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Derive Precipitation Effectiveness Indices as Evidence of Climate Change and Implications on Food Security in JOS South Local Government Area of Plateau State, Nigeria

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Abstract: ***The focus of this study is to examine changes in precipitation effectiveness indices to show evidence of climate change in Jos South Local Government Area of Plateau State. Fifty years' daily Precipitation data (1966-2015) for Jos south LGA were used to derive six important Precipitation Effectiveness Indices: onset, cessation and length of rainy season, annual rainfall, rainfall amount in months of growing season (April to October) and occurrence of pentad dry spells (5, 10 and ≥15days). The derived indices were subjected to time series analysis to determine the trend in their occurrences in the face of the current global climate change. Trend lines and linear trend line equations for each of the parameters were fitted to show the direction of change. Results of analysis showed that mean onset date was 15th of April while mean cessation date was 25th of September. This implies that the rainy season starts early in recent times while cessation dates arrive late. Consequently, the length of rainy season is long. This showed that the trend of onset and cessation dates and length of rainy season are characterized by marked variability. Additionally, long term mean rainfall was 1266.54 mm. Maximum rainfall occurred in 1969 (1720.3 mm) while the minimum was 814 mm in 1995. Results revealed more incidences of single pentad dry spells occurring all through the period compared to 10 and ≥ 15 consecutive dry spells. This implies that dry spells of 5 days were common while dry spells of 10 days and ≥15 consecutive days were fewer. This implies a decline in precipitation; its intensity, amount and duration in Jos South. These are all indications of climate change syndrome. It can be recommended that continuous data acquisition should be encouraged in areas where none existed, public enlightenment on the impacts of climate change, adopting new hybrids of short-duration crop varieties in cases of fluctuating trends, early planting and establishment of dam sites will minimize impacts of these changes on livelihood.***

Keywords: climate change, precipitation effectiveness and derived indices

1. Introduction

The Intergovernmental Panel on Climate Change (2007) defined climate change as a change in the statistical distribution of weather patterns when that change lasts for extended period of time (i.e. decades to millions of years). It is the variations in weather averages that persist for long periods. This includes shifts in the frequency and magnitude of sporadic weather events, rise in global surface temperature, and rise in sea level, continuous change in precipitation, evaporation and stratospheric ozone layer depletion.

Precipitation effectiveness is that portion of total precipitation used to satisfy vegetation need; that is the actual available precipitation used in plant development (American Meteorological Society, 2009). Precipitation is the general term for rainfall, snowfall and other forms of frozen or liquid water falling from clouds. The weather determines the supply of moisture through winds and surface evaporation, and how it is gathered together in storms as clouds. Precipitation effectiveness is defined as water requirement of a crop; that is, the amount of water needed to raise it and this includes water to meet both consumptive and special needs such as land preparation, land pre-sowing tillage, sowing, weeding and so on (Forbes and Watson, 1992). Precipitation effectiveness indices are the major control of crop yield in the West African savannah region where Jos South is located. It is not only the total amount of rainfall in the study area that matters; but how effective the rain is in terms of its time of occurrence, spread, intensity, frequency, and availability as soil moisture (Adefolalu, 1993).

Agriculture has remained the chief source of livelihood in Jos South Local Government Area of Plateau State and is the major means by which the teeming population of the community is fed. Agricultural activities, right from land preparation, through crop selection and planting, to the time of harvesting is rainfall dependent. Changes in precipitation effectiveness indices caused by climate change has affected productivity in terms of quantity and quality of crops. The rate of leaf expansion in the plant is slowed down or stopped, and leaf variation is shortened as a result of water deficit which adversely affects the development of the crop (Sale, 1973; Susnochi and Meir, 1978; Zaag and Burton, 1978; Wolfe, Fereres, and Voss, 1983). Olaniran (1984) revealed that in general, precipitation is the climatic variable of primary importance in shaping the spatial and temporal variations of agricultural production. The seasonal cycles of rainfall directly determine the tempo and rhythm of the growing seasons. It is the moisture and nutrients that are useful to the plant at sprouting to emergence stage of crop development (Burton, 1989). The amount of water available to plants depends on the seasonal onset, termination and Length of the rainy season as well as on water movement over the land and within the soil and on soil evaporation (Anyadike, 1992; Hess, Stephens and Maryah, 1995; Ati, 1996).

Several studies have been conducted towards improving crop yields in the study area by the National Root Crop Research Institute (NRCRI), Vom, Plateau State and other agricultural Research institutions in Nigeria through breeding of high yielding varieties, pest and disease resistant varieties, improved yield and cultural practices of weeding and fertilization (Solomon, Zemba and Jahknwa, 2013). Yet there is still declining crop yields per hectare in Jos South Local Government Area of Plateau State. This is mainly because of the effects of climate change on onset date of rains, cessation and length of the rainy season. This development has posed a great threat to sustainable agriculture and food security in the study area (Sawa and Adebayo, 2012; Solomon, Zemba and Jahknwa, 2013; Burton, 1989; Sale, 1973; Susnochi and Meir, 1978; Zaag and Burton, 1978; Wolfe, Fereres and Voss, 1983). Food security particularly in the semi-arid regions of West Africa where crop production is largely rain-fed is threatened by some changing characteristics of the major precipitation effectiveness indices. A good knowledge of the present status of some of these rainfall attributes will not only inform farmers of when best to start planting and undertake the other vital processes of crop production but what type of crop to plant and where best to plant it. This paper examines the current status of the major precipitation effectiveness indices visa viz the present climate change phenomenon with a view to presenting some vital information to farmers about the changing onset and cessation dates, Length of the rainy season; number of rainy days, Dry spells, Annual rainfall, rainfall amount in the months of growing season (April, May, June, July, August, September and October) and occurrence of pentad dry spells (5, 10 and ≥15days) from 1966 to 2015. This study aims at determine the changes in precipitation effectiveness indices to show evidence of climate change in Jos South Local Government Area of Plateau State, Nigeria.

2. The Study Area

Jos South Local Government Area lies within latitudes 9^0 37' and 9^0 54' N and between Longitudes 8^0 42' to 8^0 58' E (Figures 3.1 and 3.2). Jos South Local Government Area is one of the seventeen Local Government Areas in Plateau state. It is situated at the north western part of the state with its headquarters at Bukuru. Jos South Local Government is bounded to the north by Jos North to the north east by Jos East to the north west by Bassa to the south by Riyom and to the south east by BarkinLadi Local Government Areas. It is made of four districts: Vwang, Du, Gyel and Kuru. The Local Government Area has total land area of about 1,037km^2. The following wards make up the four districts in the study area, which are Bukuru, Zawan, Rafin Mangu, Shen, Vom, Gero, Rayfield, TCNN, Udu, Du, Gyel, Dogo na Hawa, Mai-adiko, Wang, Turu, Kuru, Pasa Kai, Sabon Gida, Kirana, Dutsen Kato, Barkin Nda, BarkinTintin and Anguldi.

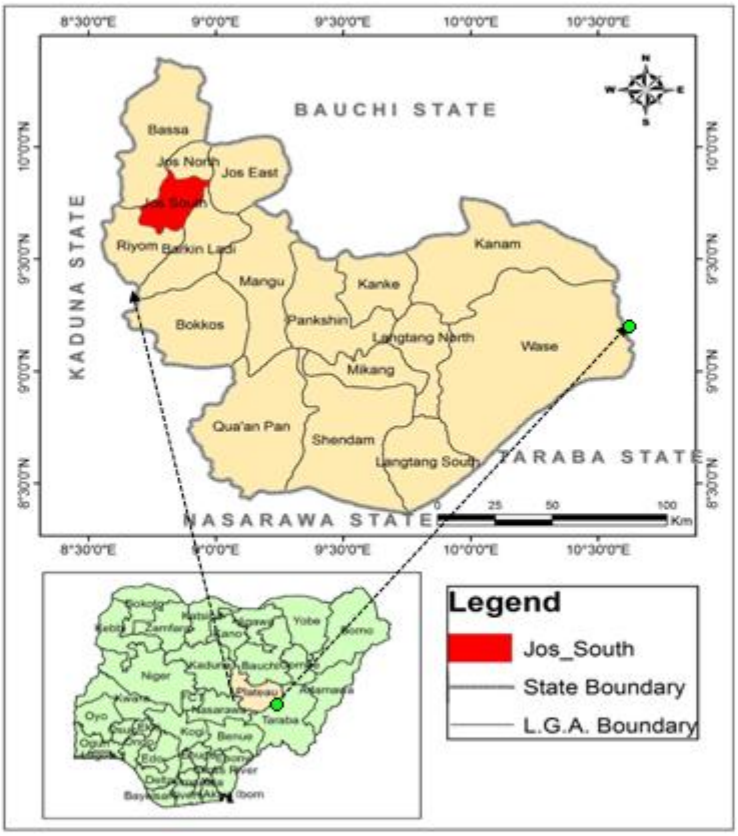

Figure 2.1: Jos South Local Government Area
Source: Adopted from Administrative Map of Plateau State (2012)

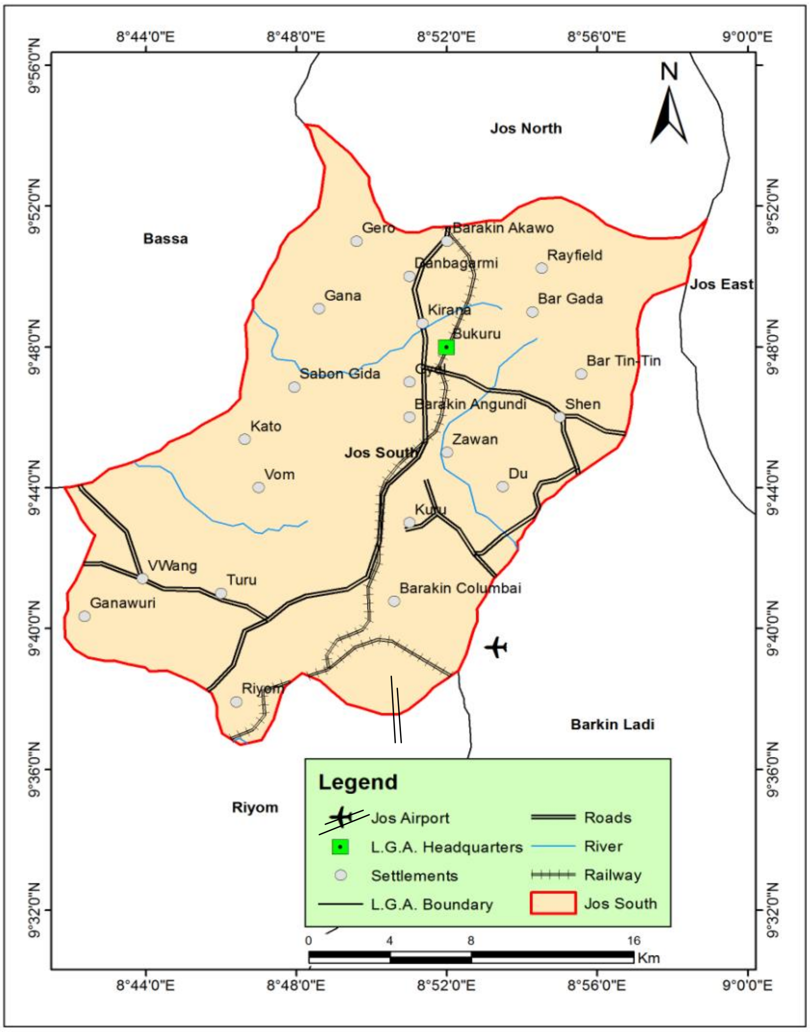

Figure 2.2: Jos South; the Study Area
Source: Adopted from Administrative map of Plateau State (2012)

The study area is characterized by alternating wet and dry seasons as tropical rainy (A_w) climate by Koppen (1918). The precipitation arises from both convectional and orographic sources, owing to the location of the city on the Plateau. Rainfall in the study area lasts between April and October, which has seven months' duration of rainy season. Rainfall is at its peak between July and August. The mean annual rainfall in Jos South varies from 1317.5mm in the southern part to 1460mm on the Plateau (Blench, Daniel and Hassan, 2003). In July, the precipitation reaches its peak with an average of 298mm, July and August are the months with the highest number of rainy days while the lowest number of rainy days occur in January, February, November and December. The greatest amount of rainfall is obtained in the southern and western margin of the high plateau than at the lowlands. Conversely, rainfall variabilities are higher on the lowlands of the State than on the high plateau. Rainfall variabilities are higher at the beginning and at the cessation of rains than in the middle of the rainy season. The pattern of rainfall distribution of Jos is explained partly by the movements and positions of the Intertropical Discontinuity (ITD) at various times of the year and partly by interplay direction of rain bearing south-westerly winds with the physiographic features in the State (Odumodu 2016). Precipitation is a very important resource in the study area as many human activities depend upon its availability (Buba,1995). Therefore, the amount and the distribution of rainfall are important factors in determining the ultimate productivity of crops under natural conditions (Bagulia, 2006). Precipitation is also considered as critical resources in the study area because its supply is confined to a season which coincides with the northern hemisphere summer (Ofuma and Nnodu 2005). Furthermore, the wet season is characterized by temporal and spatial variations, the magnitude of such variations with regard to the onset, distribution, cessation and length of the season are therefore important in planning for agricultural development and as well as for commercial planning and development. (Nieuwoit,1975). Since agricultural activities in Jos South are mostly rain fed, for a successful crop production, there is need to have reliable rainy season in each particular year (Dhameja, 2005). Jos South is situated in the tropical climate, with a higher altitude meaning that Plateau State has a near temperate climate with an average temperature between 18 and 22^{0}C, but mean monthly values vary between 19.4^{0}C in the coolest month of December when the area comes under the influence of the cool and dry desiccating north-easterly continental air mass (Harmattan) and 24.5^{0}C in the hottest month (April). The annual average maximum temperature is 28.3^{0}C, annual average low temperature is 16.9^{0}C and the average temperature is 22^{0}C.In the study area, temperatures are everywhere reduced by altitude (Eziashi, 2007). Jos enjoys a more temperate climate than much of the rest of Nigeria. Night-time temperature drops as low as 11^{0}C, resulting in chilly nights. Hail, sometimes falls during the rainy season, owing to the cool high altitude weather.

3. Materials and Methods

Data used in this study was daily rainfall records from 1966-2015 for Jos South Local Government Area of Plateau State, Nigeria which was obtained from the achieves of the Nigerian Meteorological Agency, Oshodi, Lagos.

3.1 Derivation of Precipitation Effectiveness Indices

Onset, cessation and length of the rainy season

Sawa and Adebayo (2011) in their research in Northern Nigeria saw the definition of Onset and Cessation dates and Length of the rainy season as a problematic one due to the intermittent and patchy nature of rainfall in the tropical region. These three terms have been defined in various ways for different purposes.

Various methods abound for the determination of onset and cessation dates and length of the rainy season, for example; Walter, 1967; Ilesanmi, 1972; Kowal and Knabe, 1972; Stern, Dennett and Dale, 1982b; Stern and Coe, 1982; Olaniran, 1984, 1988; Sivakumar, 1988 and Adefolalu, 1993.

Following the unreliable and patchy nature of rainfall in Northern Nigeria, Walter's (1967) method is most accurate (Sawa and Adebayo, 2011). On this premise, this method was employed by the researcher. Here, soil moisture index is related to monthly rainfall using 51mm as the benchmark for soil moisture level necessary for plants germination. Therefore, onset and cessation dates were derived considering months with rainfall greater than or equal to 51mm.

Rainfall amount in months of the growing season

This refers to the recorded daily rainfall (mm) which was added to give the monthly rainfall totals for each of the months of April to October.

Annual rainfall, Long-term mean, Standard deviation and Coefficient of Variation

This refers to the annual records of total rainfall received in a given year. The rainfall data obtained from the meteorological station for fifty years (1966–2015) was added for each of the years beginning from January to December. This gave the total annual rainfall received in Jos South for each of the fifty years (1966-2015). The long-term mean was determined by summing all annual rainfall records and dividing by the number of years. The standard deviation explains the measure of dispersion of rainfall values from the mean while coefficient of variation equals the standard deviation divided by long-tern mean multiplied by 100.

$$\mu = \frac{\sum AR}{Y}$$

where;

μ= Long term mean, AR= Annual Rainfall, Y= Years

Determination of pentad dry spells

The threshold value for a wet day by the World Meteorological Organisation is 0.1mm. A day is considered dry if the amount of rainfall is less than 0.1mm for that day while any day with rainfall amount greater than or equal to 0.1mm is considered wet. The threshold for the Nigerian Meteorological Agency (NIMET) is 1mm.Therefore, the researcher adopted the approach of the Nigerian Meteorological Agency (NIMET). A pentad dry spell occurs when a place experiences five or more consecutive days with rainfall less than 1mm. The daily rainfall observations were used to determine pentad (five day) dry spells of 5, 10 and equal to or longer than 15 consecutive days according to NIMET's standard. Here, the last rainy day in October was coded 21 and the following dry days was coded 1, 2, 3…n into November until the next wet day, which may be in April or May the preceding year. Consecutive wet days was coded 21, 22 …2n so that the daily observations were recorded as sequences of wet and dry days. The runs of pentad dry spells of the specified lengths were therefore, computed directly based on the records of the meteorological station for the 50 years (1966 - 2015). The derived values therefore, formed the data base on which analysis was based.

Statistical Analyses

The derived station year onset, cessation dates and length of the rainy season, the length of growing season, annual rainfall, rainfall amount in the months of growing season, the frequencies of pentad dry spells of the specified lengths were all subjected to time series analysis. The year to year variability in each of these rainfall effectiveness indices were smoothened by the 5-year moving average. Linear trend lines and best fit trend line equations were plotted for each rainfall parameter and presented graphically by means of EXCEL software of the computer.

4. Results and Discussion

Trends in Onset Dates at Jos South LGA

Figure 2.3, clearly indicates an increasing trend line in the onset dates. The best fit line equation is positive (y= 0.034x + 42839). This means decreasing Julian days and implies that rainfall progressively starts early in recent times in the study area. The mean onset date is 15thApril which is early enough for farmers to start pre-sowing activities. Figure 2.3 indicates that in the study area, the rains start early (April 15), such reliable information on onset date is important for local farmers to purchase seeds on time to plant early thereby avoiding the tendency of the risk of crop failure and to ensure adequate and effective food production. It is well established that early planting produces higher yields than late planting. The primary reason to plant early is to avoid environmental stresses that could impedes agricultural production (residual nutrients in the soil) in the study area, as posited by Sawa and Adebayo (2011), that late onset and early cessation could be a threat to food security and sustainable development. Higher crop yields are usually obtained when crop is planted as early as weather conditions permit mainly because of reduced pest and disease pressure late in the season and better rainfall patterns and cooler soil moisture during crop silky. As a result of early planting crops enjoy more moisture stored in the soil for germination.

Crops pollinating in late May and June will have better moisture index in most years than crops flowering in July and August. The effect of planting late could lead to increased pest and disease pressure during key growth stage especially in maize, irish potatoes, yam, cassava, cocoyam, soya bean and rice. This could also lead to less time for crops to dry down before harvest.

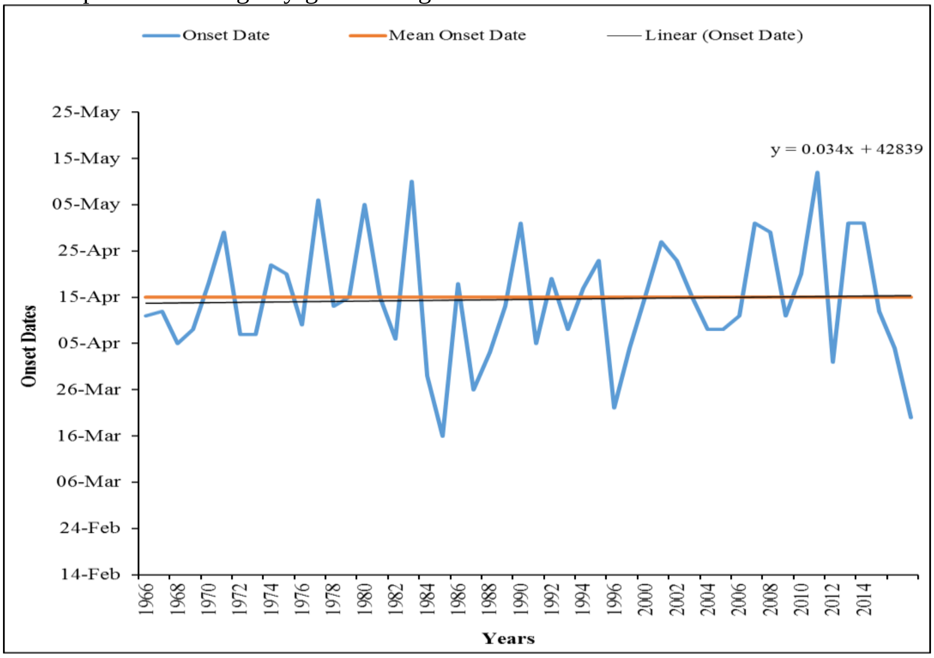

Figure 2.3: Trends in Onset dates of Rainfall in Jos South LGA, Plateau State (1966-2015)
Source: Author's Analysis (2017)

Trends in Cessation Dates at Jos South LGA

In Figure 2.4, the cessation dates of rainfall are characterized by marked 'noise' (variability) from year to year. The mean cessation date is 25th September. The graph clearly indicates an increasing trend in cessation dates as the trend line equation (y = 0.7354x + 42984) is positive. This means that rainfall cessation date comes relatively later than usual, that is, there is a slight delay in rainfall cessation date. This is also good news to farmers in the study area as crops may have adequate moisture for later stage development and more time for crops to dry down before harvest, and since the early onset in the study area is experienced before the period of late cessation, crops enjoy more moisture stored in the soil for germination. This encourages adequate crop production due to available soil moisture as a result of long duration of rainy season, this also agreed with Sawa, Adebayo and Bwala (2014), that late onset and early cessation shorten the duration of hydrological growing season which poses a great threat to surface and underground water resources management and agriculture and sustainable food security as well as biodiversity in Kano and Nigeria at large.

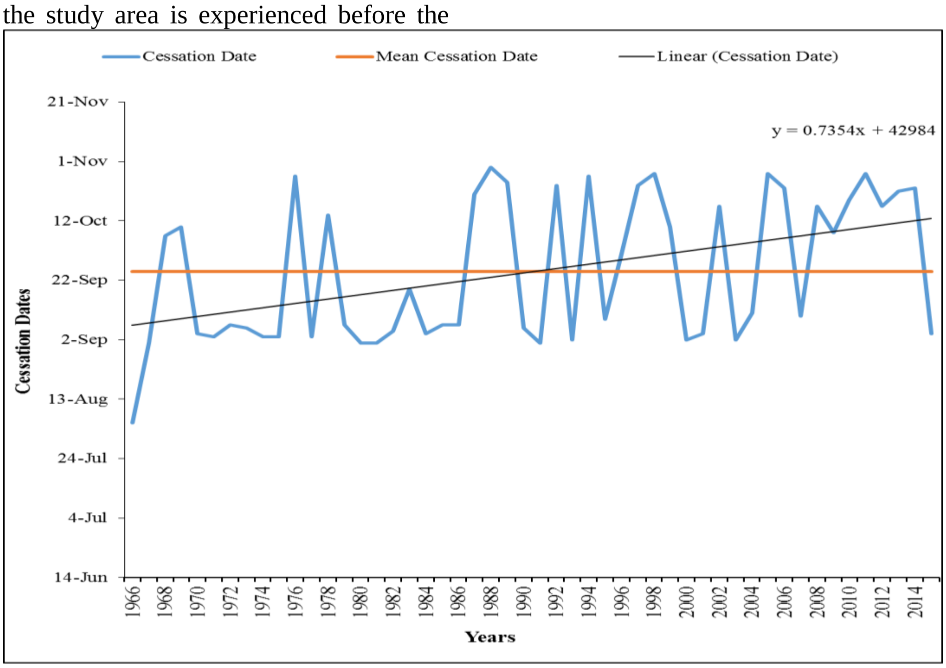

Figure 2.4: Trends in Cessation dates of Rainfall in Jos South LGA, Plateau State (1966-2015)
Source: Author's Analysis (2017)

Trends in Length of Rainy Season (LRS)

Figure 2.5 shows a positive trend line equation of y= 0.7644x+143.29, which indicates an increasing Length of Rainy Season. The mean length of rainy season was 163 days or about $5^{1/}{}_{2}$ months. However, this confirms to the marked yearly 'noises' on the trend line. For instance, in the year 1966, the LRS was as low as 116 days before shooting to a peak of 210 days in 1988 followed by 209 days in 1987 and dropping to 168 days in the year 2015 but still slightly above normal. The increasing length of rainy season is owing to the fact that the mean onset date is early (15^{th} April) in recent times compared to earlier years while the mean cessation date is late (September 25^{th}). Hence, the early onset dates and late cessation dates imply longer length of rainy season. Agriculturalists will find this very interesting because of long duration of rainfall, of about seven months, encourage available moisture stored in the soil for germination, growth and utilization by crops and long maturing crop varieties will thrive better in such environment.

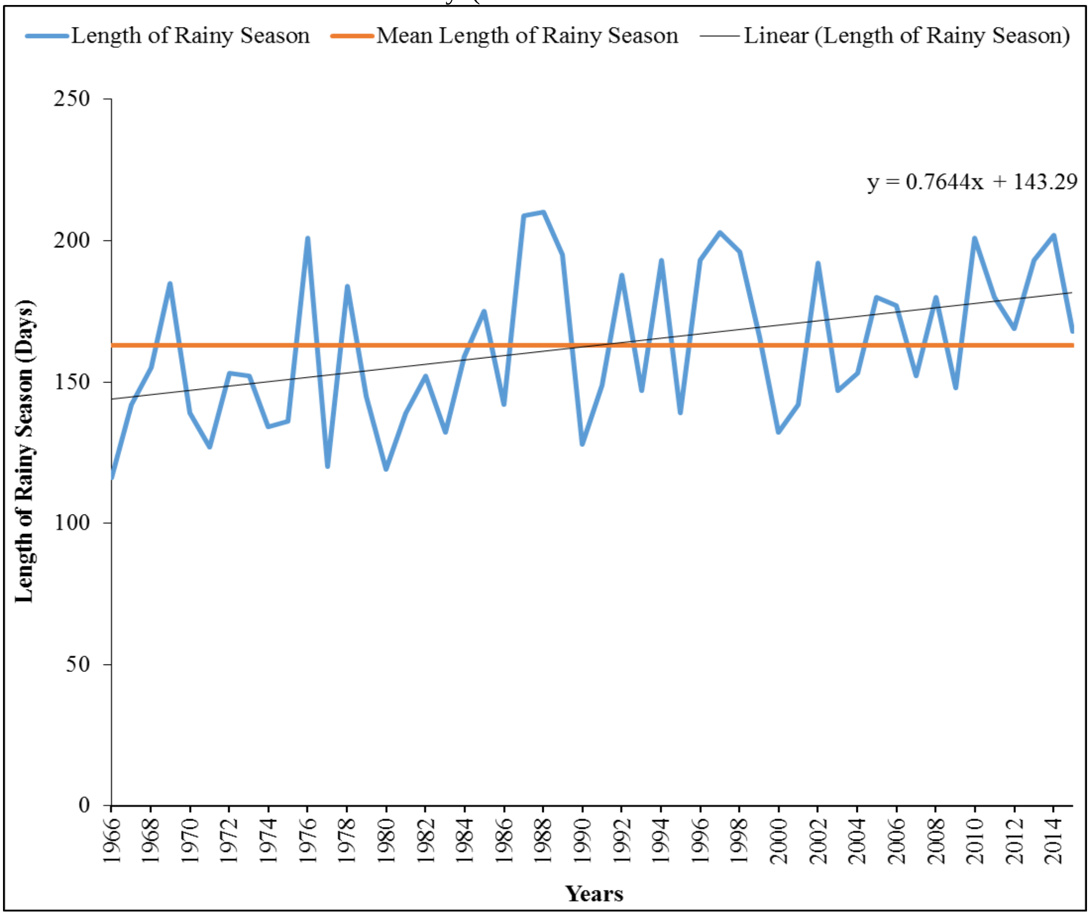

Figure 2.5: Trends in Length of Rainy Season in Jos South LGA, Plateau State (1966-2015)
Source: Author's Analysis (2017)

Trends in Annual Rainfall at Jos South LGA

Figure 2.6 showed annual rainfall amounts significantly above normal (long-term mean) from the late 1960s until 1980 (1216.4) when it declined below normal and fluctuated until 2002 to 2006 when an insignificant rise above the mean was experienced. Another partial rise occurred in 2010 and 2011. After that, annual rainfall has been below normal. Figure 4.4, reveals that from the mid-1960s to the early 1980s, annual rainfall amounts were appreciably above the long-term mean. However, from the mid-1980s to the early millennium, precipitation changes were experienced giving place for mild drought periods to set in. These fluctuations showed evidence of change in precipitation caused by climate change. The Long term mean was 1266.54mm while the linear equation for the annual rainfall is y = -2.820x + 2338, showing a negative trend line which signifies a below normal scenario.

Despite the early onset, late cessation and longer length of rainy season, yet annual rainfall in the study area is still decreasing according to Figure 2.6, this could be manifestations of the impact of the current global climate change which is a reality in the study area. This implies an evidence of climate change which will affect productivity in terms of quantity and quality of crops in the study area. This agrees with Sale (1973), Susnochi and Meir (1978), Zaag and Burton (1978), Wolfe, Fereres and Voss (1983), Cooper *et al* (2008), Sawa and Adebayo (2012), who stated that climate change adversely affect precipitation amount, its intensity and duration which in turn poses a great threat to sustainable agriculture and food security. The physiological processes such as leaf diffusion resistance, photosynthetic efficiency and partitioning of assimilation of plants are adversely affected as water deficit increases, thereby negatively influencing the development and yield of crops in the study area.

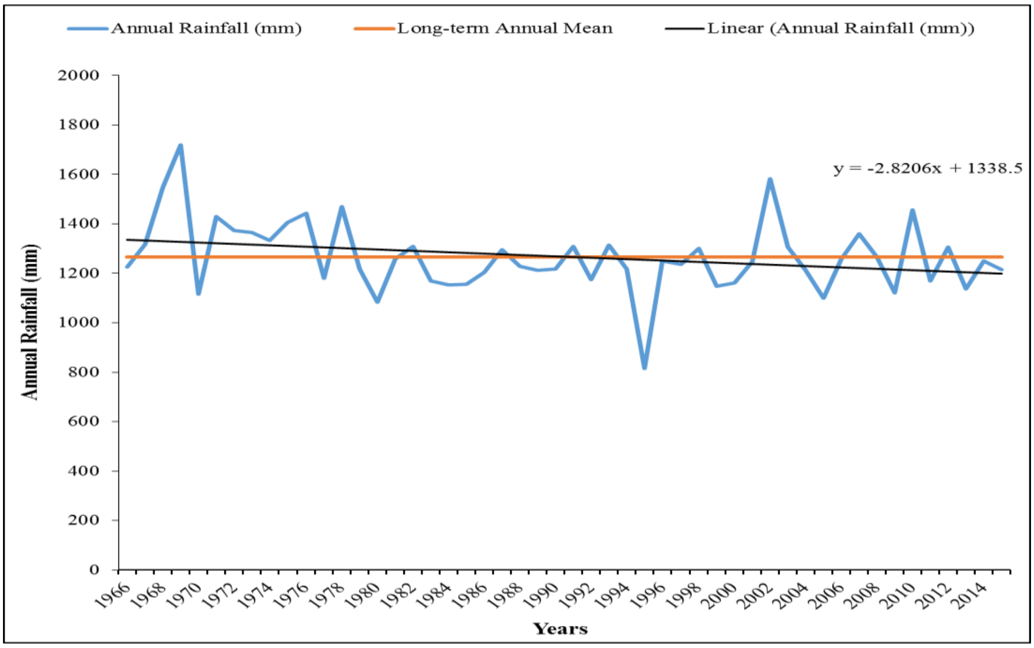

Figure 2.6: Trends in Annual Rainfall in Jos South LGA, Plateau State (1966-2015)

Source: Author's Analysis (2017)

Trends in Rainfall of Months of Growing Season

Figure 2.7 shows a declining trend in growing season rainfall where trend line equation; y= -2.5499x + 1311 indicating it is a negative trend. With the mean as 1246.1 mm, the rainfall was above normal at the beginning of the period until ten years (1966-1975) when a decline was experienced below the mean, which lasted until the early millennium when trends became normal and slightly higher than normal until the end of the period. This trend implies that droughts were gradually setting in the study area and this could cause low yield in most crops whose lifespan takes longer months to develop except for drought resistant crops. This could lead to general reductions in agricultural productivity in the study area as posited by Odofin (2003) which linked up reduced crop productivity to farmers as a result of fluctuation in moisture pattern and water availability. Similarly, the IPCC, (2001) reports concluded that most tropical and subtropical regions would be hardest hit with reductions in crop yields due to decrease in water availability, soil moisture and shortening growing periods. All these underscored the importance of precipitation as critical factor controlling crop yield in the study area. In spite of the decreasing annual amount as indicated in the Figure 4.5, yet rains are starting early and end late in the study area. This is mainly an evidence of climate change as posited by the IPCC, (2007), which states that as climate varies or changes, several direct influences alter the amount of precipitation, its intensity, frequency and duration which in turn makes improved agricultural productivity difficult because of deficit of water availability, a new or changed insect, pest and disease incidence

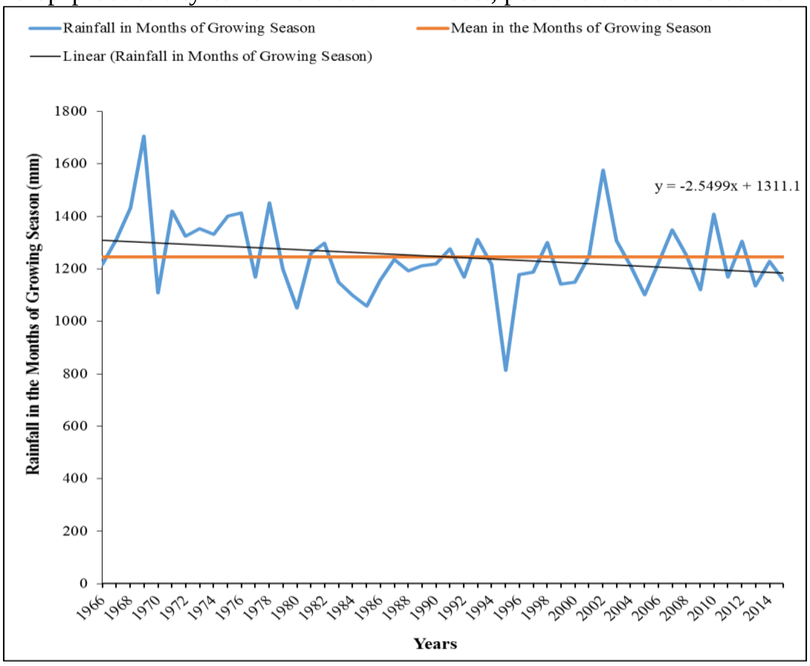

Figure 2.7: Trends in Rainfall in the Month of Growing Season in Jos South LGA, Plateau State (1966-2015)

Source: Author's Analysis (2017)

Trend in Dry Spells of 5 Consecutive Days

The frequency of occurrence of dry spells of 5 days in study area is presented in Figure 2.8

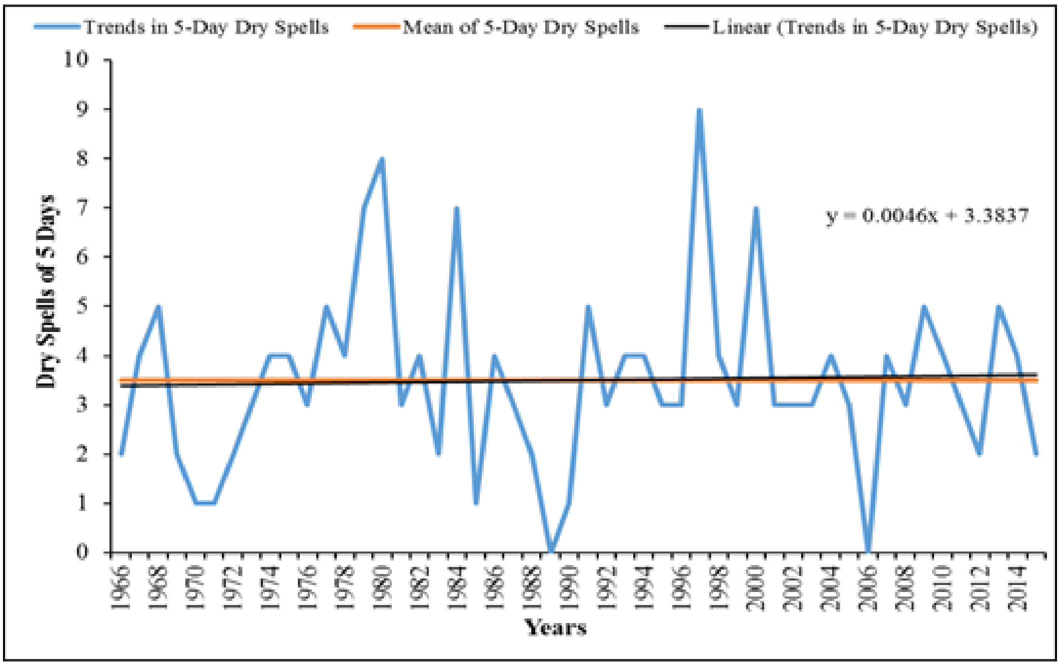

Figure 2.8: Trends in Dry Spells of 5 Consecutive days in Jos South LGA, Plateau State (1966-2015)
Source: Author's Analysis (2017)

In Figure 2.8, dry spells of 5 consecutive days are the most common than dry spells of 10 and ≥15 consecutive days. The mean value of 5- day dry spell is 3.5. It is interesting to note from this figure that the frequency of occurrence of dry spell of 5 days in the study area is gently increasing. The best fit line equation is positive (y= 0.0046x+3.3837) implying an increasing trend in its occurrence which has an average occurrence of more than 3 times every growing season. The year 1997 has the highest incidence of 5-day dry spells occurring nine times as against 1980 occurring eight times. Increasing frequency of dry spell of 5 days is diminutive to agriculture as it means more reduction of moisture in the soil for plant growth and utilization, which as a result reduce crop yield and make peasant farmers very worried. According to Sawa and Adebayo (2011), that frequent occurrence of dry spell of 5 days could cause a great threat to food security and sustainable agriculture. Nonetheless, there were no incidences of 5-day dry spells in two years (1989 and 2006).

Trends in Dry Spells of 10 Consecutive Days

From this figure 2.9, it is seen that the average occurrence of dry spells of 10 days in the study area is about 1 every growing season. The trend line shows a negative best fit line equation (y= -0.0161x+1.3902). The pattern of occurrence of dry spells of 10 days in the study area shows a decreasing trend meaning its frequency is declining as indicated in Figure 4.8. The year, 1973 had the highest incident peak of four times. Two years (1970 and 1985) recorded its occurrence thrice each, seven years (1966, 1968, 1971, 1976, 1986, 2002 and 2011) recorded its occurrence twice each while 15 years had no record of two consecutive pentads dry spells (1967, 1969, 1975, 1977, 1980, 1983, 1990, 1995, 1997, 1998, 2000, 2006, 2007, 2010 and 2013). Other years witnessed it only once each. This is good to the farmers because incidences of prolonged dry spells which leads to droughts are diminishing in the study area as posited by Ati (2006), that false start of rainy season, characterized by isolated showers and uncertain intensity with rainless periods of varying duration which last up to two weeks or more, dries out soil moisture necessary for plant germination, and leads to repeated and late planting resulting in crop failure or preclude optimal crop yield.

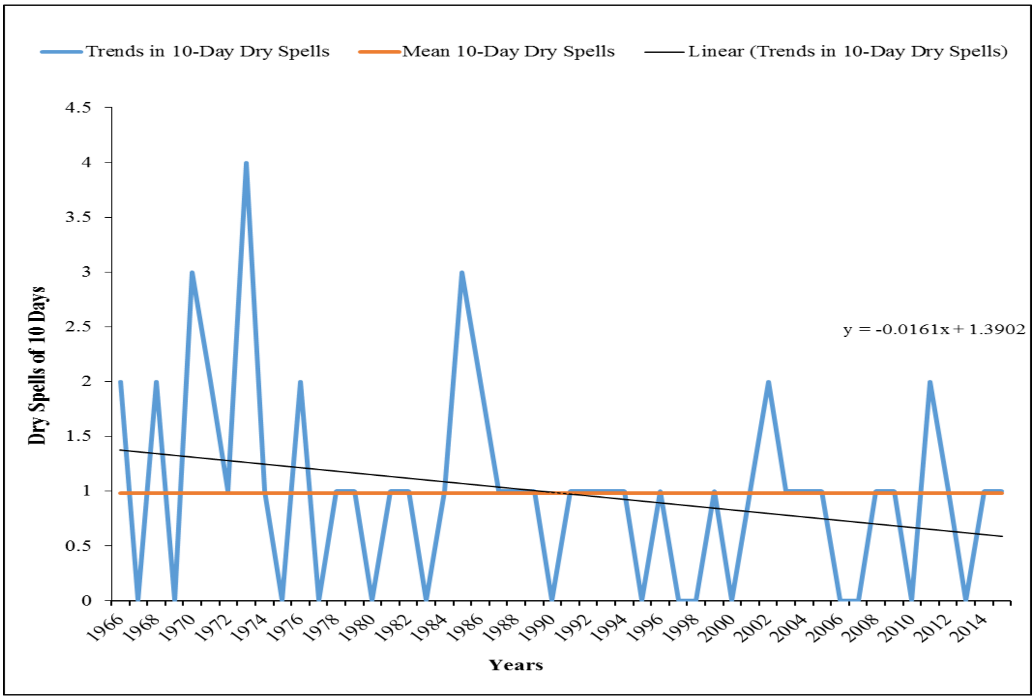

Figure 2.9: Trends in Dry Spells of 10 Consecutive days in Jos South LGA, Plateau State (1966-2015)
Source: Author's Analysis (2017)

Trends in Dry Spells of ≥15 Consecutive Days

Figure 2.10 reveals that the dry spell incidents of ≥15 consecutive days was recorded only eight times in 1972; five times in 1975; four times in 1986, 1997 and 2006 and three times during the period under review in 1978, 1996, 2007, 2011 and 2015. There was no record of dry spell incidents of ≥15 consecutive days in 16 years under the period of 1966, 1969, 1973, 1974, 1981, 1985, 1989, 1990, 1994, 1995, 1998, 2001, 2005, 2008, 2009 and 2012. Other years witnessed it only twice and once. It had an average occurrence between one and two times every growing season. Here, the trend line equation is negative (y= -0.004x+1.566). The trend line graph dropped below normal between 1966 and 1970 but rose above the mean in 2015. This implies that the fluctuating and unreliable ≥15days dry spell pattern has great implication in an agro-based economy resulting to longer periods of drought within three dry spell pentad days. A higher frequency of dry spells of this length has a negative impact on crop yield and food security in the study area. This is because dry spells longer than 15days cause drought consequently if it is prolonged, crops may wilt and may completely dry leading to complete failure. Both surface and underground water become diminished and scarce. This agreed with Adebayo and Onu (2012) in Adamawa State, that frequent and prolonged dry spells leads to reduced crop yield. However, it is imperative to farmers to engage in soil conservation methods and drought resistant crop planting in the study area.

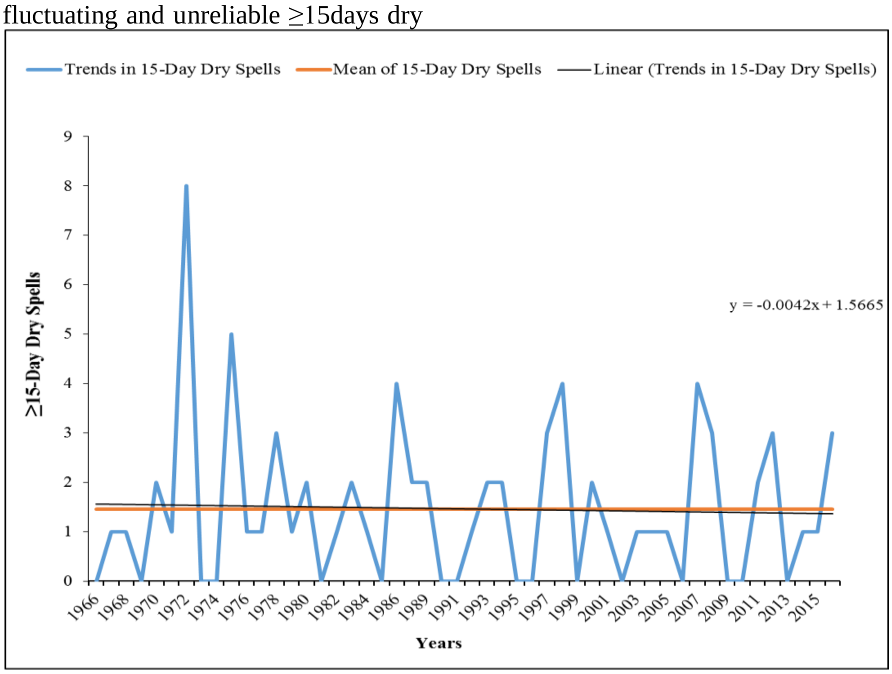

Figure 2.10: Trends in Dry Spells of ≥15 Consecutive days in Jos South LGA, Plateau State (1966-2015)
Source: Author's Analysis (2017)

Implications of the Findings for Agriculture and Food Security in Jos South

The implications of the findings of this research are obvious. It is evident even though rain start early and cessation end late, there is an increased frequency of dry spells of 5days, decreased total annual rainfall, number of rainy days and months of hydrological growing season, all these are evidences of climate change gradually occurring in the study area, which in turn could pose a great threat to sustainable agriculture. Graze lands for nomads will no longer be adequate so pastoralists will have to encroach into farmlands. This will lead to constant clashes between farmers and Fulani men. Secondly, both surface and subsurface water are threatened in this region. All these portray and validate climate change in Jos South Local Government of Area of Plateau State, Nigeria.

5. Conclusion and Recommendations

The major source of water available either for agricultural or human consumption is precipitation. This is the reality in the study area where the ultimate productivity of crops under natural conditions are determined by the amount, distribution and variability of rainfall. Rainfall distribution and variability occurs as a result of climate changes and these changes will impact on agriculture in Jos South LGA. The Precipitation effectiveness indices analysed showed that there is an indication that there are earlier onset of rainfall and late cessation in the study area. Result also showed an increased frequency of dry spells of 5days, decreased total annual rainfall, number of rainy days and months of hydrological growing season, all these are evidences of climate change gradually occurring in the study area, which in turn could pose a great threat to sustainable agriculture. The results of this study showed that the trend of these precipitation effectiveness indices are characterized by marked "noises" and variability. Onset dates, cessation dates, length of rainy season, dry spells of 5, 10 and ≥15 consecutive days are characterized by inter-annual variability for example, onset ranges from 12th May in 2009 to 16th March in1985, showing a marked distinction of more than two months between these dates. For cessation dates, it fluctuates from August 5th in 1966 to October 30th in 1988. Similarly, for LRS it ranges from 116 days in 1966 to 210 days in 1988. The mean onset date is April 15th (early onset) while mean cessation date is 25th September (late cessation). Consequently, the early onset and late cessation showed a longer length of rainy season in the study area. The long term mean rainfall was 1266.54 mm. Maximum rainfall occurred in 1969 (1720.3 mm) while the minimum was 814 mm in 1995. Annual range of rainfall was 906.3 mm. There were more incidences of single pentad dry spells occurring all through the period compared to 10 and ≥ 15 consecutive dry spell days. For 5days dry spell, it has the highest incidence of dry spells occurring nine times in 1997 and none in the years 1989 and 2006. For 10days dry spell, its highest level of occurrence is four times in 1973 while most of the years had none. For 15 consecutive days, its highest level of occurrence is eight times in 1972, most years had twice and once, and other years had none. For the number of rainy days, the highest was recorded in 1969, followed by 1978 and 2010 while the least rainy days occurred in 1987.

This study therefore acknowledges that the changes in precipitation effectiveness indices is as a result of the effect of climate change which indeed is a reality in the study area and with time, its effects, if not properly managed by employing effective adaptation strategies, would be felt severely on water resources, agriculture and other living conditions and occupation of the populace in the area. Based on the findings of this research, the following recommendations are proposed:

1) Since the characteristics of onset dates and cessation dates, length of rainy season, total annual rainfall, hydrological growing season, anomalous years and dry spells of 5, 10 and ≥15 consecutive days are inconsistent and variable in the study area, it is therefore, recommended that land preparation and planting of crops can be done from 15th of April, which is the established mean onset date of rainy season in the study area. This is to allow the crop that do not require amount of rainfall to mature early enough to avert the danger of incidence of pest and disease and high rainfall which characterized the month of August. This is because this high rainfall is unhealthy to the tuberous of the crops depending upon the crops e.g. long maturing rice variety like WITA 4, SIPPI, FARO 140
2) Since there is a high incidence of dry spells of 5 consecutive days in the study area, farmers should introduce other crops and seed varieties of high yield that can tolerate short dry spells in order to boost crop production in the study area. Examples of such crops include Irish Potato (Solanum Tuberosum), maize (Zea mays) and cowpea.
3) More weather stations should be established in areas where none existed so as to facilitate generating climatic data all over the area to provide information for long term planning and development of agriculture generally in the study area. Research works need to be conducted in other areas like cultural practices on the farm, soil factors so as to understand the contribution of each of these factors

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Appendix I: Pentad Calendar Table

January		Feb		March		April	
Pentad No.	Dates	Pentad No.	Dates	Pentad No.	Dates	Pentad No.	Dates
1	1^{st} -5^{th}	7	1^{st} -5^{th}	13	1^{st} -5^{th}	19	1^{st} -5^{th}
2	6^{th} -10^{th}	8	6^{th} -10^{th}	14	6^{th} -10^{th}	20	6^{th} -10^{th}
3	11^{th} -15^{th}	9	11^{th} -15^{th}	15	11^{th} -15^{th}	21	11^{th} -15^{th}
4	16^{th} -20^{th}	10	16^{th} -20^{th}	16	16^{th} -20^{th}	22	16^{th} -20^{th}
5	21^{st} -25^{th}	11	21^{st} -25^{th}	17	21^{st} -25^{th}	23	21^{st} -25^{th}
6	26^{th}-31^{st}	12	26^{th} -28^{th}/ 29^{th}	18	26^{th} -31^{st}	24	26^{th} -30^{th}
May		June		July		August	
Pentad No.	Dates	Pentad No.	Dates	Pentad No.	Dates	Pentad No.	Dates
25	1^{st} -5^{th}	31	1^{st} -5^{th}	37	1^{st} -5^{th}	43	1^{st} -5^{th}
26	6^{th} -10^{th}	32	6^{th} -10^{th}	38	6^{th} -10^{th}	44.	6^{th} -10^{th}
27	11^{th} -15^{th}	33	11^{th} -15^{th}	39	11^{th} -15^{th}	45	11^{th} -15^{th}
28	16^{th} -20^{th}	34	16^{th} -20^{th}	40	16^{th} -20^{th}	46	16^{th} -20^{th}
29	21^{st} -25^{th}	35	21^{st} -25^{th}	41	21^{st} -25^{th}	47	21^{st} -25^{th}
30	26^{th}-31^{st}	36	26^{th} -30^{th}	42	26^{th} -31^{st}	48	26^{th} -31^{st}
September		October		November		December	
Pentad No.	Dales	Pentad No.	Dates	Pentad No.	Dates	Pentad No.	Dales
49	1^{st} -5^{th}	55	1^{st} -5^{th}	61	1^{st} -5^{th}	67	1^{st} -5^{th}
50	6^{th} -10^{th}	56	6^{th} -10^{th}	62	6^{th} -10^{th}	68	6^{th} -10^{th}
51	11^{th} -15^{th}	57	11^{th} -15^{th}	63	11^{th} -15^{th}	69	11^{th} -15^{th}
52	16^{th} -20^{th}	58	16^{th} -20^{th}	64	16^{th} -20^{th}	70	16^{th} -20^{th}
53	21^{st} -25^{th}	59	21^{st} -25^{th}	65	21^{st} -25^{th}	71	21^{st} -25^{th}
54	26^{th}-30^{st}	60	26^{th} -31^{st}	66	26^{th} -30^{th}	72	26^{th} -31^{st}