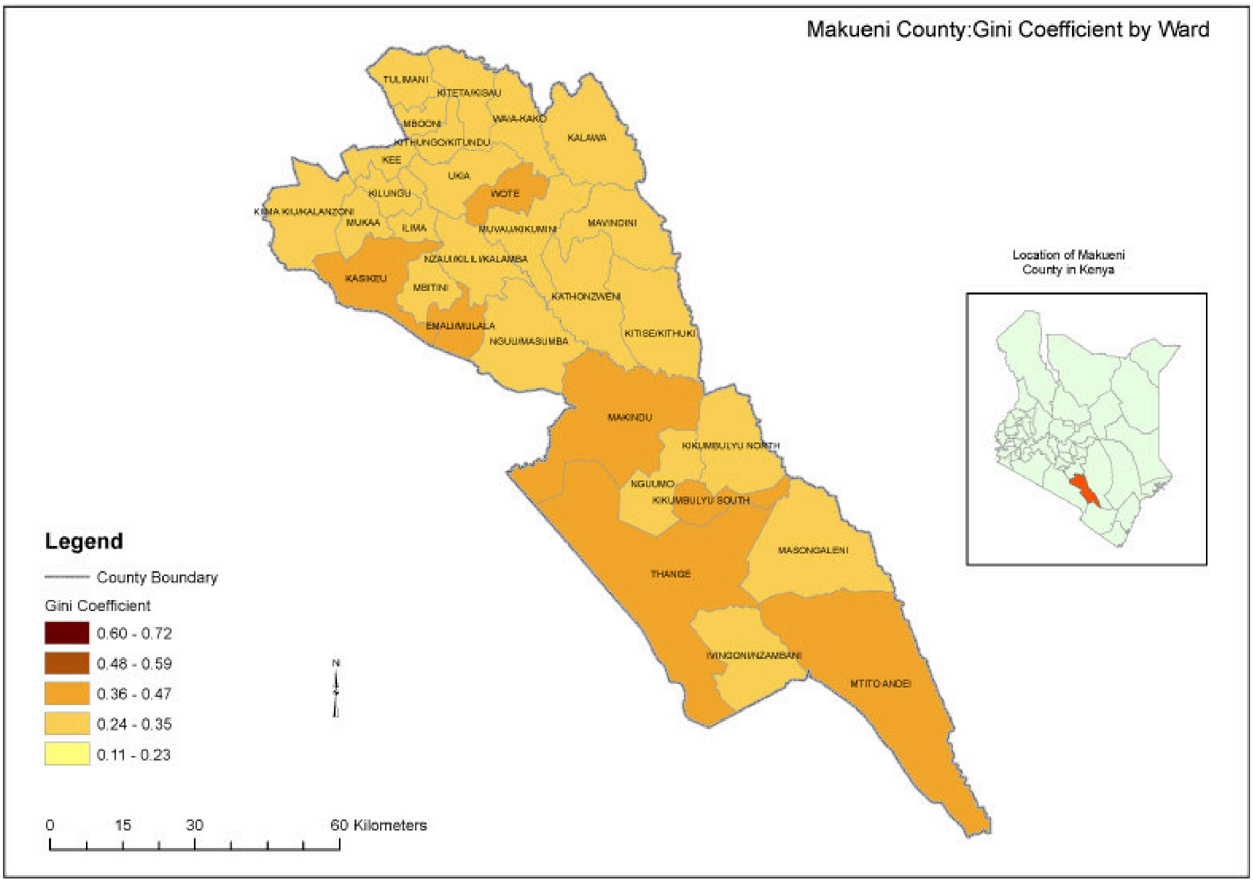

Figure 1.1: Map of Makueni County inset in a Map of Kenya (Source: researcher, 2015)

DATA

The data used in this study is of secondary nature comprising of rainfall elements measured on rain gauge instruments in the study area. The rain gauge data series used comprised of records for the period 1990-2011 for three different stations. Table 1.1 here under shows the stations and the respective locations of the rain gauge data used in the study.

Table 1.1: Weather Stations and the respective locations of the rain gauge data used in the study area.

Station Name	**Kibwezi**	**Mavindini**	**Makindu**
Station Number	9237002	9137145	9237000
Latitude	-2.4	-1.81667	2.283333
Longitude	37.9	37.78333	37.83333

The agricultural production potential in the county is largely determined by physical factors, primarily soil and climatic conditions, as well as the complex interaction of socioeconomic, cultural and technological factors. Makueni County is classified into five major agro-ecological zones (Jaetzold et al 2006). The lower highland zones comprising of the hill areas of Kilungu, Kaiti, Tulimani hills, with agriculture potential for crops such as wheat, barley, maize, pyrethrum, dairy, potato, etc; the upper midland zones with potential for growing coffee, sunflower, maize sorghum, livestock etc; The lower midland zones comprise the largest surface area of Makueni county occupying over 70% of the total land surface of the county. These areas have agriculture potential for growing cotton, livestock, sorghum and millet; the inner lowland zones, have agriculture potential for livestock and millet (Jaetzold et al 2006).Agriculture activities in Makueni are almost entirely dependent on rainfall (Wokabi 1997).

Data Analysis Approach

Three types or techniques of data analysis were considered to achieve the objectives of this study; the inverse distance weighting interpolation technique, correlation analysis and the least squares regression method.

Computation of Drought Indices

Computation of SPI followed McKee et al. (1993). The software DRINC (Tigkas *et al*., 2014) was used to compute the SPI values at 1 month time step. The drought indices computed have different range of values for defining the characteristics of a drought event particularly the drought severity. For inter comparison of various indices, dryness conditions indicated by the analysed indices is generally categorized as near normal, moderate, severe or extreme drought conditions based on respective estimated values of the index. This classification was used as indicated in table 1.2 below as indicated by (McKee et al. (1993).

Condition	Extreme wetness	Severe wetness	moderate wetness	Normal wet	moderate dryness	Severe dryness	Extreme dryness
SPI	2.00 or more	1.50 to 1.99	1.00 to 1.49	0.99 to -0.99	-1.00 to -1.49	-1.50 to -1.99	-2.00 or less

Computation of Drought Parameters

Drought parameters considered in this study include: duration, magnitude and severity. Measurement of drought parameters was done as defined by Keyantash and Dracup, (2002).

Drought Duration

In the mathematical modelling of droughts conditions, the duration of drought was defined as follows: Where a time series of drought indices, X_1, X_2, X_3... Xn, is truncated at a threshold value, X_0. Hence, simply and conceptually, drought was defined on the basis of comparing a given time series with a threshold value and, according to their relative positions, different drought features appear. Among these features, the following objective properties were identified which are all random, probabilistic or stochastic in their behaviour.

A wet spell was observed when any time series value at the ith instant is greater than the threshold level, ($X_i > X_0$). Accordingly, the difference ($X_i - X_0$) > 0 is named as the surplus. Otherwise, a dry spell takes place as ($X_i < X_0$). Accordingly, the difference ($X_0 - X_i$) < 0 is the precipitation deficit. A sequence of wet spells preceded and succeeded by a dry spell is referred to as the duration of wet period during which there is no drought. If the two successive dry spells that separate a wet period are Xi and Xj, then the duration of this wet period is equal to (j – i + 1).

Similarly, if a sequence of dry spells is preceded and succeeded by a wet spell, it was referred to as the duration of dry period. If the two successive wet spells that separate a dry period are Xk and Xl, then the duration of this dry period is equal to (l – k + 1). Any uninterrupted sequence of deficits was regarded as a drought length (duration) equal to the number of deficits in the sequence, designated by L, (L = 1, 2, 3, ...,). Thus drought duration was computed using equation (1)

$$D_i = \sum_{i=1}^{m}(L_i - k + 1) \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Drought Magnitude

Drought magnitude, M_j, is defined as in equation 2 :

$$M_j = \sum_{i=1}^{m} |X_0 - x_i| \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

where m is the number of deficits during a drought period and X_0 is the standardized truncation level for each drought description, as 0, –1.0, –1.5 and –2.0. The standardized truncation level was calculated using equation (3).

$$|X_0 - x_i|/S_x \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Drought Severity

Drought severity (S) is the product of the drought duration (D) (period during which the drought index values are consistently below a truncation level) and the drought magnitude (M) (departure of drought index values from truncation level during the drought period).

Drought severity (*S*) is the product of the drought duration (*D*) (during which the drought index values are consistently below a truncation level) and the drought magnitude (*M*) (which is the mean departure of the drought index values from that truncation level during the drought period) as in equation (4).

S = D x M…………………………(4)
Where
S is the drought severity
D is the drought duration
M is the drought magnitude

Results and Discussion

Meteorological drought are common phenomenon in Makueni as evidenced by the computed SPI indicating extreme, severe to mild classes of meteorological drought that occurred during the period 1991-2011 in Makueni. Three occasions of extreme meteorological droughts are identified during the months of April 2003, Jan 1997 and April 2011 in Mavindini. The years which are identified having meteorological droughts are 1999,2000, 2001, 2003,2004,2005, 2006,2007,2008, 2009 and 2011 as shown in figure 1.2 to 1.4 below.

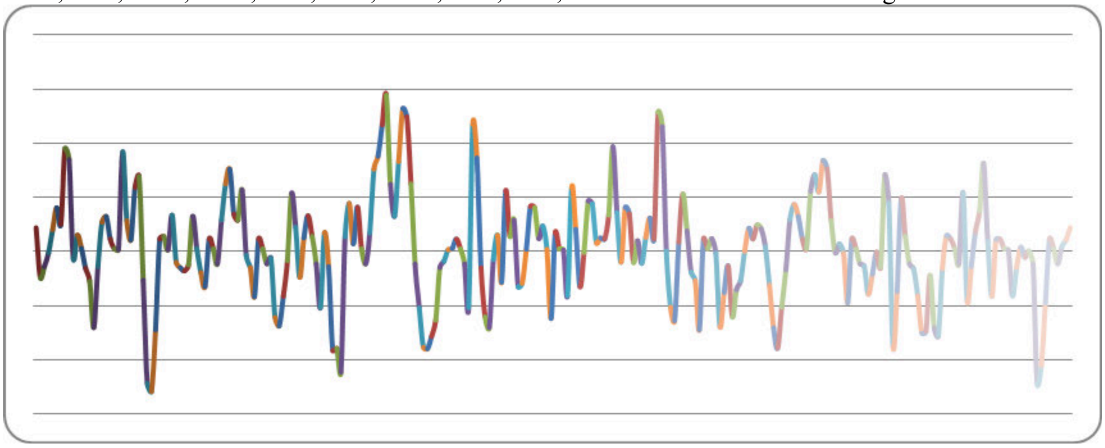

Figure 1.2 SP II for Mavindini

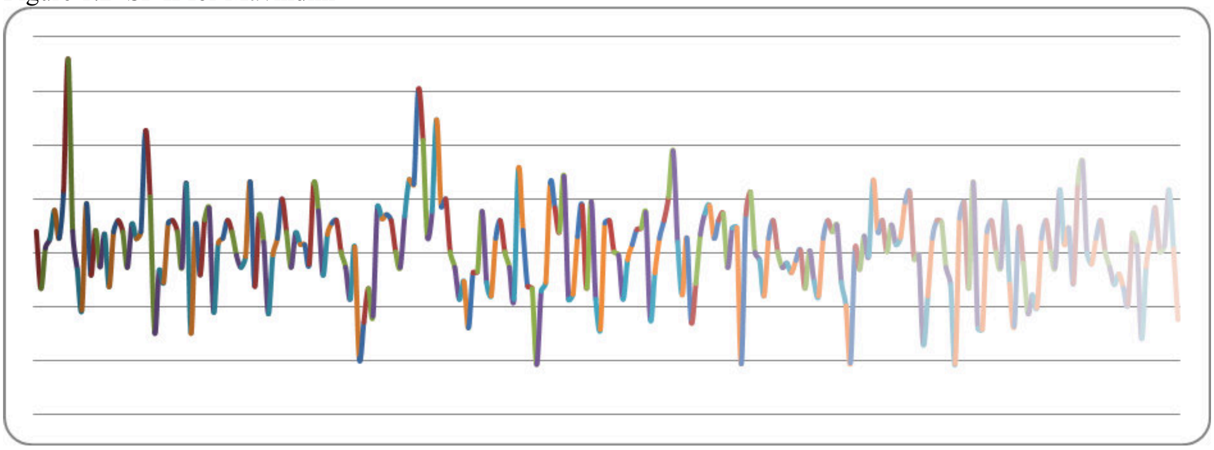

Figure 1.3 SP II for Kibwezi

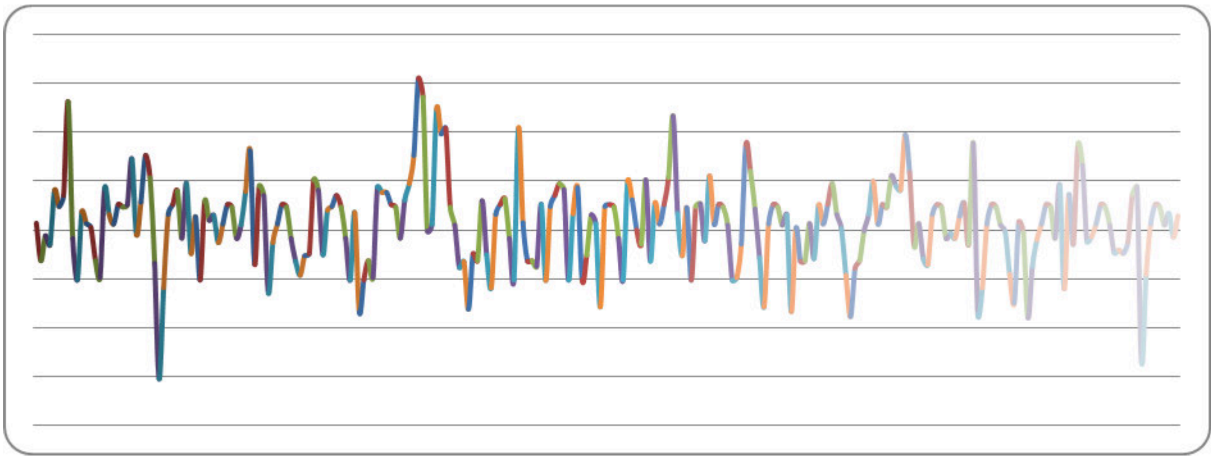

Figure 1.4 SPI 1 for Makindu

Agricultural droughts

The time series of SPI time steps of 3-6 months are used to analyse occurrence agricultural drought as given in the Figure 1.5- 1.6 below . From SPI time series, values for short term time steps (1-2 months) may also constitute agriculture droughts particularly when they occur during the crop growing period March, April and May(MAM) and October-November-December (OND) (Bänzinger et al., 2000) and may be considered both as Meteorological and agriculture droughts. Awange et al. (2007) showed that as meteorological drought severity increases i.e severely and extremely dry conditions (SPI below -1.5 and -2), at I – 2 month time steps, it causes crop failure, and expose population to shift to food relief. Therefore, these droughts in critical stage of crops in the periods through MAM and OND were singled out. Furthermore, persistent moderate droughts through the entire growing season, could also lead to crop failures, and such droughts were identified in this characterisation as agriculture droughts.

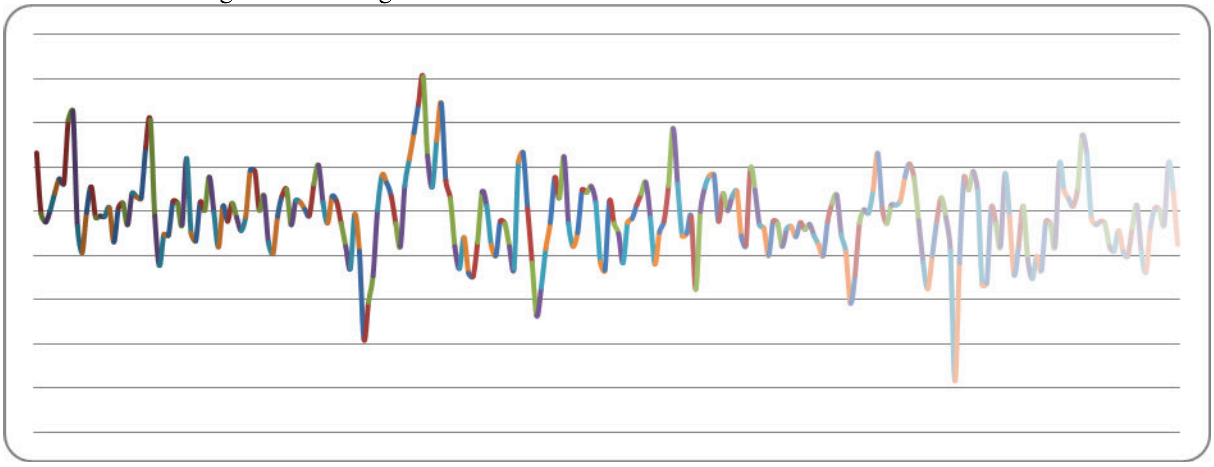

Figure 1.5 SPI II for Kibwezi

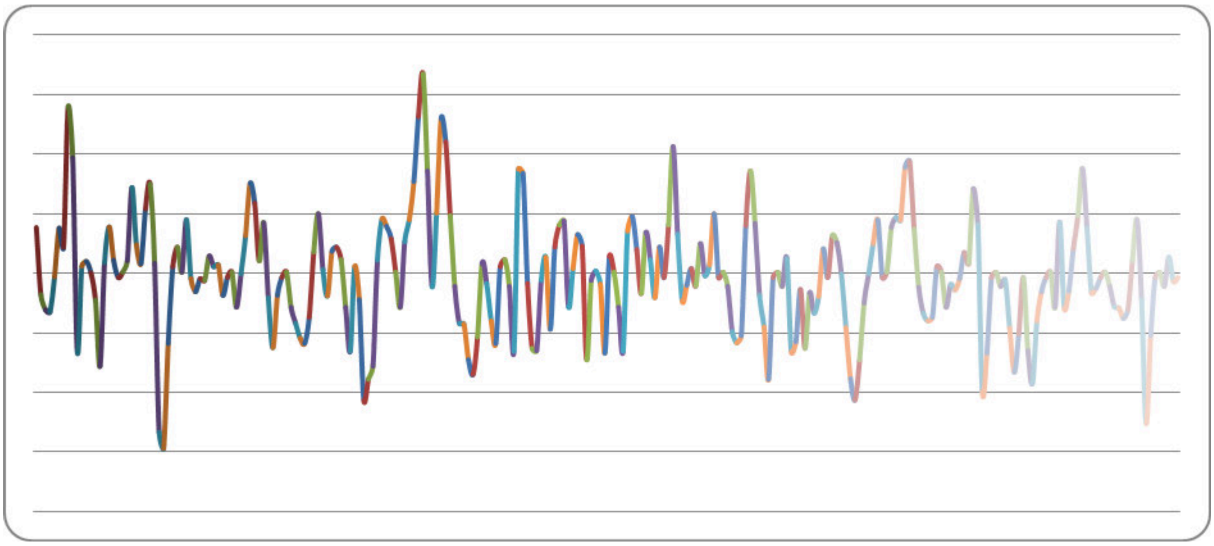

Figure 1.6 SPI II for Makindu

In Makindu, five extreme and eight severe agriculture droughts were analysed, during the study period. Frequency of agricultural drought in Makueni is increasing with adverse impacts on the economy, social life and on environment. During the period 1999 – 2011, Makueni experienced meteorological droughts, and 5 extensive agricultural droughts. Makueni has however been under water scarcity conditions since the year 2004, with perpetual hydrological drought persisting for over 8 years. The 36 month and 48 months SPI shown in figures 1.7 and 1.22 for Kibwezi station used in this study to confirm this condition.

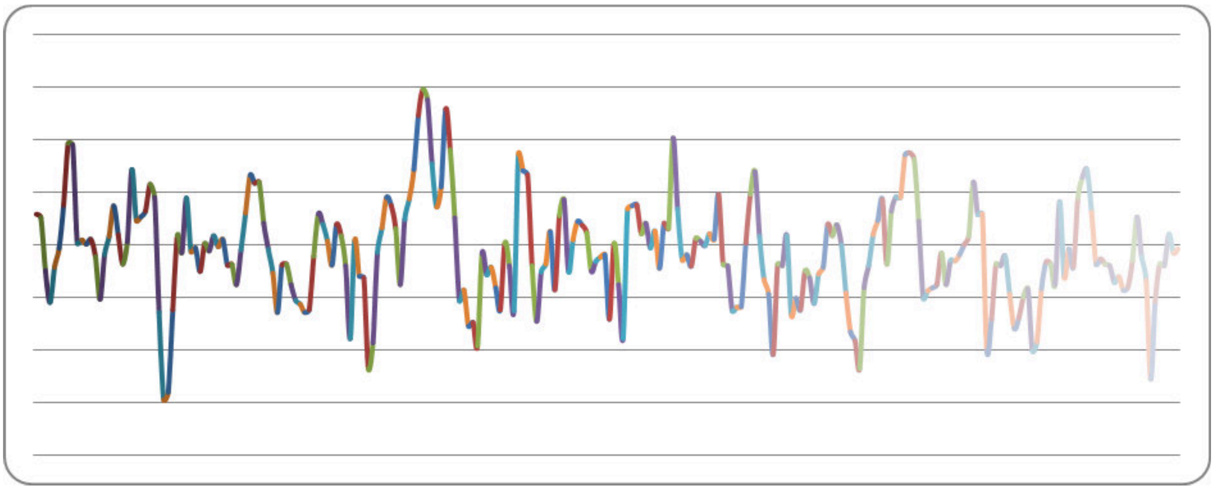

Figure 1.7 SPI-3 Makindu

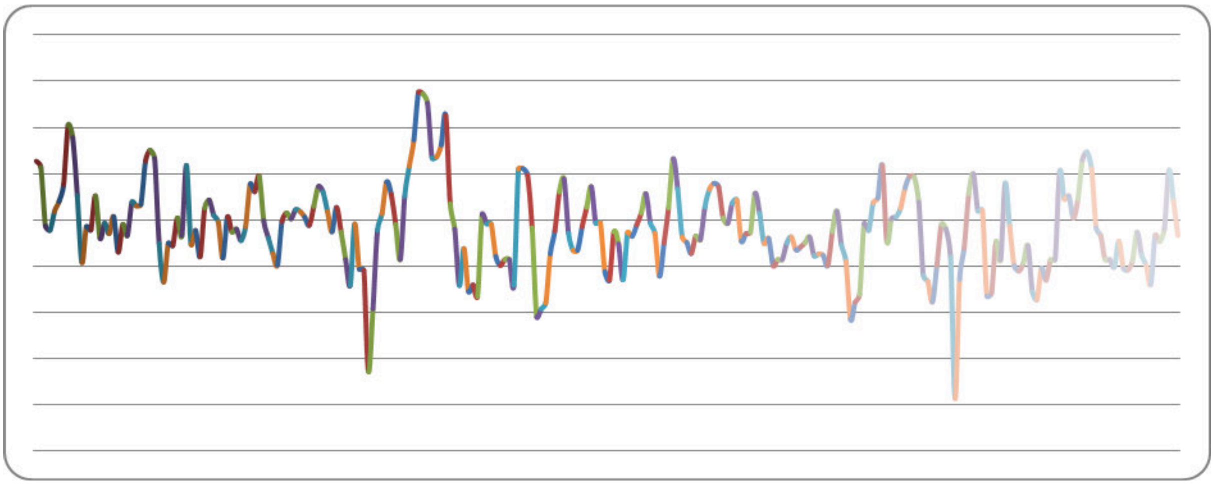

Figure 1.8 SPI-3 Kibwezi

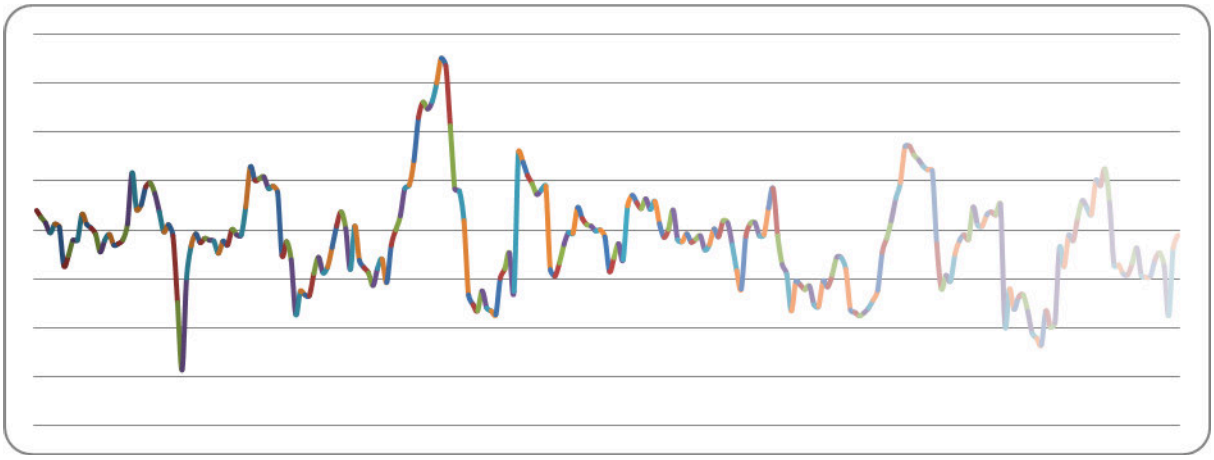

Figure 1.9 Makindu SPI 6

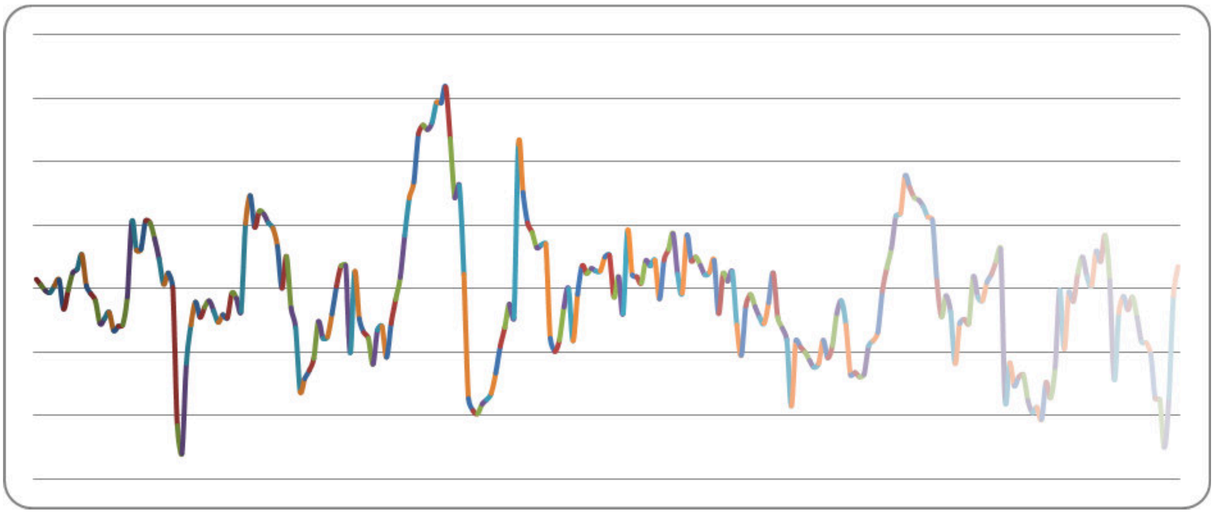

Figure 1.20 Mavindini SPI6

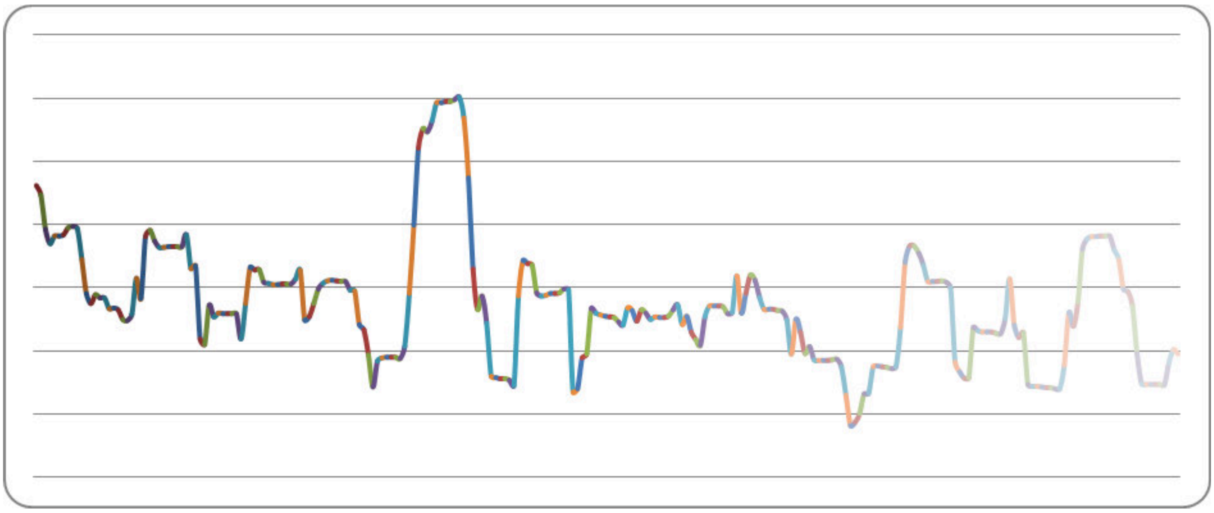

Figure 1.21 Kibwezi SPI-6

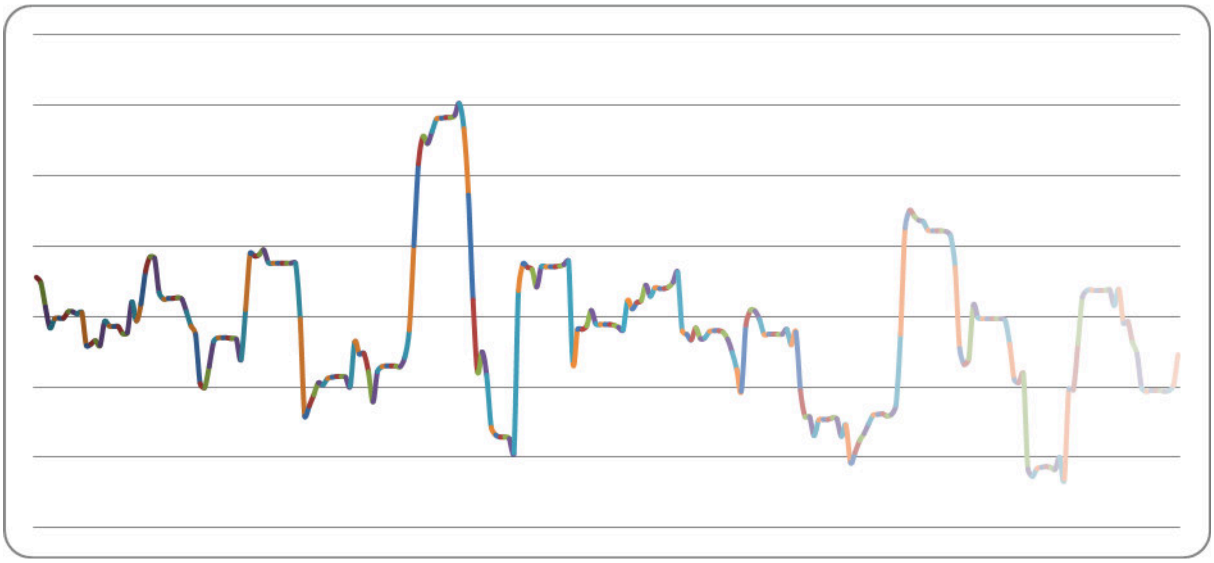

Figure 1.22: Makindu SPI -6

Hydrological droughts

The average 12- and 36 month SPI time steps time-series (figures 1.23- 1.28 below), shows the sustained and

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intense hydrological droughts in Makueni since 2005 with its peak value (-2.01) another intense period of drought is also observed from in the early 2000s with its peak value (-1.99) in the year 2002. However, the average 48-month SPI time series gives a clear indication of the sustained and intense droughts from 1999 to 2011 with its peak value (-2.01) in the year 2005. Another intense period of drought has also been observed from 2008 to 2011 with their peak value (-2.09) in the year 2008.

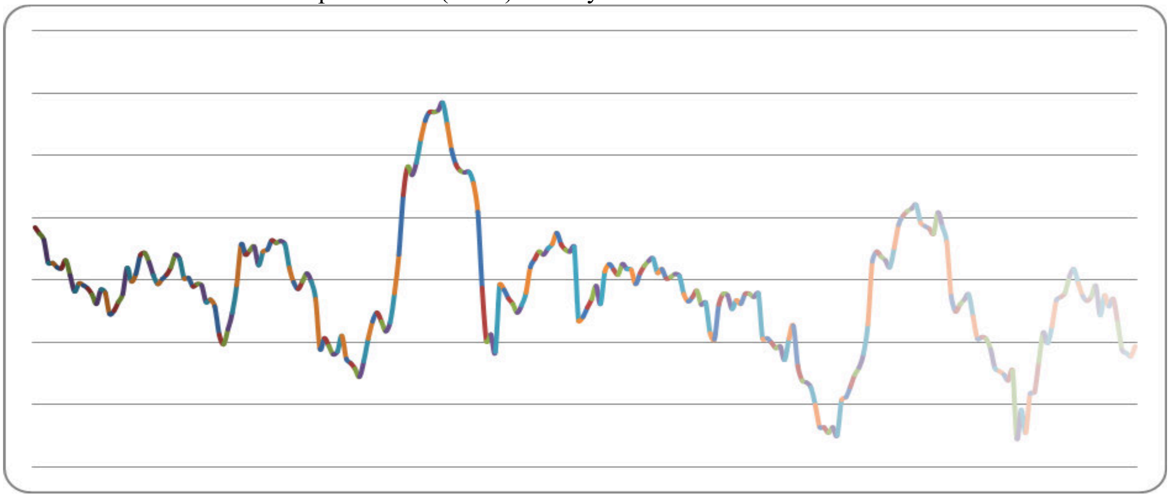

Figure 1.23: SPI-12 Makindu

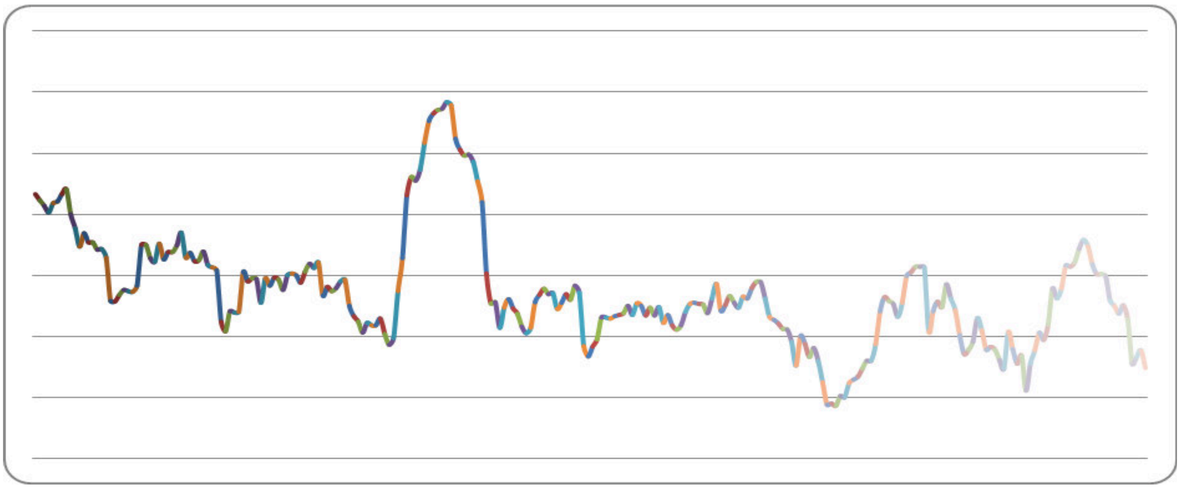

Figure 1.24: SPI-12 Kibwezi

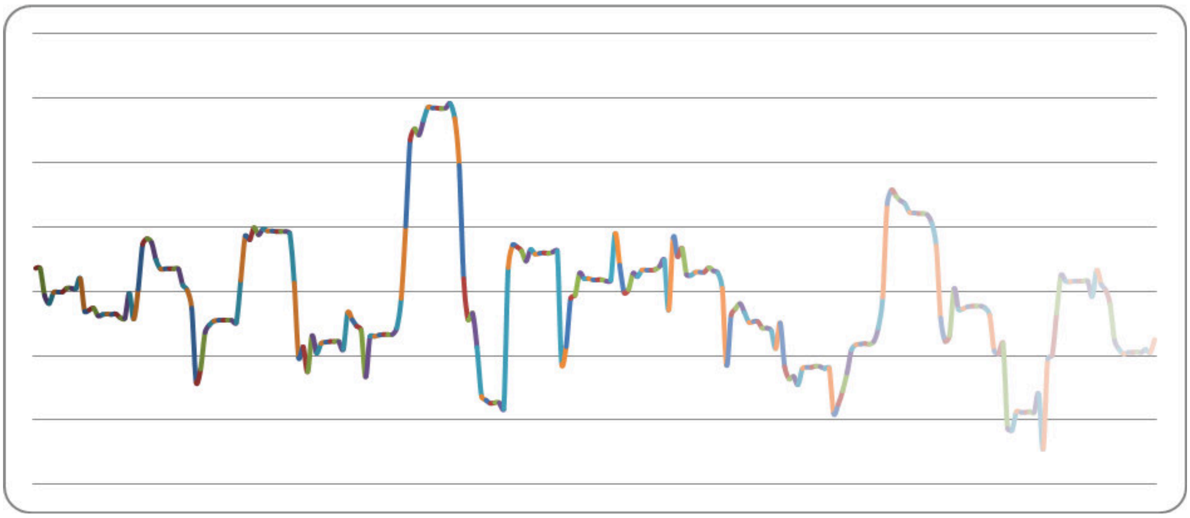

Figure 1.25: Mavindini- SPI 12

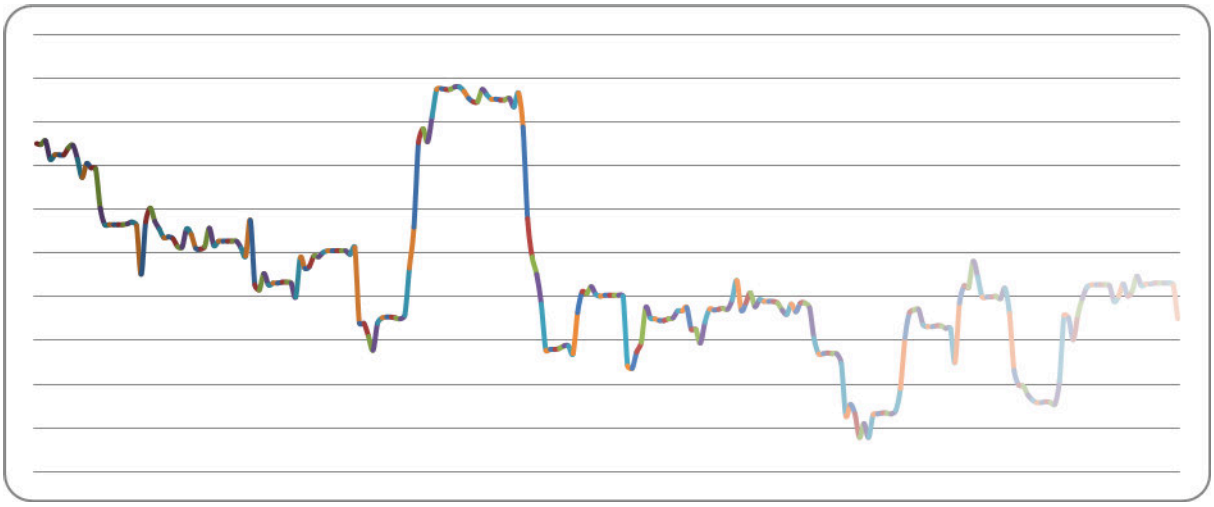

Figure 1.26: Kibwezi SPI 24

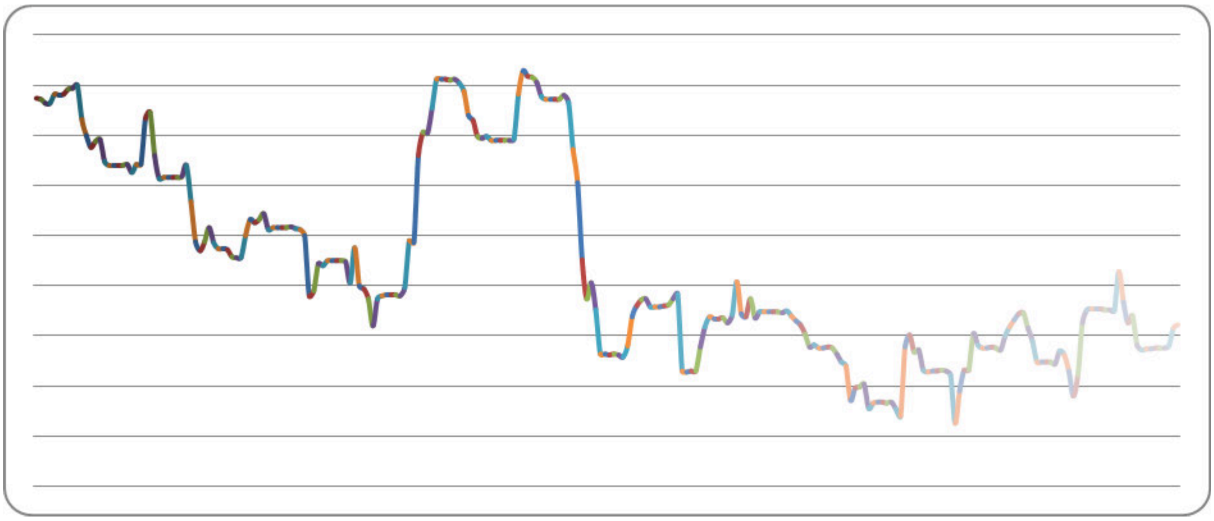

Figure 1.27: Kibwezi SPI 36

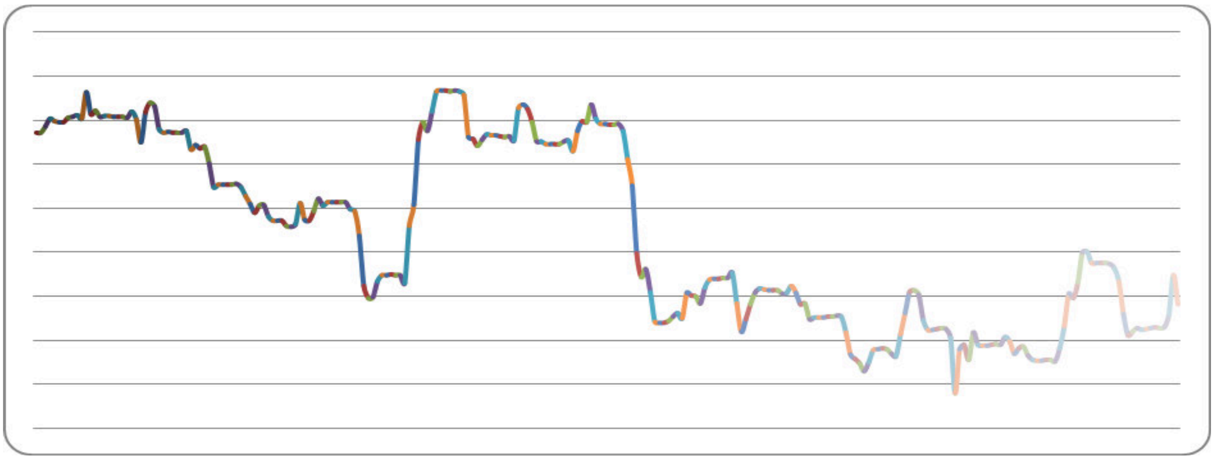

Figure 1.28: Kibwezi SPI 48

Conclusions

Makueni experienced three occasions of meteorological droughts identified during the months of April 2003, Jan 1997 and April 2011, the other years were this drought was experienced were 1999, 2000, 2001,2004, 2005, 2006,2007,2008, 2009 though not extreme. Occurrence of drought was identified every time the SPI comes to -1.0 or less. Five extensive agricultural droughts were also experienced as analysed in Makindu. Makueni has however been under water scarcity conditions since the year 2004, with perpetual hydrological drought persisting for over 8 years. It was however noted that none of the respondents was aware of the type of drought they were experiencing. This kind of scientific information should be available to farmers to enable them build capacity to adequately prepare and respond to droughts.

Availability of weather forecast information is a preliquisite for drought informed decision-making to strengthen the resilience of the poor and the vulnerable against severe impacts of drought. This is because the respondeds did not know the right time to plant their crops, and what crops to plant depending on the nature of rainfall they expected. When the respondents were asked to explain whether they had access to weather forecast information for early warning purposes, majority did not have any form of information.. This group practiced farming with no information on weather changes at all.

Recommendations

The Government through the institutions dealing with climate should make a deliberate effort to create awareness of the types of drought experienced in Makueni County. It was noted that farmers in the study area did not know the type of droughts they experienced hence poor preparation and response a big knowledge gap was identified in this area.

There is also need for integration indigenous household perceptions of drought with scientific meteorological data on rainfall and temperature trends for better planning and targeting of interventions.

Recommendations for further research

i) Further, a research that will use GIS and remote sensing incorporated with survey methods is encouraged to enable understand and predict events that are inaccessible, yet significant in regard to drought management for informed decision making and early warning purposes.

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