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STATISTICAL RELATIONSHIP OF INTER-ANNUAL RAINFALL VARIABILITY AND CROP YIELDS IN NASARAWA STATE, NIGERIA

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Abstract
The study investigated the relationship between inter annual rainfall variability and crop yield in Nasarawa State. Only the secondary sources of data were employed for the study. Data on crop yield was collected from the archives of Nasarawa Agricultural Development Program (NADP), this include crop yield data in metric tons from 1998 to 2015. While the rainfall data was collected from a remote sensing package of Tropical Rainfall measuring mission (TRMM) which covers the entire state. Daily rainfall records of each point or Local government Area was recorded in millimeters from 1998 to 2015. A simple regression analysis was adopted to analyze the relationship of rainfall against crop yield in Nasarawa State. The result was presented for each agricultural zone in the State i.e North, South and West. The result shows that rainfall has no significant influence on both yam, Maize and Rice in all agricultural zone in the state. The results show that crop farming is not under any threat from drought thus high yield is guaranty.

Key Words: *Regression, Yam, Maize, Rice, Inter annual rainfall*

Introduction

Climate change phenomenon has taken a center stage in every facet of human endeavor. Adejuwon (2004) noted that the issue of climate change has become more threatening not only to the sustainable development of socio-economic and agricultural activities of any nation but to the totality of human existence. The friction and crisis between herdsmen and farmers in the north central zone of Nigeria, is primarily a consequence of changing climate. This is because the North is getting drier and herdsmen have to move southward for greener pasture. Farmers on the other hand need to expand on their farm size in order to maintain a higher yield due to the danger posed by the changing climate.

A noticeable change or unpredictable pattern of rainfall onset, cessation and length of the growing season exist in Nasarawa State. This will have a negative consequence on the farmers in the state who depend on rainfall for their farming activities. In Nigeria, rainfall variability could affect the rain-fed agriculture in which many of the population depend on. Crops may lose their viability and the farmers lose their source of income (Obasakin, 2006). Although, inter annual rainfall variability may not be the sole reason for crops yield decline, it is the chief agent. Oladipo *et al.* (2002) observed that one of the major limiting factors to agricultural production, after soil fertility is water supply deficiencies.

Nigeria Meteorological Agency (NIMET, 2016) predicts that the country as a whole will witness late onset and early cessation, with the increasing uncertainty of the onset, cessation and length of rainfall season, agriculture will be the most affected. Adamgbe and Ujoh (2013) also noted that rainfall has been characterized by pronounced variability from year to year and place to place, and that onset of effective rainy season seems to have been delayed in an unpredictable manner in recent years without delay in cessation. The duration of rainy season (length of rainy season) as well as the annual amount/distribution and number of rainy days also vary significantly.

Many farmers in developing countries depend on traditional methods of farming which places them at a disadvantage with any alteration in nature. The intergovernmental panel on climate change (IPCC, 2007) observed that, the rising temperature, erratic rains, drought, floods, desertification and weather extremes will severely affect agriculture especially in the developing world. This is because most of the developing countries lack the capacity to predict and swiftly act in terms of extreme weather events.

Rice, yam and maize are important stable food in Nasarawa State. They are not only Source of food but of livelihood. Many communities in the state depend on these crops for their economic gain.

Rice is the world most important staple food crop. It is consumed by more than half of the world's population. This is represented by over 4.8 billion people in 176 countries; with over 2.89 million people in Asia, over 150.3 million in America and over 40 million people in Africa (IRRI, 2004). Nigeria is major rice producing country as well as consumption. Erabor and Ojogho (2011) noted that since mid-80, rice consumption has increased at an average annual rate of 11% with only 3% explained by population growth.

Yam is an important staple food in Nigeria. Nigeria Bureau of Statistics, (2011) affirmed that Nigeria is the leading producer of yam in the world, contributing two-third of global yam annually. As important as yam is to the economy and source of food in Nigeria it yields can be affected by inter annual rainfall variability. Reuben and Barau (2012) observed that rainfall distribution and occurrence of moisture stress condition during the vegetative period are critical for the yield formation of tuber crops at Kaba, Kogi state, which lies in the same ecological zone as the study area.

Maize is an important staple food crop not only in Nigeria but the entire sub-Sahara Africa. Maize is an important source of vitamin B, Carbohydrate, Protein and mineral to many poor Africans. Adamgbe and Ujoh *et al.* (2013) observed that despite the importance of maize in sub-Sahara Africa it yields continue to decline.

Climate change give rise to a lot of consequences especially in the technologically less developed countries, where human livelihood is still dependent on natural supplies. Corey *et al.* (2016) noted that 10% decline in global crop production between 1964-2007 can be accounted by climatic phenomenon. Rainfall which is the most important variable of climate in connection to agriculture in the tropics has a great tendency to affect crop yield. The essential role of rainfall to crop production especially in the tropics is obvious, to a larger extent, rainfall determine what, where, when and how to plant. This shows there is a strong relationship between rainfall and crop production. Rainfall is more important to agriculture in the tropics because it is highly variable in time and in space while other climatic elements are relatively stable. Rainfall is undoubtedly the most important climatic variable especially in the tropics and it has a far reaching influence on agricultural production (Adejuwon, 2005). Zhang and Yao (2012) observed that rainfall not temperature account for the decline in China's cereal decline. The change in the average yearly rainfall pattern of a place is known as inter annual rainfall variability and it is a reason behind most agriculture failure.

Yield of crops keep decreasing all over the world and climate variability especially rainfall is seen as a major cause. Govinda (2013) noted that yield of rice in northern Darchula district of Nepal decrease with decrease in rainfall. Vaidah, (2015) observed that "In terms of crops; yield are projected to decrease across Africa due to climate change, especially sugar cane, sweet potato, maize, rice and cassava production. International Plant Protection Convention Project stated that without appropriate adaptation, Africa can witness up to 40% decrease in cereal production by 2050". Ayanlande *et al.* (2009) also noted that Inter-annual variability in rainfall has been the key climatic element that determines the success of agriculture in Guinea Savanna ecological zone of Nigeria. Climate variability has been the most important determinant of the crop yields in Nigeria as well as in other parts of West Africa (Awosika *et al.,* 1994).

Several studies have been undertaken to investigate aspect of climate change impacts on crop yield. Blanc (2012) noted that two main techniques are used to evaluate the impact of climate change on yields; 1) crop growth models and 2) regression analysis. The crop growth yield model produce almost precise crop yield responses to whether events, while the regression analysis is based on quantification of weather changes on crop yield in actual cropping context. This study will adopt the regression analysis model to determine the relationship between rainfall and crop yields. According to Mesike and Esekhade (2013) that there are many factors influencing crop production and these include soil, climate and diseases among others. In relation to climate, rainfall is the dominant controlling variables in tropical agriculture since it supplies moisture for crops and grasses for animals. Nyong *et al.* (2007).Also noted that major impact of climate variability on agriculture production will come from changes in temperature, rainfall, ultra violet (UV) radiation, and carbon dioxides (CO_2) levels. These with the combination of shifts in seasonal climatic pattern and increasing frequency of extreme events are gravely unsettling agriculture.

One of the most significant climate variation in Africa Sahel since the late 1960s has been the persistent decline in rainfall (Abaje *et al.,* 2010). There are other factors like population explosion and soil content which may affect crop yield but overwhelmingly as shown In studies by Deepak *et al*. (2015) that crop yield variation can largely be accounted by inter annual climate variation. The West African region has experienced a marked decline in rainfall from 15% to 30%, depending on the area (Niasse, 2005). In the tropics the rainfall is often the only input that varies markedly from year to year, so the predicted variability in crop index or water balance is due only to the variability in rainfall (Odekunle, 2004). Countries in sub-Sahara Africa like Nigeria with predominantly rural economies and low levels of agricultural diversification are at greater risk. The pattern of rainfall in northern Nigeria is highly variable in spatial and temporal dimension (Oladipo, 1993).

Oladipo (1993) and Adejuwon (2004) observed that, as a result of the large inter annual variability of rainfall; it often results in climate hazards, especially floods and severe and widespread droughts with the devastating effects on food production and associated calamities and suffering. Omotosho *et al. (*2000) noted that, the variations in the onset date could be up to 70 days (10 weeks) from one year to another at a single station. Thus, the rainfall distribution characteristics during the course of a year in a typical Nigeria climate dictate the schedule of agricultural activities from the land preparation, through the crop variety selection and planting, to the time of harvesting. In other words, reliable prediction of rainfall onset and cessation times, and thus the length of the growing season, will greatly assist on-time preparation of farmlands, mobilization of seed/crops, manpower, and equipment and will also reduce the risk involved in planting/sowing too early or too late. World Meteorological Organization (WMO, 2000) observed that rainfall variability is a major determinant of agricultural production in both developed and developing countries. As can be seen in the climate variation of 1971 to 1972 for example which reduced Agricultural contribution to GDP in Nigeria from 18.4% in 1971-72 to 7.3% in 1972-1973 (Abubakar *et al.* 2013)

In Nigeria, large segment of its population live on agriculture and it is highly dependent on rainfall. Bassey (2009) observed that 40% of Nigeria's Gross National Product (GNP) is obtained from agriculture and 70% of all African labour is employed in this sector. The dominant role of agriculture makes it obvious that even minor climate deterioration can cause a devastating economic consequence, because it is the mainstay of local livelihoods and Gross Domestic Product (GDP). Agriculture becomes more vulnerable because in spite of recent technological advances, weather and climate are still the most important variables in agricultural production (Ayoade, 2004). Rain-fed agriculture is the common farming practice in Nigeria and the farmers lack basic knowledge of climate or science to be able to predict the changing pattern of the rains and its implication on crop yield. It is on this note that the study sought to test the hypothesis which stated that there is no significant influence of inter annual rainfall variability on crop yield in Nasarawa State, Nigeria.

Study Area

Nasarawa State is located in the central part of Nigeria otherwise known as the middle belt. The state lies between latitude 7° 45′ and 9° 25′ N of the equator and between Longitude 7° and 9° 37′ E of the Greenwich meridian as shown in figure 1. It has a total landmass of about 27, 137.8 km^2, a population of 1,863.275 according to the 2006 census report and has a population density of 130. Nasarawa State has a total of 13 Local Government Area which are; Akwanga, Awe, Obi, Karu, Nasarawa, NasarawaEggon, Keffi, Wamba, Doma, Lafia, Kokona, Toto and Keana. The State Shares boundary with Kaduna State in the North, Plateau State in the East, Benue State in the east while Kogi State and FCT bounded the state in the West (Binbol *et al*., 2005).

Precipitation in Nasarawa State like elsewhere in the tropics consists entirely of rainfall; it is the most variable element of tropical climate. The mean annual rainfall across the state is between 1400mm and 1500mm, with the highest in August about 1560mm and the lowest in October about 328mm. the rapid decrease in the monthly rainfall is attributed to the rapid retreating of the ITD at a speed of 320 km per month as against 160km for the South North movement (Ayoade, 2004). The onset of rain varies within the state; some northern parts of the state witness rain early around 29th March then the southern part around 1st April while the western and eastern parts is between 4th and 5th April. The mean cessation dates of rains in the state are 24th October. Nasarawa State has a tropical sub-humid climate, with two distinct seasons which are wet season and dry season. The wet season lasts for seven months which is between April and October, while the dry season is between November and March (NIMET, 2005). Temperatures are generally very high during the day, particularly in March and April. Nasarawa State records average maximum and minimum daily temperatures of 35°C and 21°C in rainy season and 37°C and 16°C in dry season respectively (NIMET, 2005).

A maximum is reached in March when temperature can be as high as 39^{o}C. Minimum temperature on the other hand in the State can drop to as low as 17°C in December and January (Binbol, 2007). There is a spatial variation in temperature distribution over the state; mean monthly temperature ranges between 26.8^{o}C in the southern part to about 27.9^o in the northern part of the state (NIMET, 2011). The temperature in Nasarawa State is generally high, partly because of its location in the tropical sub-humid climatic belt and the high radiation income in this part of the globe, which is evenly distributed throughout the year, (Binbol, 2007). Agriculture is the main economic activity in Nasarawa State. Nasarawa State Agricultural Development Program (NADP, 2010) observes that farming in the state is subsistence and generally rain fed cultivation of annual crops. Although there are many rivers in the state, the population engaged in irrigation farming are insignificant. Crops grown include grains such as rice, wheat, Soybeans, beans, maize and millet and tuber crops such as yam and cassava.

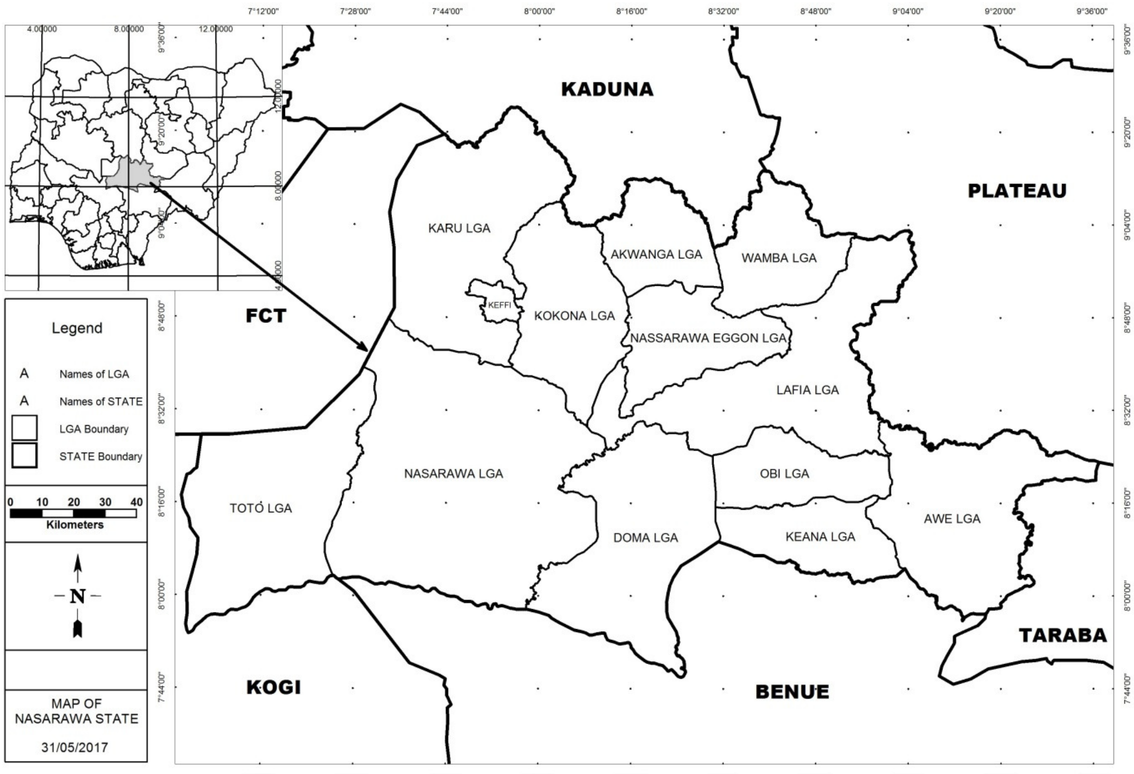

Fig. 1: Map of Nasarawa State *(source NAGIS, 2017)*

Methodology

The rainfall data was based on the (TRMM) satellite data version for the period 1998–2015 across the entire state as shown in figure 4.1. Satellite-based rainfall estimates are based on the electromagnetic spectrum, which can be measured by thermal infrared or passive microwave sensors (Barbosa *et al.,* 2015). The TRMM satellite combines both sensors, overcoming their intrinsic limitations. For instance, the first sensor tends to underestimate warm rain and the second one is not available in geostationary satellites (Dinku *et al.*, 2011). TRMM data was downloaded from the Mirador website (http://mirador.gsfc.nasa.gov/) and rainfall time series for the study area was extracted using GrADS (Grid Analysis and Display System) software. These datasets can also be accessed via File Transfer Protocol (ftp://trmmopen.gsfc.nasa.gov/pub/merged). Gridded rainfall from TRMM have a spatial resolution of 0.25º over regions between 50º N and 50º S (Huffman, Adler , Bolvin , Gu , Nelkin , Bowman, Hong, Stocker, Wolff, 2007) and 3-hourly data since 01/01/1998 is available

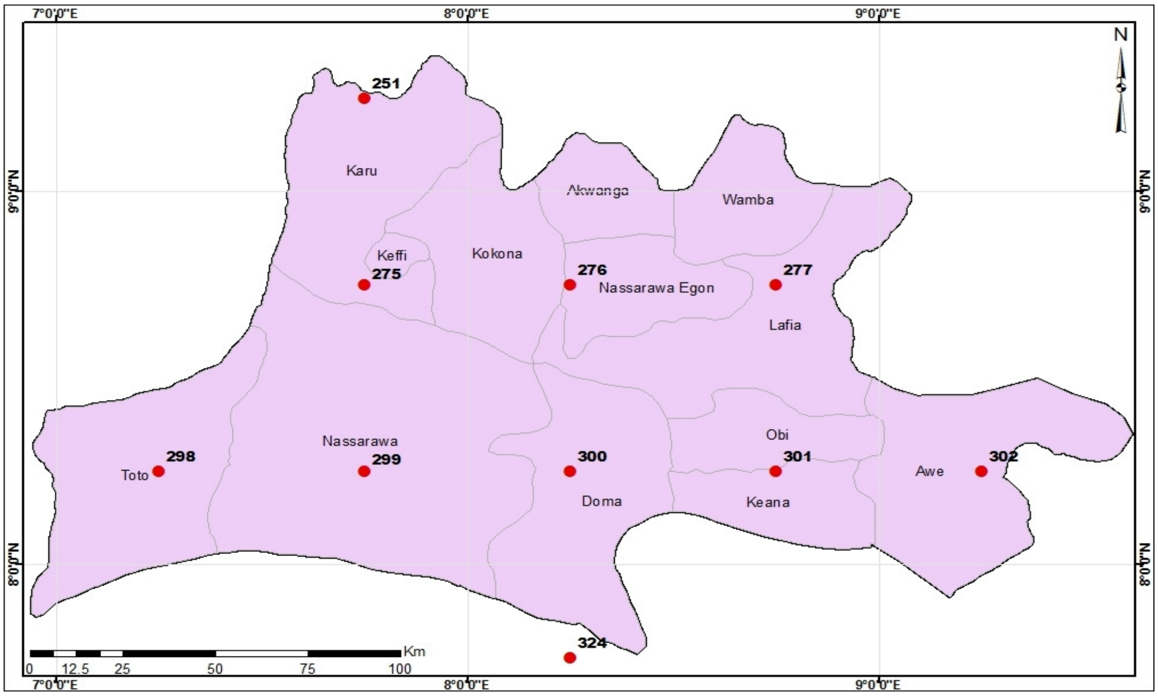

Fig. 2: Map of Nasarawa State showing TRMM Points

Methods of Data Analysis

This was done to establish the influence of rainfall variability on the selected crop yield (Yam, Maiz and Rice). The model for simple linear regression analysis is;

$$y = a + bx + e$$

Where:

y=estimated value of the dependent variable

x=value of the independent variable

a= the y intercept

b= regression coefficient

e= the residual or random error terms

Rainfall is the independent variable (x) while crop yield will be the dependent variable (y); this is to derive information on rainfall-crop yield relationship. This answered or tests the null hypothesis for this study.

Results and Discussions

Regression Analysis of Rainfall on Crop Yields

In order to get the influence of inter annual rainfall variability on crop yield in Nasarawa State. Regression analysis of the Yam, Rice and Maize yield was run with rainfall data in all TRMM points. Rainfall data is the independent variable while crop yields are the dependent variables. Table 5.39-5.41 shows the result of the analysis for the different crop.

Regression Analysis of Rainfall on Yam Yield

Table 1: Regression analysis of rainfall on yam yield

POINT	R	R^2	SSE	F	Sig
251	0.049647	0.002465	3.488635	0.039535	0.039535
252	0.044253	0.001958	3.489521	0.031394	0.861587
253	0.010887	0.000119	3.492736	0.001896	0.965803
275	0.254289	0.064663	3.378123	1.106136	0.308549
276	0.205291	0.042145	3.418546	0.703982	0.41381
277	0.284593	0.080993	181.2631	1.410097	0.252371
298	0.260388	0.067802	3.372451	1.163734	0.296688
299	0.113973	0.01299	3.470182	0.210572	0.652491
300	0.274561	0.075384	3.358708	1.304472	0.270203
301	0.334369	0.111803	3.291897	2.014015	0.17504
302	0.212938	0.045343	3.412835	0.759938	0.396241
324	0.050093	0.002509	3.488558	0.04025	0.843521

Table 1 show the regression analysis of rainfallon yam yield revealed that, rainfall has no significant impact on yam yield in all the points. The highest relationship between rainfall and yam is 11% in Obi and Keana LGA (point 301) the least is in 0.1% in Wamba LGA (point 253). The influence of inter annual rainfall variability on yam yield in the study area is not significant hence we accept the null hypothesis which states ‘there is no influence of inter annual rainfall variability on crop yield in Nasarawa State. The findings on yam yield differs with the result of (Akpenpuun *et al*., 2013) which noted that 99% variation in yam yield in Kwara state can be attributed to climate variables.

Rainfall distribution over the state shows a normal distribution; because each year has sufficient rainfall above 1000mm which can support crop production. Hence other factors can explain for yam yield other than inter annual rainfall.

Regression Analysis of Rainfall on Rice Yield

Regression analysis as shown in table 2 shows that in all the points rainfall has no significant impact on rice yield. The highest variation on rice yield that can be accounted by rainfall is 15% in Awe LGA (point 302) while the lowest is 0.6% in Lafia and Karu LGA (points 277 and 251 respectively). The variation in the yield of rice cannot be accounted by the inter annual rainfall variation. Therefore the influence of inter annual rainfall variability can be said not to be not significant hence the null hypothesis shall be accepted. This agrees with the findings of (Saliu *et al*., 2015) in their studies of the effects of rainfall variability on rice yield in Nigeria, which noted that the effect of rainfall variability on the national rice yield across the entire vegetation Zone was not statistically significant during the period of study.

Table 2 Regression analysis rainfall on rice yield

POINT	R	R^2	SSE	F	Sig
251	0.082646	0.00683	0.330462	0.110038	0.744407
252	0.12185	0.014848	0.329125	0.241141	0.630051
253	0.1756	0.030835	0.326444	0.50906	0.485824
275	0.120791	0.014591	0.329168	0.236905	0.633051
276	0.187521	0.035164	0.325714	0.583133	0.456201
277	0.077988	0.006082	0.330586	0.097909	0.758396
298	0.142457	0.020294	0.328214	0.331431	0.572826
299	0.184053	0.033875	0.325931	0.561012	0.464723
300	0.101365	0.010275	0.329888	0.166104	0.688999
301	0.105088	0.011043	0.32976	0.178668	0.678147
302	0.39437	0.155528	0.304721	2.946746	0.105344
324	0.082693	0.006838	0.33046	0.110164	0.744265

This implies that other variables other than rainfall may account for Rice crop yield. Rahman *et al.* (2013) in their study of Analysis of Technical Efficiency of Rice Farm in Nasarawa State also found out that in order to improve output levels in rice production there is need to increase farm size, seed, labour and quantity of agrochemical used in production of rice. This further proof that other variables can account for rice yield in Nasarawa State other than rainfall variability.

Regression Analysis of Rainfall on Maize Yield

Regression of rainfall on as shown in table 3 shows that maize yield has a much stronger relationship than the other crops under study. 27% of variation on crop yield in Doma (point 324) and Karu (point 251) can be accounted by rainfall, while Keffi, Karu and Doma (point 300 and 275) has 15%. Awe and Wamba (point 302 and 253) has 14%. The rest are 1% in Lafia (Point 277), 2% in Toto (point 298), 3% in Obi and Keana (point 301), 4% in Kokona and Nasarawa Eggon (point 276), 5% in Akwanga (point 252) and 8% in Nasarawa (point 299).

The influence of inter annual rainfall on maize yield can be said not to be significant thus the null hypothesis will be accepted. This finding differs from the findings of (Aamani *et al.*, 2012) in their study of Climate Change and Maize Production: Empirical Evidence from Kaduna State, Nigeria; which noted that annual rainfall contributes significantly and positively to maize production in the study area in spite of climate change.

Table 3: Regression analysis of rainfall on Maize yield

POINT	R	R^2	SSE	F	Sig
251	0.521208	0.271658	0.386654	5.967703	0.026548
252	0.237853	0.056574	0.440057	0.959469	0.341901
253	0.386937	0.14972	0.417768	2.817341	0.112671
275	0.397284	0.157835	0.41577	2.998647	0.102566
276	0.21163	0.044787	0.442797	0.750196	0.399217
277	0.122878	0.015099	0.449626	0.245288	0.627146
298	0.165973	0.027547	0.446775	0.453237	0.51041
299	0.288593	0.083286	0.433782	1.453645	0.245472
300	0.389827	0.151965	0.417217	2.867141	0.109781
301	0.191293	0.036593	0.444692	0.607728	0.447023
302	0.381503	0.145544	0.418793	2.725374	0.118254
324	0.520267	0.270677	0.386914	5.938165	0.026871

The state is normal and length of growing season for maize is short, it shows that it has adequate moisture throughout the growing period.

Conclusion

Regression analysis was done to determine the influence of inter annual rain fall variability on selected crop yields (Rice, Maize and Yam). The results show that in all local Government Area or TRMM points that there are no significant influence of inter annual rainfall variability on the selected crop yields in Nasarawa State. Thus the null hypothesis was accepted, that there is no significant influence of inter annual rainfall variability on selected crop yield in Nasarawa State. This therefore means that other factors may be responsible for crop yield decline but not inter annual rainfall. Other factors like the use of improved and drought resistant seeds might be the contributing factor to cushion the negative effects of climate variability. This also imply that all the local Government Areas of Nasarawa State can support rainfall farming and hence make it easier for subsistent famers who may not have access to irrigation farming to depend on the natural source for farming. Another implication for this result is that crop farming in Nasarawa State is not under any threat of drought and thus bountiful yield is guaranty.

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