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Analysis of Historical Rainfall Variability, Droughts and Wet Seasons. A Case of Wiyumiririe Laikipia County

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ABSTRACT

The importance of historical rainfall pattern in gaining a sound understanding of climate change in any particular region is paramount. This study investigated rainfall variability at Wiyumiririe location of Ngobit ward, Laikipia County Kenya. The study sought to gain insight into rainfall variability, intensity, and frequency of droughts and wet periods as a pointer to the distribution, reliability and total amount of rainfall received both for the long and short growing seasons. The study relied on historical rainfall data derived from the nearby Lamuria weather station (code: 9036213; 0o08'S 36o 52'E) operated by the Water Management Authority (WMA) for Kenya Meteorological Department (KMD), for the period between January 1958 and December 2017. The choice of the weather station was based on the fact that it was the only one of its kind within a radius of 100 kms from the study site and in the same Agro Climatic Zone V. Moreover, it contained credible historical weather data. Rainfall Anomaly Index (RAI) was used for analysis. Results of the study showed that over the years, the total amount of rainfall was declining; the frequency and intensity of droughts are increasing while the wet periods are reducing in numbers and intensity. Therefore, for farmers to improve food security and adapt to the changing climate, there is a need to focus on how to maximize on the available rainwater while at the same time remain cognizant of the changing patterns of rainfall. The significance of the study was that the information is likely to help farmers and policy makers make informed decisions while choosing appropriate adaptation options. From these findings it would be necessary to develop sound micro-water harvesting technologies, and embrace drought escaping crop varieties among other coping mechanisms to mitigate the negative effects of declining rainfall and the emergent trend of droughts and wet seasons.

1. Introduction

According to studies done by (Simelton et al., 2013; Adehisi-Adelani and Oyesola 2014; and Zake and Hauser 2014), more than 95% of agricultural production in sub-Saharan Africa is rainfed. Moreover, it is the main source of livelihood for majority of smallholder farmers in rural Africa. This category of farmers are likely to be more vulnerable to climate change because of the compounding effects of poverty, low infrastructure and technological development and; high dependence on rain fed agriculture (Lipper et al.,2014; Erickson et al., 2011; Nelson et al.,2013; Adimassau and Kessler, 2016). Climate projections for Africa point to increased turbulence with extremes for drying and warming being anticipated in most subtropical regions and; mild increased precipitation within the tropics (Adehisi-Adelani and Oyesola 2014; Christensen et al., 2017; Abegaz and Wims, 2015). Within the East African region, majority of Global Circulation Models (GCM) point to an increased but erratic rainfall and a temperature rise of about 2.5o C by the year 2050 based on the IPPC A1B2 scenario (Jones et al., 2009). A Study carried by (Nicholson, 2014) indicated that in the horn of Africa, the frequency of droughts has increased with rainfall totals of at least 50-75% below recorded in most parts, amounts of which are too little to support crop and pasture growth. Related studies showed that Kenya has experienced droughts in every 10 years in the 1960s/1970s to ones every 5 years in the 1980s and once in every 2-3 years in the 1990 and has become increasingly unpredictable since the year 2000. This was reinforced by the (IPCC, 2002) report which indicated that there is likely to be an increase in intensity of drought related risks by 2050 which undoubtedly will greatly affect climate sensitive economic sectors. The Arid and Semi-arid regions of Kenya have experienced drought since time immemorial. With climate change and expected increase in evapotranspiration due to increased temperatures, the arid and semi-arid lands (ASALs) are expected to experience frequent climatic extremes, increased acidity, increased water stress, and diminished yields from rain-fed agriculture and increased food insecurity and malnutrition (Thornton and Lipper 2014). Many studies indicate that drought poses serious challenges for populations whose livelihood depends on natural resources.

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The ASALs of Kenya which have experienced increased frequency and intensity of droughts since 1960s are the most vulnerable (Nkedianye et. al., 2011).

One major extreme weather phenomenon associated with rainfall is drought. There is no consensus to its definition but generally it's referred to as a prolonged period of time in months or years during which precipitation is less than annual averages and result in water scarcity (Wilhite 2000; Downing and Bakker, 2000; Whetherald and Manabe, 2002). The World meteorological organization categorized drought into three; meteorological, (lack of precipitation for a period of time); hydrological, (a period with inadequate surface and subsurface water resources); agricultural (a duration of declining soil moisture and resultant crop failure and; socioeconomic (failure of water resources to meet demand that have a direct or indirect impact to human life), Hounam et al., 1975. The definitions provided by world organization are vague as they do not give in details, the severity of drought on a predetermined scale. The Kenya meteorological service (2010) defines normal meteorological drought as a period in which rainfall over a particular area is less than 75% of the climatologically normal. This definition as observed by (Wilhite and Glantz 1985) is inadequate as it does not account for temporal distribution of rainfall. Moreover, the conventional terms used by KMD such as normal, above or below normal rainfall are ambiguous to listeners. Additionally neither the World meteorological organization nor the KMD has made efforts to describe wet periods in a succinct manner.

Therefore, the current study relied on computed rainfall anomaly index values to develop insight into rainfall variability, droughts and wet periods in order to characterize climate change of the study area. Rainfall Anomaly index (RAI) is a meteorological index that was developed by Van Roy (1965). It integrates a ranking procedure to allocate for the magnitude of precipitation in a linear scale for positive and negative values. The positive values indicate a rainfall season while negative values imply a dry season. RAI Values greater than positive four indicate an extremely wet season while those that are lower than negative four points to a very dry season respectively. A value of zero indicates a normal season in which both wet and dry days are evenly distributed. Rainfall variability is the degree at which rainfall amounts vary across a geographical region or through time. It is viewed in two dimensions; areal and temporal. Rainfall variability from one season to the other determines water availability especially for rainfed farming (Harvestchoice, 2010). Thus it directly influences crop productivity. At the same time it is indicative of the nature of climate in a particular place. From computed RAI values, the wet periods were described as those with a positive RAI value while the droughts were defined by negative RAI values. The analysis was done with the assistance from 'AgriMetSoft' a reputed computer application software company based in the USA. The reliance on rainfall data only from Lamuria weather station (code: 9036213; 0o08'S 36o 52'E) was based on the fact that it is the only station of its kind in the locality that has historical weather data records. The study site fall within the 100 km radius of the Lamuria station and therefore climatologically representative, according to the World Meteorological Organization guidelines. Moreover, and as noted by (Mwoga et al., 2016), since most of agricultural productivity is basically agro-ecological specific and its necessary to confine to rainfall data from one station to counter spatial and temporal variations.

2. Materials and methods

2.1 The study site

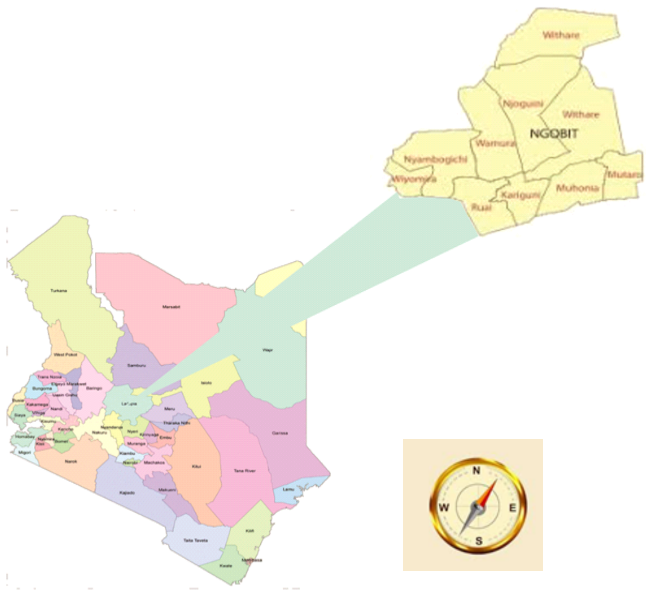

Figure 1: Ngobit ward, Laikipia County, Kenya [-0.076612; 36.56338 to -0.136569; 36.868048]

The study was carried out at Shalom, Ngobit ward, Wiyumiririe Laikipia County (Figure 1). Ngobit ward is located about 80kms South-west of Nanyuki town and borders Nyeri and Nyandarua counties. It covers approximately 40 square kilometers with a population of approximately 368,686 persons in 6760 households with a population density of 564persons per square kilometer. Most of the residents are found in Wiyumiririe and Nyambugichi locations. Ngobit ward is within Laikipia East constituency, Laikipia County. The ward is comprised of five locations: Wiyumiririe, Nyambugichi, Mwituria, Ngobit and Sirima. The main source of livelihood is mixed farming. Crop cultivated are spring onions, maize, Irish potatoes, beans and horticultural crops (Tomatoes, cabbages, French beans and bulb onions). Livestock reared are dairy cattle, sheep and indigenous poultry. Most of the soil in Ngobit ward is black cotton soils (Montemomorilorite) and are generally fertile and suitable for crop cultivation. Nevertheless, food security in the ward is not promising. Despite the presence of suitable soils for cultivation of crops, rain fed agriculture remains precarious because of inadequate and erratic rainfall exacerbated by high temperatures and sporadic strong winds.

Historical weather data was acquired from the nearby Lamuria agro meteorological station operated by the Water Management Authority (WMA, for KMD Kenya) for the period between 1958 and 2017.

Rainfall Anomaly Index (RAI) was calculated to determine inter-seasonal and intraseasonal rainfall trend, variability and intensity and to analyze severity of drought and wetness during the main (March -July) cropping season and the short (October -December) cropping season respectively. To calculate RAI, seasonal rainfall data was arranged in a descending order. The ten highest and ten lowest values were averaged to form thresholds for positive and negative anomalies respectively as indicated by the two equations shown below.

$$\text{RAI} = +3\left(\frac{RF - M_{RF}}{M_{L10} - M_{RF}}\right) \quad \text{.......................................}1$$

$$\text{RAI} = -3\left(\frac{RF - M_{RF}}{M_{L10} - M_{RF}}\right) \quad \text{.......................................}2$$

Source. Ayanlade et.al., 2017

Where: RF is the total amount of rainfall for the season in reference: MRF is the mean seasonal rainfall for the entire period: MH10 and ML10 are the mean of the ten highest and lowest values for RF (Ayansina et. al., 2017). The arbitrary threshold values of +3 and -3 were accordingly assigned to the mean of the most extreme positive and negative anomalies. From that, nine abnormality classes ranging from extremely wet to extremely dry were allocated on a linear numerical scale of the relative rainfall Anomaly index. RAI values that exceed 4 indicate an extremely humid season. Values in the range 0 to 2, means a humid season and between 2 and 4, very humid. On the opposite side of the spectrum, values of between 0 and -2 are for a dry season, -2 to -4 very dry season and below -4 extremely dry seasons. NB. The seasons were derived from the crop calendar of the area. Table 1 shows the classification of seasons based on RAI values.

Table 1: Classification of Rainfall Anomaly Index Intensity

	RAI range	Classification
	Above 4	Extremely humid
Rainfall Anomaly Index	2 to 4	Very humid
	0 to 2	humid
	-2 to 0	Dry
	-4 to -2	Very dry
	Below -4	Extremely very dry

Source: Freitas (2005)

3. Results and discussion

The results are presented in the following parts; Annual trends for the total rainfall; Rainfall anomaly index for long and short growing season; Severity of drought for long and short growing season; Severity of wetness for long and short growing season, frequency of droughts and wet seasons based. NB Both the computed values for severity of wetness and drought were derived from RAI indices as described in the previous section.

3.1 Historical annual rainfall trend

The annual rainfall totals trend during the study period is as provided in figure 2.

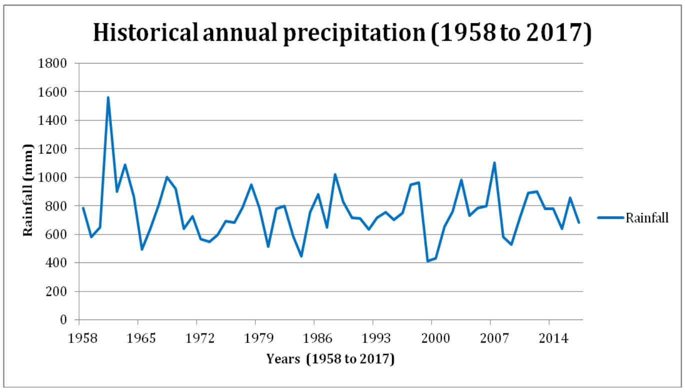

Figure 2. Annual precipitation form 1958 to 2017

Analysis of annual totals of rainfall reveals a declining trend from 1961 to 2017, with a pick in 1961 (figure 10). Earlier years were characterized by high rainfall; the highest amount recorded (1558.4mm) was in the year 1961. The other peak years when rainfall exceeds 1000mm was in 1988 (1022.4mm) and in 2007 (1103.3mm) respectively. Respondents who have been farming for more than 30 years cited 1982 to 1984 as the driest periods and 1997-1998 to be the wettest, which did not necessarily correspond with the observed data. The declining amounts of rainfall over the last decade was observed, a phenomena collaborated by farmers in focus group discussions (FGD), confirming that climate change is a reality. The findings are in agreement with other studies that have predicted declining rainfall in Eastern Africa in the 21st century (Hulme et al., 2001; IPCC, 2001).

3.2 Rainfall Variability and Anomaly during the Long Rainfall Season [March-July]

Results showed great variability in rainfall during the (March-July) long rainfall growing season for the 60 years under review (Figure 3). The very humid seasons occurred in the years: 1968, 1988, 1997, 1998, 2002, 2003 and 2007 with respective rainfall anomaly indices of: 3.812, 3.136, 2.8, 2.495, 3.141, 3.278 and 3.673. Henceforth, it was accurate to infer that only seven out of sixty years the area received high rainfall. The rest of the years were characterized by average to low rainfall. However, the distribution of wet and dry seasons showed half the seasons registering positive RAI values while the other half had negative values. Near normal rainfall for the long rainfall season was received only in three years (1962, 1994 and 1995). However, the trend was inconsistent. For instance, 1968 had a very humid season. However, it took another 20 years for the situation to recur in 1997. Between 1997 and 2017, the number of very humid seasons more than doubled, presumably because of the El Nino phenomena during the 1997-1998 seasons. Conversely, in spite of an increase in humid seasons over the past 20 years, rainfall has been erratic. Unlike the gradual change encountered between 1968 and 1973, drastic changes were observed beginning 1998. In that year RAI values of was 2.495 (very humid) but the following year 1999, the RAI figure dropped to (-3.864, very dry) signifying a huge reduction in the amount of rainfall during the March-July growing season. The same situation recurred between the years 2007 to 2009 season.

The implications of such erratic rainfall pattern was difficulties in making farming decisions; an observation collaborated by farmers in focus group discussion (FGDs) and by key informants.

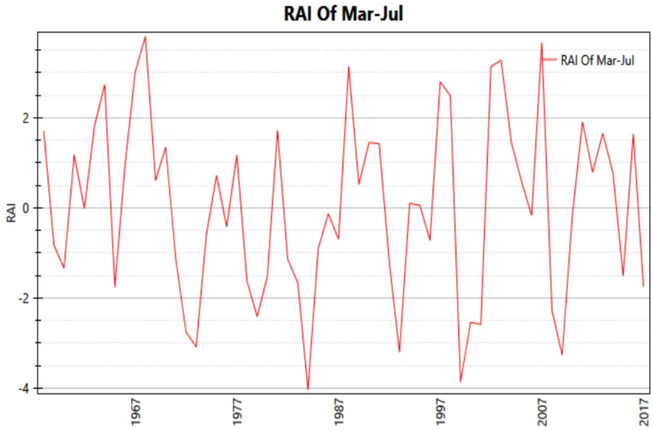

Figure 3: Rainfall Anomaly Index of the March- July long rainfall season (LGS)

3.3 Frequency and intensity of droughts during the March- July long rainfall season (LGS)

In total, there were ten dry periods between 1958 and 2017. Four of them lasted for a duration of one year and were generally less severe: In 1960, 366 days (severity 0.348); 1965, 365 days (severity 0.764); 2015, 365 days (severity 0.514) and 2017, 365 days (0.752) Table 2. There were four very long dry spells each extending to 1096 days. I.e. running through three consecutive seasons; 1971 (Severity 4.01)), 1978 (Severity 2.593), 1982 (Severity 3.861). The driest year with a severity index of 3.046 was 1984, accounting for the highest proportion (79.4%) of the 1982 drought period. The findings of this study were in tandem with a previous one done by (Shisanya, 1990) which reported a severe drought occurring during the 1983-1984 seasons that compelled the Kenya Government of the day to launch a nationwide food relief program.

Table 2: Rainfall Anomaly Index, the severity of drought for March-July long rainfall season

Number of droughts	Start of drought period	Duration	Number of seasons	Severity of drought
1	1/1/1960	366	One	0.348
2	1/1/1965	365	One	0.764
3	1/1/1971	1096	Three	4.01
4	1/1/1978	1096	Three	2.593
5	1/1/1982	1096	Three	3.861
6	1/1/1992	731	Two	2.427
7	1/1/1999	1096	Three	6.015
8	1/1/2008	731	Two	3.553
9	1/1/2015	365	One	0.514
10	1/1/2017	365	One	0.752

3.4 Rainfall Anomaly Index (RAI), the severity of wetness for [March-July] long rainfall season.

For thirty-six years, between 1959 and 2017, the RAI, severity of wetness was zero. Implying that in those years and seasons the amount of rainfall received was negligible and could not support crop growth. Therefore, the target farmers who solely depended on rainfed farming had to rely on other sources of livelihoods as adequate since adequate crops yields from their farms wasn't guaranteed because of water scarcity. Results of the incumbent study were in tandem to what farmers had experienced in which they said that for the past five years, it was only in the years 2013 and 2016 when significant rains were received during the March- July growing season. From figure 4, the decade between 1997 and 2007 was most wet with three pick periods perhaps mainly because of the El Nino affect that commenced in 1997. The previous period from around 1970 to 1996 was characterized by very few wet seasons, a situation that appears to recur since the year 2007. Evidently, from the year 2002 to 2017, the wet seasons have increased proportionately but are however less severe as indicated by low RAI values. None of the wet seasons that have occurred during the last ten years attained a severity of wetness close to 1.0 compared to the previous decade. The results are an indication of declining rainfall amounts during (March-July), the main growing season. In the study area, the March-July rainfall season constitutes the main growing season. The decline in the amounts of rainfall is of concern a similar trend was observed in South-Western Nigeria for the early growing season (Ayanlade et al., 2017)

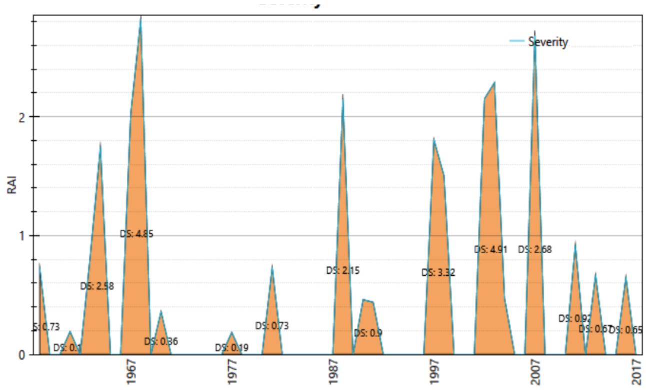

Figure 4: Rainfall Anomaly Index, Severity of Wetness for the [March-July] Long Rainfall Season

3.5 Rainfall variability and anomaly during the short rains [October- December] (Short Growing Season)

The October-December rains coincides with short growing season (SGS) that is mainly associated with cultivation of early maturing maize variety, beans, onions, pasture and fodder crops. Both the total and variability in are important aspects for the short rains because there are a number of crops that are grown during this season thus contributing to food security for many households. The season beginning October 1961 with a RAI value of (9.074) had the highest rainfall recorded. The other humid seasons occurred in the years: 1962, 1963, 1968, 1978, 1982, 1984, 1988, 1994, 1997 and 2007 (figure 5). From 2007, the trend indicated no humid situation observed during the short growing season (SGS) for the next ten years, supporting fears from farmers and key informants that the declining precipitation was aggravating food insecurity. Generally, the variability of rains during the short growing season is high with only the years, 1985, 1987, 1989 and 1992 receiving near normal rainfall.

The other years, rains were mostly below average and erratic as indicated by the negative and positive RAI values.

For instance, between 1968 and 1978 there was not a single year that above normal rainfall was recorded, suggesting that maybe low yields were obtained in the stated period. Then between 1978 and 1988, five seasons were humid while the rest were dry. Important to note however is that, even though the seasons have remained erratic during the last ten years (2007 to 2017), the within season rainfall has considerably reduced as indicated by declining RAI values compared to the previous decade (1997 to 2007).

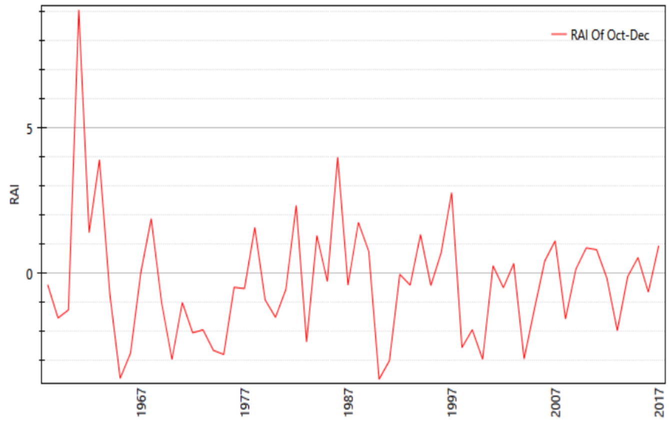

Figure 5: Rainfall Anomaly Index (RAI) of the October-December Short growing season (SGS)

3.6 Rainfall Anomaly Index, Severity of Drought for the [October-December] Short Growing Season (SGS)

Drought regimes were also considerably high and severe as shown in table 3. From table 3, ten periods of drought were recorded. Three of which were extremely severe; 1965 (severity 2.65), 1990 (severity 2.67) and 1991 (severity 2.03). The dry period commencing October 1969 was the longest lasting 2556 days and severity of 7.552. The implications were probably there no meaningful cultivation that took place for the five consecutive seasons, a trend that old farmers interviewed recounted during focus group discussions. However, the drought periods were fewer between 1977 and 1987, surprisingly so because it is during that period when the most severe drought was recorded, 1983-1984.

Table 3: Rainfall Anomaly Index, Severity of Drought for October -December (Short Rainfall Season)

Number of drought	Start of drought period	Duration	Number of seasons	Severity of drought
1	1/1/1959	731	Two	0.838
2	1/1/1965	730	Two	4.40
3	1/1/1969	2556	Seven	7.552
4	1/1/1980	366	One	0.534
5	1/1/1983	365	One	1.384
6	1/1/1990	730	Two	4.698
7	1/1/1998	1096	Three	4.521
8	1/1/2004	731	Two	2.212
9	1/1/2008	366	One	0.587
10	1/1/2013	365	One	0.993

3.7 Rainfall Anomaly Index, Severity of Wetness for the [October –December] Short Rainfall Season

Results for the severity of wetness are almost the complete opposite of the drought periods (figure 6). The wet periods were fewer than and not as severe as the drought periods. The wet period commencing October 1961 was the wettest with the severity of 11.409, a situation that extended up to the next two successive seasons in 1962 and 1963. From then onwards, the frequency of wet periods became low and wet periods shorter. For instance, between 1964 and 1977, only one low key wet season was recorded in 1968 (severity 0.888). A notable positive trend was observed between 1982 and 1988. During that interval, a substantial amount of rainfall was recorded in four of those years despite some of those seasons e.g. in 1984, falling in one of the driest years. The findings signify the importance of the October –December short rains in addressing food security. The potential for interpolation exist to make the findings attain a wider application because according to (Kisaka et al., 2015) reconstruction is feasibly for rainfall data analysed using rainfall anomaly index.

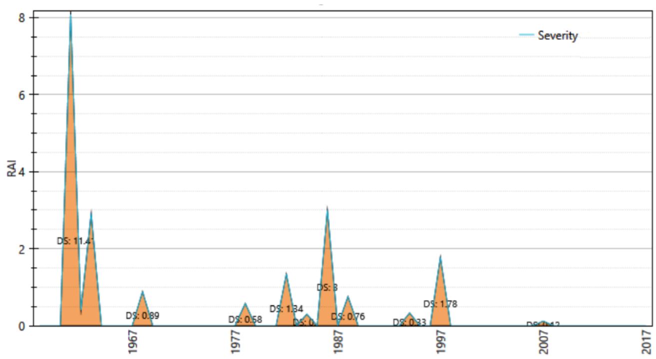

Figure 6: Rainfall Anomaly Index, Severity of Wetness for October -December short Rainfall Season

Conclusion

This article demonstrated Rainfall Anomaly Index (RAI) as an effective tool in analyzing rainfall variability, frequency and intensity of both wet and dry seasons in a way that helped in developing a nuanced understanding of the Climate for Wiyumiririe- Ngobit Ward as well as the effects of climate change. Results indicated a decline in the total amount of rainfall over the decades, increase in frequency and intensity of dry seasons and a reduction in frequency and intensity of the wet seasons. Moreover, the findings, served to dispel misconceptions about certain years and periods being drier than others, especially with regard to the phenomena of climate change. This information is of significance to agricultural production because; the trend, possible impacts and plausible coping and adaptation options can be planned and executed beforehand.

This study therefore recommends to improve our understanding of rainfall pattern and climate change in general. There is a need to put into policy and practice analysis of historical rainfall data using Rainfall anomaly index (RAI). Additionally, there is a need to embrace farmers own knowledge and perceptions about climate change. Further, KMD should endeavor to do a more detailed analysis of rainfall data and the information subsequently passed to farmers so that what happened in 1984 when farmers failed to take advantage of the short rainfall season does not recur.

It is envisaged that a detailed analysis of rainfall data will adequately inform the likelihood occurrence of droughts or wet seasons which if passed on timely to farmers; it will undoubtedly serve as an impetus for them to plan ahead, knowing which season is likely to yield benefits for them. While that is being sought, the timelines for onset of rains and subsequent cessation before crops have attained physiological maturity are aspects of rainfall that require investigation.

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