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Analysis of Agro-climatic condition in Taraba State and the Implication for Agricultural Development

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Abstract

The aim of this research is to examine the temporal and spatial pattern of the climatic variables (1979-2017) of Taraba State and it implication for Agricultural planning. The variables were analyzed over time and Space using trend and spatial analysis tools in excel and Arc GIS respectively. Result of the trend and spatial pattern of the climatic elements in the study area revealed that, the moisture indices which include; Mean annual rainfall, Onset date of rain, Cessation date of rain and Hydrological Ratio showed a significant positive slope trend at p=0.027, 0.047, 0.005, and 0.021 for the parameters respectively while, Relative Humidity showed a significant negative slope trend at p=0.037. Heat parameters such as Mean annual temperature, Maximum temperature and Solar Radiation on the other hand showed a significant positive slope trend at p<0.01. In terms of spatial pattern of the moisture indices, the indices in the study area showed a similar spatial pattern in which their values decrease as Latitude increases but increases with increases in Altitude. Unlike the moisture parameters, heat parameters on the other hand increase with decrease in Altitude. Result of the implication of the moisture indices revealed that, the duration of rainy season is decreasing and that will not support the growth and yield of longer mature crop. In addition, result on the heat parameters suggested that, temperature record in the study area is increasing annually which can lead to negative impact on crop growth and yield while the negative trend of wind speed signified that, the rate of carbon dioxide intake by plant will be optimized since low wind speed increase turbulence in canopy and replenish the carbon dioxide supply to plant. Result on the spatial pattern of the moisture parameters explained, that Altitude and movements of maritime air mass are the major factor determining the spatial distribution of the indices as such, crops with high moisture requirements will grow well in the southern part of the state compared to the Northern part of the State.

Key Words: Agro-climatic, Taraba State, Implication and Agricultural Development

Introduction

In Nigeria, Agriculture as one of the major activities of the people, provide employment for about 60 - 70% of Nigerians (Mayong *et al.*, 2005). The sector plays a very important role in economy of the nation by generating 22.21 percent to the country Gross Domestic Product (GDP) and serves as source of raw materials used in the processing industries and mean of livelihood to over half of the growing population (Ademola, 2020; Mohammed-Lawal & Atte 2006). However, in spite of all these positive contribution, the sector is being affected by many challenges among which are climate (Odo, 2014; Nchuchuwe and Adejuwon 2012). Climate is one of the major factors affecting agricultural activities, it plays a very significant role in crop production; from land preparations, selection of crops, crop growing, harvesting, storage, transportation and marketing of the product (Adebayo, 2010; Eregha., Babatolu & Akinnubi, 2014: Ayoade 2005). For example, it was documented that, the amount and distribution of Precipitation, solar radiation, wind speed, temperature, relative humidity and other climatic parameters affect and solely influence the global distribution of crops, it productivity and hence farmers' profit (Ayoade, 2005; Stigter, 2004). Similarly, the amount of Sunlight, temperature, moisture and carbon dioxide (CO_2) determines seed germination, the time emergence of plant, the rate of growth of roots, stems, and leaves and flower development. They also determine when plant produces flowers, and consequently the filling of grain or the expansion of fruits (David & Mark 2007).

In Taraba State, evidences were observed on how climate affect crop production. For example, recent study by Angela and Fidelis (2013) revealed that, rice farmers in the state are facing serious climatic challenges which include stunted rice growth, wide spread of pest and diseases, difficulties in predicting rice planting period, drying and withering of rice seedlings, delayed rainfall and too much heat which evaporates water from rice plant. In the same vein, Jifin (2017) reported that, climate affect agricultural production in the state in many aspects of farming activities which includes; change in agricultural pattern, pests and disease attack on crops, crop failure and poor harvest. Following the role of climate on agriculture, there is therefore a need to examine the trend and spatial distribution of the climatic parameters and then state it implications for agricultural planning in the State.

Taraba State was carved out of the former Gongola State on 27th August 1991 by the then regime of General Ibrahim Babangida. The State is one of the Nigerian thirty-six (36) state which is located in North-Eastern part of the country and has a coordinate of latitude 6°30' and 8°30' North of equator and longitude 9°00' and 12° 00' East of the Greenwich meridian (Figure 1).

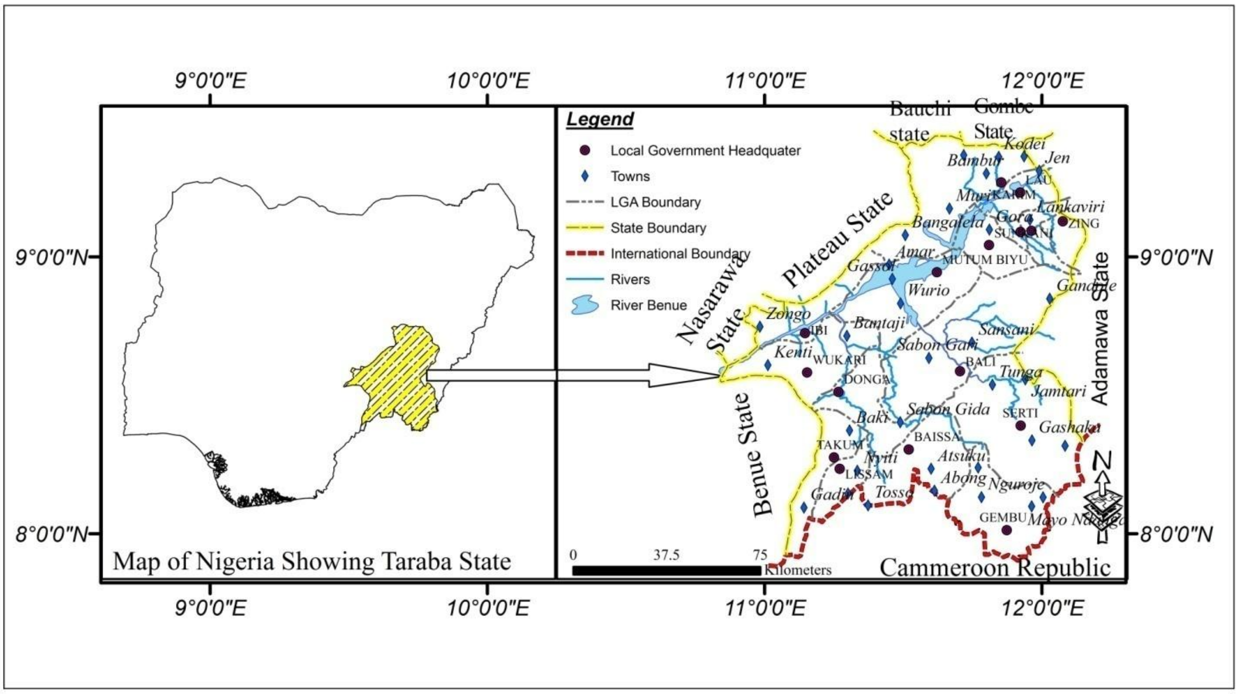

Figure 1: The study area

The area is made up of high plains which covered those parts of the Benue low lands lying above flood level but below 1000 ft contour line and include places around Karim Lamido, Jalingo, Sunkani and some part of Wukari while the high highlands are erosional in nature and are cut in sedimentary formations. River Benue is the major river in the state (Adebayo and Umar, 1999) while River Donga and Taraba are the other dominant river systems which flow across the Muri plains to drain the entire State together with the minor ones, such as the Lamorde and Mayo Ranewo (TYPA, 2009).

Climate of the State is mainly influenced by the rain-bearing south-west air mass and the dry dusty north-east trades or harmattan. Rainy season in Mambilla Plateau lasts from February to November with a mean annual rainfall of about 1850mm, while at the other part of the state lasted from April to October with mean annual rainfall varying between 1058mm around Jalingo and Zing, to about 1300mm around Serti and Takum (Emeka and Abbas, 2011). Temperature during rainy season in Mambilla drops to as low as 15°C while the mean annual temperature around Jalingo is about 28°C with maximum temperature varying between 30°C and 39.4°C and minimum temperatures range between 15°C to 23°C (Emeka and Abbas, 2011).

Alluvial soil type are found on the flooded plains of rivers they run along Benue River and other rivers, and do not depend highly on climate and vegetation for their formation but their underlying parent rock is the most important factor in their formation (Iloeje, 2001). Sudan Savanna, Northern Guinea Savanna, Southern Guinea Savanna, Forest derive savanna and mountain forest and grassland are the major vegetation types in the State (Ekaete, 2017). Sudan Savanna covered places around Karim Lamido, Lau, Jalingo, Ardo Kola, Yorro and Zing LGA, while Northern and southern Guinea savanna covers the major part of the State and include LGAs such as Gassol, Ibi, Wukari, Donga, Bali, Takum, Ussa, Kurmi and Gashaka LGA. Mountain forest on the other hand are found in the higher altitude of the state around Gembu.

Materials and Methods

Annual rainfall, monthly rainfall, dry spell, onset date of rain, cessation date of rain, Length of Rainy Season (LRS), seasonality index and hydrological ratio were extracted from the daily, monthly and annual rainfall for a period of 38 years (1979 to 2017) while, monthly and annual minimum temperature, maximum temperature, mean temperature, relative humidity, solar radiation and wind speed for the period 1979 to 2015 which is the longest period for which records of the variables are available in the State were obtained from Upper Benue River Basin Development Authority (UBRBDA), Taraba State Agricultural Development Program (TADP) (Area, Zonal and Head office) in the State, Taraba State University Jalingo, Federal Polytechnic Bali and Nigerian Meteorology (NIMET) Ibi. Climate Forecast System Reanalysis (CFSR) is another daily and monthly climatic data source which was downloaded from globalweather.tamu.edu website. Mean spatial climatic map of monthly rainfall, minimum temperature, maximum temperature, solar radiation and wind speed were also used in this study. Maps of these variables were downloaded from worldCli-Global Climate data version 2 (www.worldclim.org) produce by Fick and Hijmans (2017).

In order to examine the temporal and spatial pattern of the agro-climatic variables of the study area, precipitation effectiveness indices (onset, cessation, length of rainy season, dry spell, seasonality index, hydrological ratio and mean rainfall amount in different months within the rainy season) as well as minimum temperature, maximum temperature, solar radiation, relative humidity and wind speed were computed from daily, monthly and annual Climatic data. All the climatic indices were analyzed using regional method were trend graph and spatial analysis tools in Excel and ArcGIS were used respectively. Trend graph in excel was used to examine the trend pattern of the climatic variables over time while, kriging interpolation in spatial analysis tool of Arc GIS 10.2 was used to produce the spatial map of the climatic variables in other to show the spatial distribution of the indices. This spatial and trend method of analyzing climatic variables were tested to be the reliable method of studying variation of climatic variables over time and space (Abu et al 2013; Sawa and Adebayo, 2011; Zakaria et al, 2014).

Onset, Cessation and Length of Rainy Season

Onset is the period in which a place receives an accumulated amount of rainfall that is sufficient for growing crops. Onset is not the first day rain falls but the period at which the soil moisture is sufficient for establishment of crop while Cessation is the termination of the effective rainy season (Adebayo, 2000). Length of rainy Season (LRS) on the other hand is the total number of rainy days between the onset and cessation date. Given the nature and characteristics of rainfall in Northern Nigeria, Walter's (1967) method is said to be most accurate (Sawa and Adebayo, 2011). In regards to this, Walters (1967) and Olaniran (1988) methods were use in this research. According to the two methods, soil moisture level required for plants germination is ≥ 51mm and a month with rainfall of such amount was used. However, in a situation where rainfall amount of a month immediately after the onset is less than 51mm, the subsequent month with greater than 51mm will be consider as onset month (Olaniran, 1988). In computing the indices, onset date of Rain starts from beginning of the year (January) while Cessation date of rain start from the end of the year (December). Below are the equations;

$$\text{Onset} = \frac{x_n(51-\sum x_r)}{y} \qquad (1)$$

$$\text{Cessation} = \frac{x_n(51-\sum x_r)}{y} \qquad (2)$$

Where;

x_n = Number of days in the first month whose rainfall is ≥ 51 (For onset date of rain)

$\sum x_r$ = Rainfall total of the previous month y = Total rainfall of the first month with rainfall ≥ 51mm.

Dry-spell

Dry-spell is a period in which there is a break in rainfall during the rainy seasons. It is not expected that precipitation will occur every day in rainy season, the break that will occur in rainfall is therefore known as dry-spell. Precipitation of less than 2mm are refers to as trace because the amounts have no significance for agriculture since most of these small amounts will evaporate before infiltrating the soil (Adebayo, 2000). In respect to this, period of consecutive rain fall of less than 2mm for five to ten days during the rainy season was considered to be dry spell as also observed by Sawa and Adebayo, (2011).

Seasonality Index

Seasonality Index is the sum of absolute deviation of mean monthly rainfall from the overall monthly mean divided by the mean annual rainfall. It measures the spread and steadiness of rainfall during the wet season (Adebayo, 2000). In this study, monthly and annual rainfall of all the selected meteorological stations was used for the analysis.

According to the method of Walsh and Lawler (1981), the seasonality Index was computed as follows:

$$SI = 1/R\sum\left|Xn - \frac{R}{12}\right| \qquad (3)$$

SI = Seasonality Index (Absolute value), Xn = Mean Rainfall of month n and R = Mean annual Rainfall

The method was used to derive the spread of the rainy season in the area: The higher the SI values, the shorter the spread of the rainy season, implying the drier the place, and vice versa.

Hydrological Ratio

Hydrological Ratio is the ratio between mean annual rainfall and potential evaporation of a place. The value shows the level of wetness or dryness of a place. The index helps in decision making in agriculture because it provides a guide on the best choice of an area where a particular type of crop will not only thrive but will equally have high yield or reach optimum growth level (Adebayo, 2000). The ratio is measured as:

Hydrological Ratio = precipitation (P) / potential evapotranspiration (PE)

Results and Discussion

Trend of the Agro-climatic Elements

Figures 2 and 3 showed the trend pattern of Mean Annual rainfall, the Onset date of rainfall and Cessation date of rainfall in the study area, and the results revealed a significant positive slope trend at $p<0.05$, $p<0.05$ and $p<0.01$ respectively for the three parameters. The positive slope of all these parameters showed that the study area is experiencing annual increase in the amount of the selected climatic variables of annual rainfall. In addition, the increase pattern of the Onset date of rain revealed that the date is increasing toward December thereby reducing the LRS. This slope pattern of the onset date of rainfall clearly signifies that the parameter has an inverse relationship with LRS which can be seen in trend graph (Figure 3) where the index showed a negative slope line of 0.0167 which mean that, as onset date of rainfall increases, the LRS decreases. Another parameter that showed an inverse relationship with LRS and revealed a clear evidence of a decrease in LRS is 5-days dry spell (Figure 4). The 5-days dry spell in the study area is another precipitation index which also revealed a positive trend of 0.001. This inverse trend pattern between 5-days dry spell and LRS clearly explained that, as the number of 5-days without rain increases, the LRS decreases following the fact that, the number of rain days in rainy season determines the LRS. Hydrological Ratio (Figure 4) as one of the moisture parameter that measure the rate of dryness and wetness condition in an area also showed a significant positive slope trend of 0.0025 at $p<0.05$ while seasonality index (Figure 5) showed a non-significant positive trend. Relative humidity (Figure 5) on the other hand showed a significant negative trend at $p<0.05$.

Heat parameters which include Solar Radiation, Mean and Maximum temperature were also analyzed and presented in figure 6 and 7. The parameters showed a significant positive slope trend of 0.0272, 0.045 and 0.011 at $p<0.01$ respectively, while Minimum temperature (figure 7) showed a not significant positive trend of 0.0279. The positive trend of the variables showed that they increase with the increase in time and a unit increase in time lead to an increase of 0.0272, 0.045, 0.011 and 0.0279 in the Parameters respectively.

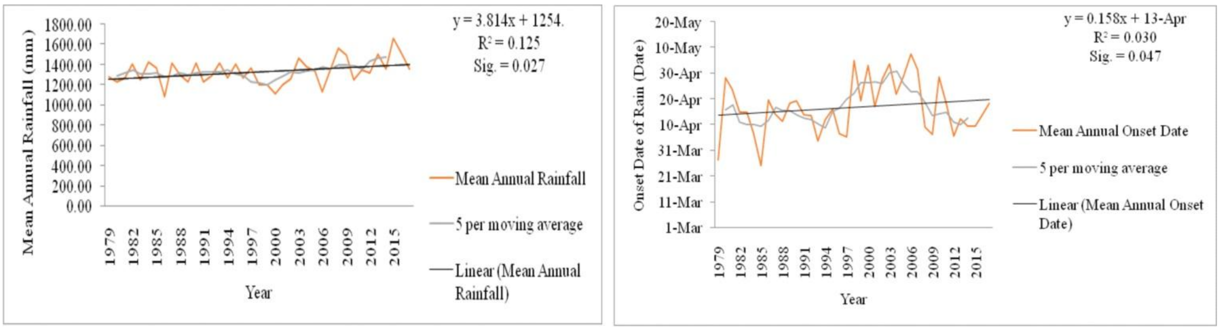

Figure 2: Mean Annual Rainfall and Onset Date of Rainfall trend

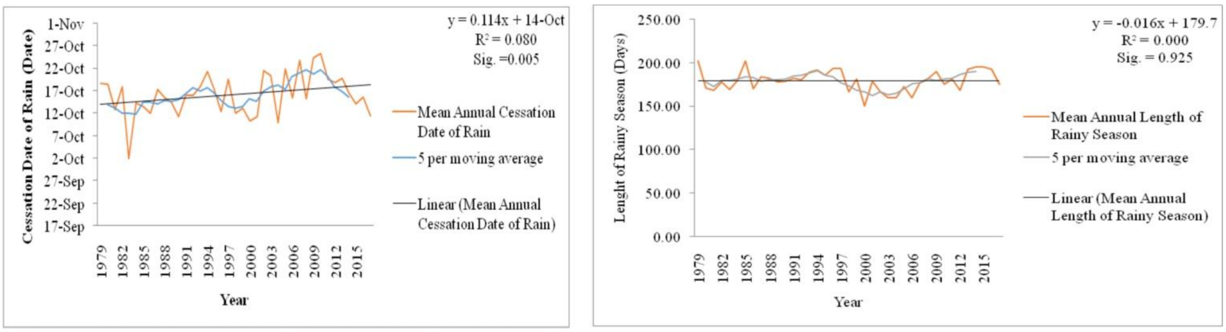

Figure 3: Mean Annual Cessation Date of Rain and Length of Rainy Season trend

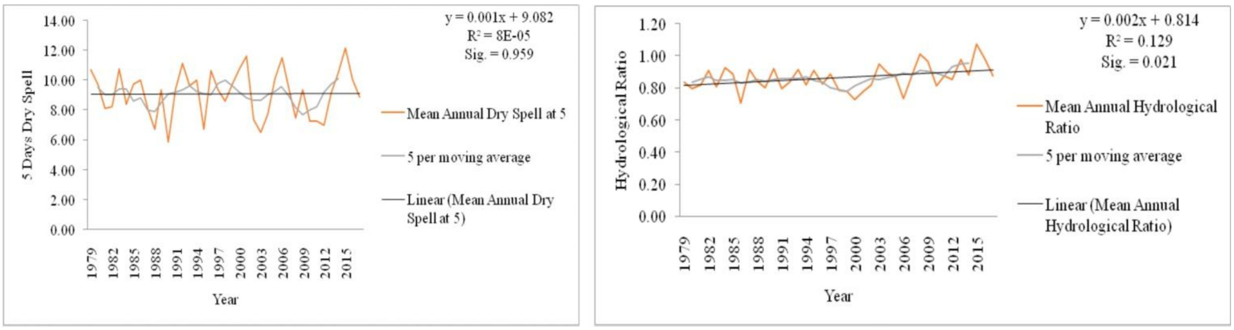

Figure 4: Mean Annual 5-day Dry Spell and Mean Annual Hydrological Ratio trend

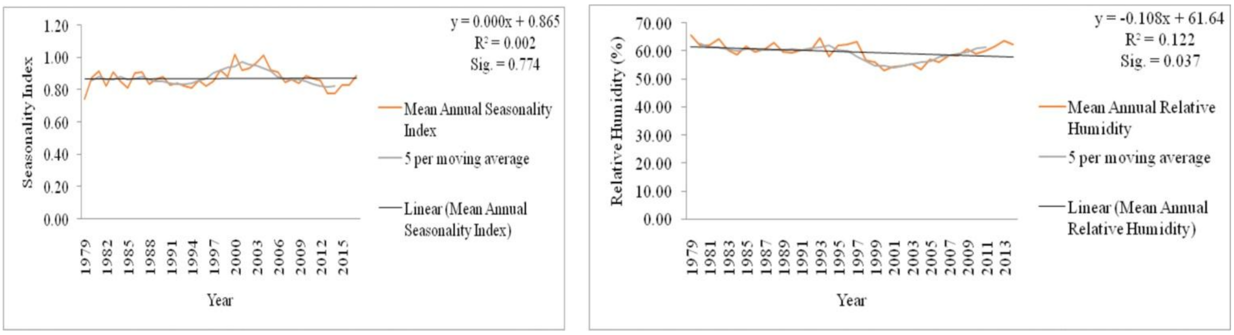

Figure 5: Mean Annual Seasonality Index and Mean Annual Relative Humidity trend

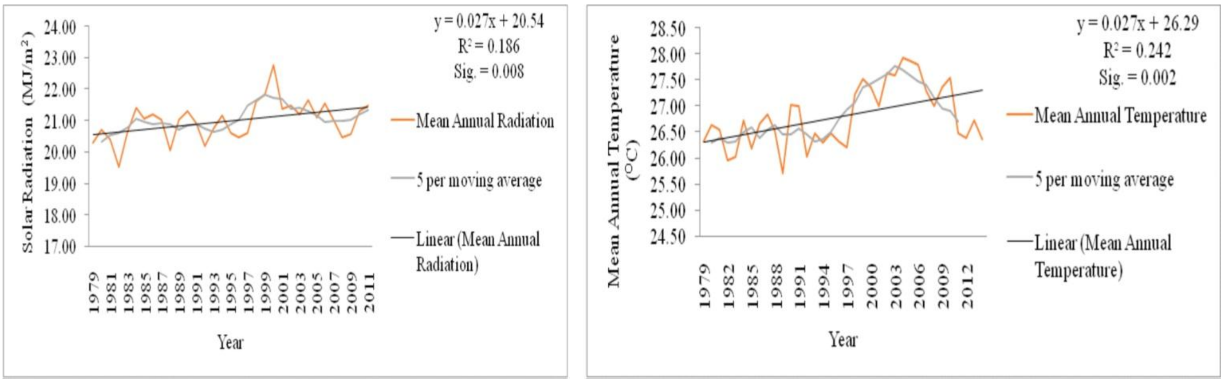

Figure 6: Mean Annual Solar Radiation and Mean Annual Temperature trend

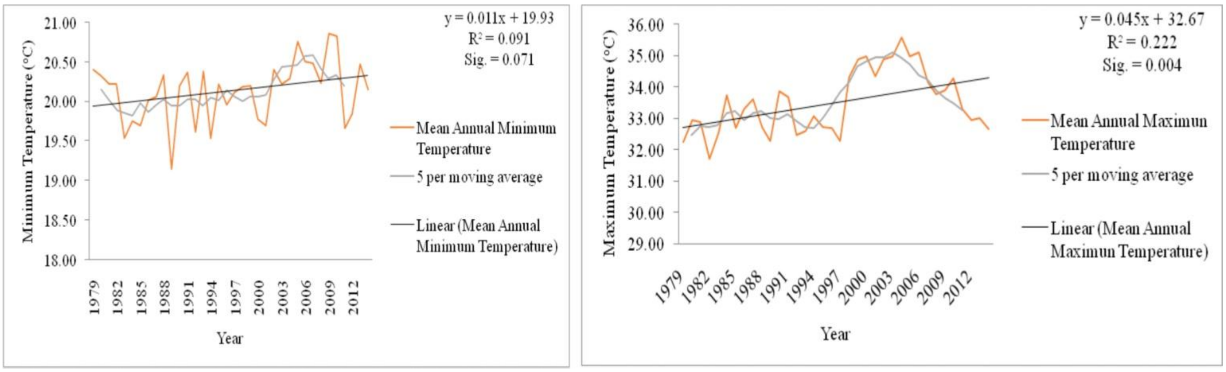

Figure 7: Mean Annual Minimum Temperature and Mean Annual Maximum Temperature trend

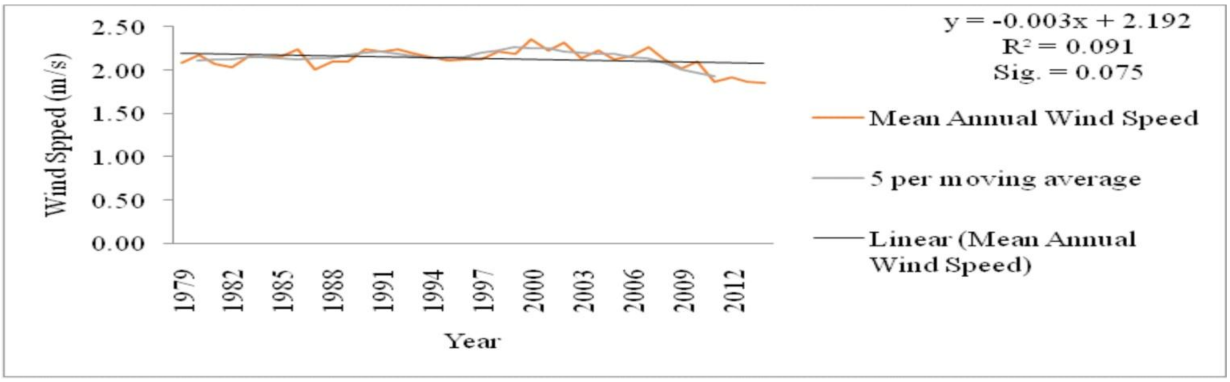

Figure 8: Mean Annual Wind Speed trend

Spatial Pattern of the Agro-climatic Variables

Results in terms of spatial pattern of the moisture and heat parameters are presented in figure 9 and 10. Mean Annual Rainfall, Onset of date of Rain, Cessation date of Rainfall, Hydrological Ratio, Relative Humidity and LRS showed a similar pattern of movement where the highest value of the variables were recorded in the southern part of the State around Sardauna, Ussa, Kurmi, Takum and Gashaka LGA, while places like Karim Lamido, Lau, Ardo-Kola, Jalingo, Zing, and Yorro LGA have the lower value of the moisture parameters. In some areas where precipitation indices are having 5-drys spell and higher Seasonality index value are found in the Southern Stations of the study area compared to those stations in the Northern part of the State. This result clearly explains that the values of the parameters decrease as latitude increases and increases as Altitude increases, which also explained the influence of maritime air mass and altitude. This result of the spatial rainfall explained that, the northern part of the State around Karim, Lau, Sunkani, Jalingo, Zing and Yerro has a mean annual rainfall of 1,034mm to 1,201mm while places around Gembu, Mayo Ndanga, Nguroje, Maisamari, Lissam Sambo, Tosso and Gadin has a mean annual rainfall of between 1,640 to 1970mm. Onset date of rain, on the other hand, showed that rainfall in the

Northern part of the State around Karim, Lau, Sunkani and some part of Jalingo start around 1st-10th May while the Southern part of the State around Gembu, Mayo Ndanga and Nguroje experience start of rain around 16th-31st March. In a similar pattern, the cessation date of rain in the northern part of the State end between 1st-10th October but, lasted in the Southern part of the state between 1st and 5th November. This result on the rainfall patterns clearly revealed that, rainfall in the Northern part of the State lasted for a short period of time compared to the Southern part of the state where rainfall lasted for a longer period of time thereby making a longer LRS. Unlike the mean annual rainfall, onset date of rain, cessation date of rain and LRS which recorded lower value in the Northern region of the State and high value in the Southern region of the State, seasonality index, on the other hand, showed a reverse pattern of movement in which its amount increases as one move toward the northern part of the State. Result of the analysis also revealed that, Seasonality index in the Northern region of the State showed a value between 0.95-1.02 which clearly explained that, the region recorded high rainfall in few months and is markedly seasonal with long drier season, while the southern region of the State has a seasonality index value between 0.68-0.75 which explained that, the southern region is characterized by seasonal rainfall.

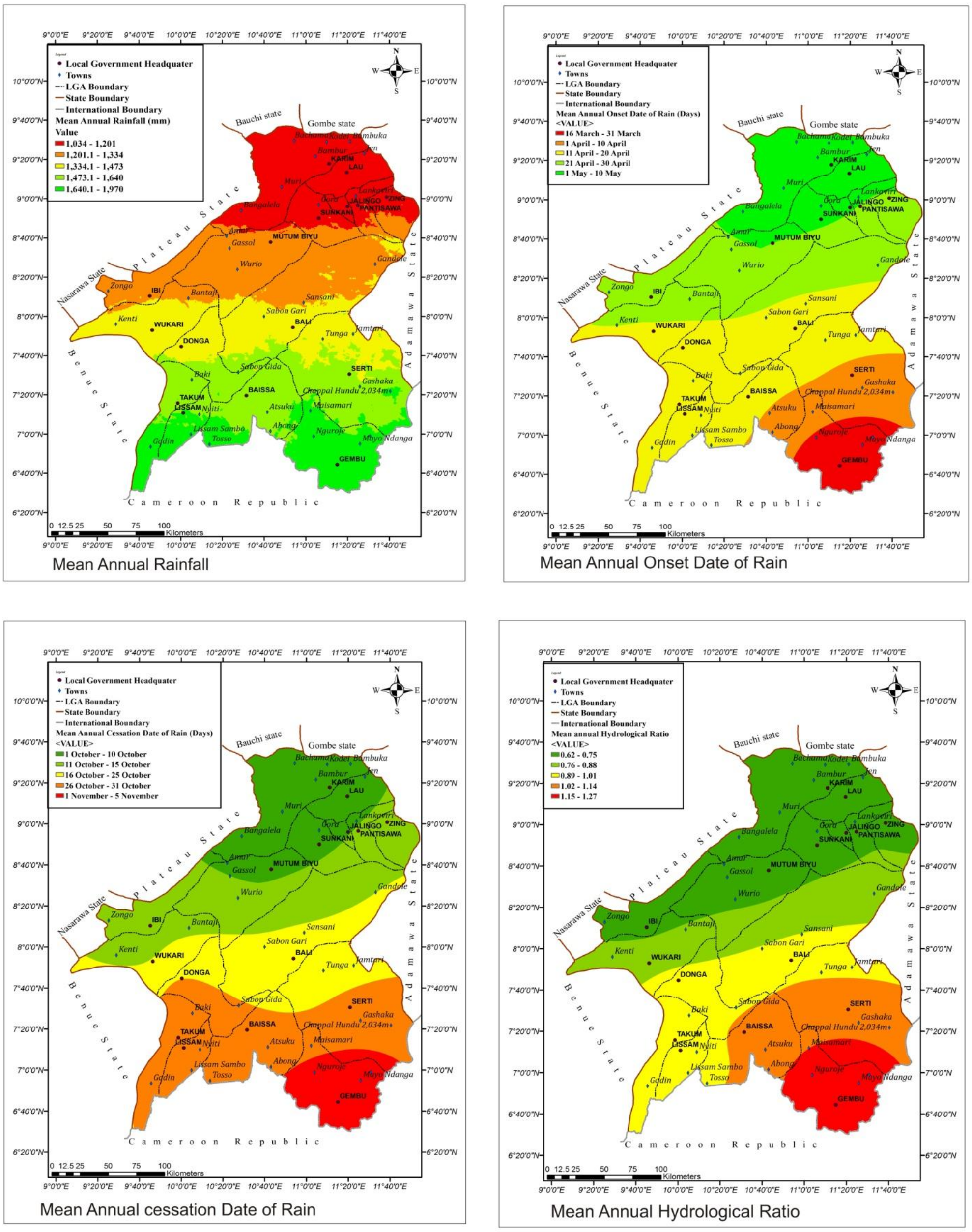

Figure 9: Spatial patterns of Moisture parameters (a)

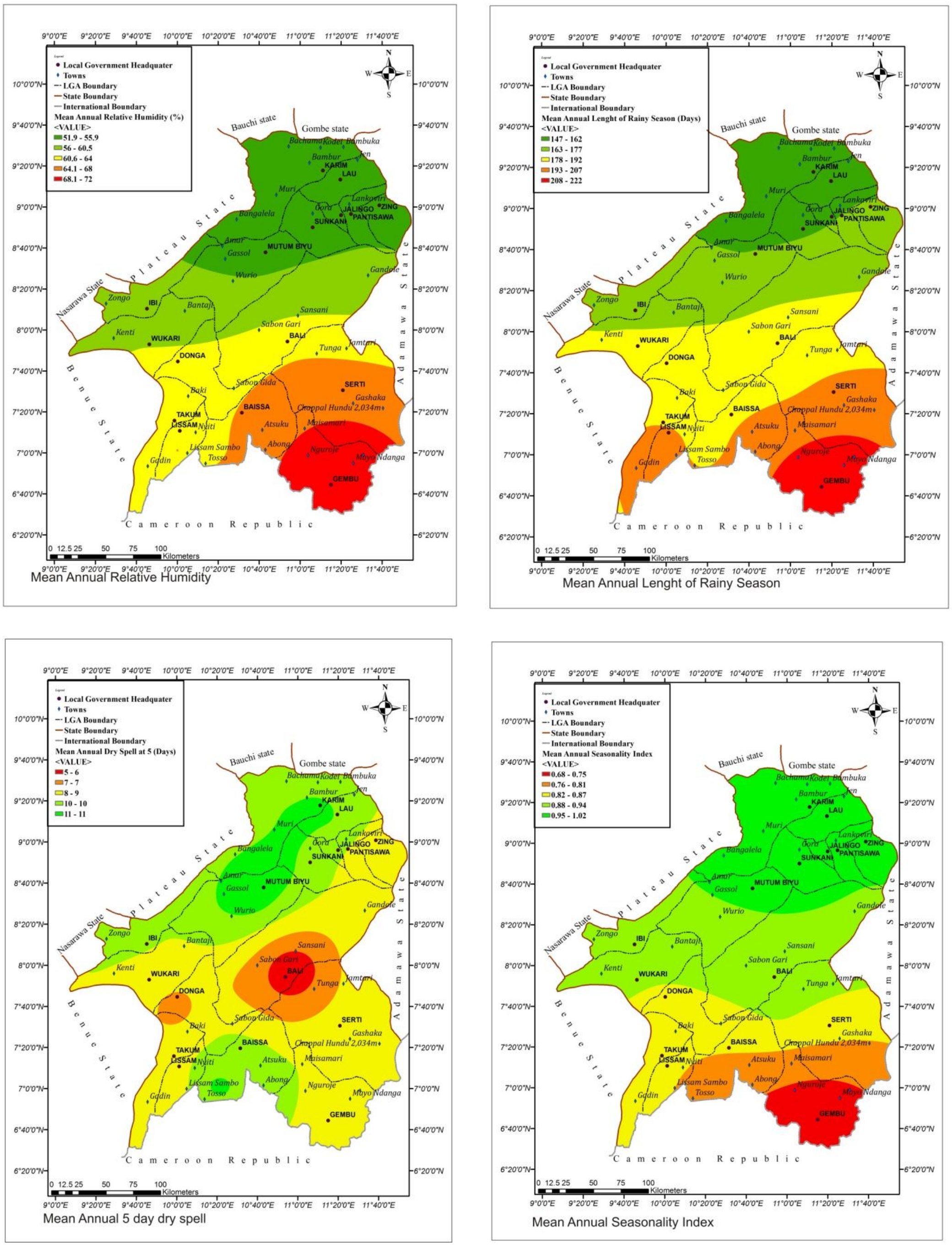

Figure 10: Spatial patterns of Moisture parameters (b)

Unlike the mean annual rainfall, onset date of rain, cessation date of rain and LRS which recorded lower value in the Northern region of the State and high value in the Southern region of the State, seasonality index, on the other hand, showed a reverse pattern of movement in which its amount increases as one move toward the northern part of the State. In the case of heat parameters which include Mean, Maximum and Minimum temperature in the State showed a similar spatial pattern of distribution in which places like Sardauna, Gashaka, Kurmi, Ussa and some part of Yorro LGA recorded low mean temperature amount between 16.8ºC to 22.3ºC compare to places like Ibi, Karim Lamido, Lau, Jalingo and Bali LGA which recorded high mean annual temperature amount between 27.1ºC to 28.0ºC. This spatial pattern of the temperature distribution is highly influenced by the nature of Altitude in the State where the southern part of the state which is characterized by high Altitude has low temperature amount compared to the northern part of the State and some places along River Benue

(Lowland places) recorded high temperature amount (Figure 11). Mean Wind Speed and Solar Radiation as other climatic parameters also showed a similar pattern of movement with heat parameters, where highland region of the state around Gembu recorded low values of wind speed compared to the lowland places of the State like Gassol, Ibi, Karim and Lau where it recorded low value of wind Speed (Figure 12). Following the trend and spatial pattern of Seasonality Index and Hydrological ratio in the State, it is clear that the study area is getting drier

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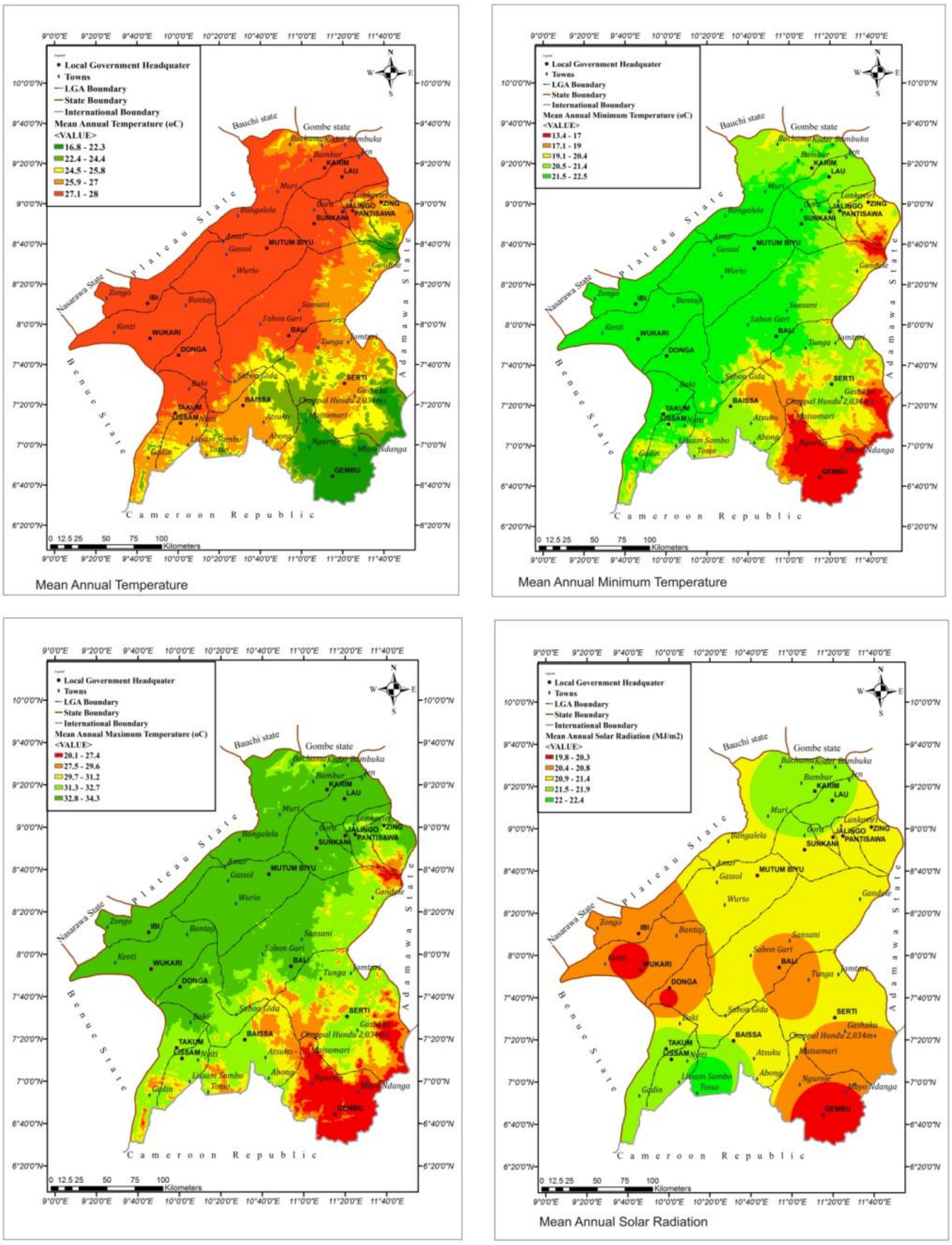

Figure 11: Spatial Pattern of Heat Parameters

Mean, Minimum and Maximum temperature in the study area showed a similar spatial pattern of distribution. The parameters showed a reverse pattern of a relationship with highland as shown in Figure 5 where their amount increases with a decrease in altitude.

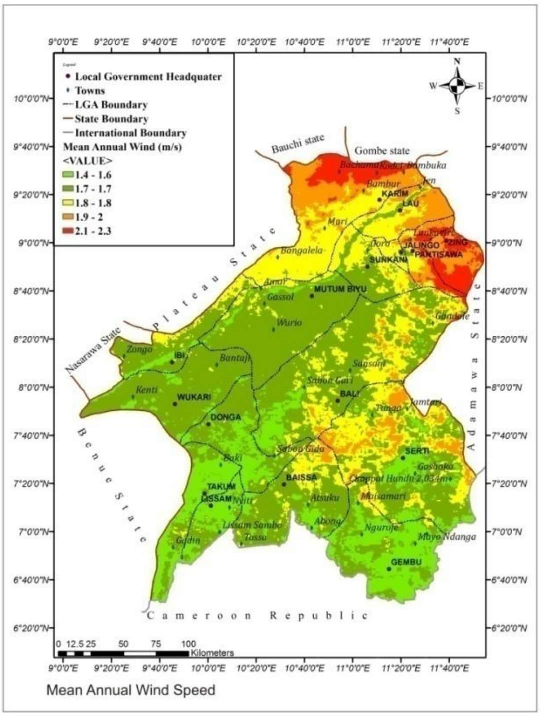

Figure 12: Spatial Pattern of Wind Speed

Implication of the Agro-climatic Condition for Agricultural Development

In regards to the result obtained on LRS, it is clear that, LRS in the study area is decreasing and that will have a negative impact on long maturing varieties of crops because the LRS which determines the duration of the rainy season is decreasing and that will not support the growth and yield of longer mature crop. In similar case, the positive slope of Seasonality Index is clear evidence that the study area is getting drier annually. In other word, the study area is affected with shorter spread and steadiness of rainfall during the rainy season which is based on the fact that, the amount of seasonality index in the study area is increasing annually thereby making the area to be more drier which leads to negative impact on crop growth and yield as also suggested by Adebayo, (2000). This result of the moisture indices is similar with the findings of Sawa and Adebayo (2011), while the onset and cessation date of rain concurred with the findings of Pierre and Mbaye (2003). The negative trend of wind speed on the other hand signified that, the speed of the wind in the study area is decreasing; as such the rate of carbon dioxide intake by plant will be optimized as also viewed by Ayoade, (2005). Increase in trend pattern of Temperature, Seasonality Index, Hydrological ratio and LRS is a clear indication that study area is getting more drier, as such, crops especially rice will be affected as also documented by Craufurd & Wheeler, (2009).

Following the spatial pattern of the moisture parameters explained, it is clearly that Altitude and movements of maritime air mass are the major factor determining the spatial distribution of the indices which are also the factors influencing rainfall distribution in Nigeria. The implication of this spatial distribution is that; crops with high moisture requirements will grow well in the southern part of the state compared to the Northern part of the State. In the case of spatial pattern of the heat parameters, the variables displayed an reverse relationship with Altitude as such, Altitude in the state is the major factor that influences temperature distribution and the implication of this is that, crops with high temperature requirement will not survive in all those places with low temperature, while those with high temperature requirement will not survive in low temperature region of the State. In regards to this, the low temperature value recorded in the Southern part of the State makes it inefficient for crop growth and yield of some crops especially rice compared to the northern part of the state which recorded high temperature (Expert System for paddy, 2018; Agropedia, 2018; Teh, 1998).

Conclusion

Based on the findings of this research, it was concluded that, the duration of rainy season is decreasing and that will not support the growth and yield of longer maturing crops. In similar case, the positive slope of Seasonality Index is a clear evidence that the study area is getting drier annually which can lead to negative impact on crop growth and yield while the negative trend of wind speed signified that, the speed of the wind in the study area is decreasing; as such the rate of carbon dioxide intake by plant will be optimized since low wind speed increase turbulence in canopy and replenish the carbon dioxide supply to plant. The positive trend of heat parameters such as solar radiation, mean, maximum and minimum temperature on the other hand is a clear indication that the study area is also getting drier because of the increase in heat parameters which can affect crop growth and yield.

Following the spatial pattern of the moisture parameters explained, it was concluded that Altitude and movements of maritime air mass are the major factors determining the spatial distribution of the indices as such; crops with high moisture requirements will grow well in the southern part of the state compared to the Northern part of the State. It was also concluded that, heat parameters displayed an inverse relationship with Altitude as such; Altitude in the state is the major factor that influences temperature distribution.

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