

RAINFALL VARIABILITY AND MAIZE YIELD PRODUCTION PATTERN IN SOUTHWESTERN NIGERIA

Olanrewaju, R.M. Aderibigbe, S. O. and Akpan, G. P.

Department of Geography and Environmental Management, University of Ilorin, Ilorin, Nigeria

Corresponding Author's email: godisgood885@gmail.com



DOI: **10.29816/sjss.7.1.14**

ABSTRACT

Rainfall is one of the key climatic elements that determine the success of agriculture and water resource characteristics in many parts of Nigeria. However, climate and rainfall variability has impacted negatively on maize production in different regions of the country. The paper examined the impacts of Inter annual rainfall variability on the yield of maize in Southwest Nigeria for a period of 24 years (1990-2013). The three states of Ondo, Oyo and Ogun were selected for the study. The selection is due to availability of data. Climatic data of rainfall was sourced from the archives of the Nigerian Meteorological Agency (NIMET), while maize yield data were obtained from the Agricultural Development Programs (ADP) of each state. The data were subjected to descriptive statistics like percentage among others. Inferential statistics used include Pearson moment correlation, simple regression analysis and GIS interpolation analysis. The Coefficient of variation (CV) of rainfall amount in all the three states revealed that rainfall amount within the three locations is highly heterogeneous, while the Standard Anomaly Index revealed that Ondo State received the highest total amount of rainfall, followed by Oyo and Ogun State respectively. This trend was also reflected in the pattern of annual maize yield which was highest in Ondo (2.19 tons/ha), as compared to Oyo and Ogun that observed yields of 1.57 ton/ha and 1.40 tons/ha respectively. The result of Simple regression analysis showed that inter annual rainfall variability accounts for 63.40%, 38.90% and 57.00% variation in maize yield across Ondo, Ogun and Oyo States respectively. The study recommends that Maize production should be monitored to identify the most critical phase of maize growth to various climatic factors particularly rainfall among others.

Key words: Inter annual, Rainfall, Variability, Maize and Agriculture.

Introduction

Maize (*Zea mays*) which is regarded as the most important staple cereal crop in Sub Saharan Africa and an important staple crop in Nigeria (IITA, 2015) like many other crops has been noticed to be affected by climate change. Several studies have reported that the availability of adequate rainfall is by far the most important limiting factor in maize

production in Sub Saharan Africa (CIMMYT, 1998; Diallo *et al.*, 1989 among others).

Climate limits the production area of maize. Lack of rainfall (drought) or too much of it (flood) can result in 100% loss of maize output (Chi-chung and Mccarl, 2004). Similarly, it is projected that crop yield in Africa for many other crops may fall by 10-20%

by 2020 due to climate change (Ajetumobi and Abiodun 2010; Ajetumobi, Abiodun and Hassan, 2010; and BNRCC, 2008). This is because African agriculture is predominantly rain-fed and therefore dependent on the vagaries of weather. Historically, there has been a decline in precipitation of between 10-15% per decade in the humid regions of West Africa, including parts of southern Nigeria since the beginning of the century (Ojo *et al.*, 2001). In Nigeria, this is evident by the late arrival of rains, drying up of streams and small rivers that usually flow year round and the gradual disappearance of flood-recession cropping in riverine areas (Adebayo, *et al.*, 2011). These inconsistencies in rainfall have made it generally difficult for farmers (Macchi, 2008) and scientists (IPCC, 2001) to predict precipitation patterns. These fluctuations in rainfall pattern as reported by Adejuwon (2004) have put Nigeria's agriculture under serious threat and stress, since agriculture in Nigeria is mostly rain-fed. It follows therefore, that any change in climate is bound to impact agricultural productivity and other socio economic activities in the country. This is in line with the findings of Awosika, *et al.* (2004) who reported that rainfall has been the most important determinant of crop yield in Nigeria as well as other parts of West Africa. Hodder (1980) also confirmed that of all the climatic parameters affecting crop production and yield, moisture is the most important and it is primarily gotten from rainfall, which in the tropics is cyclic and fairly dependable (Ezedinma, 1986).

Studies have shown that the decrease in the production rate of food is climatically

linked (Adejuwon 2004, Chi-chung and Mccarl, 2004, Mortimore and Adams, 2001). Since agricultural practice in this zone (South West Nigeria) is rain fed, even if there is sufficient rainfall, its irregularity can affect yields adversely if it fails to arrive during the crucial growing stage of the crops (Mowa and Lambi, 2006; Rudolf and Hermann, 2009).

Thus, the objective of this study is to examine the pattern of rainfall anomalies in the study area as compared with the magnitude of variation in maize yield. The study also examined the relationship between maize yield and rainfall in the study area as well as the spatial and temporal pattern of rainfall and maize yield with the aim of assessing the impact of rainfall variability on maize yield in South west, Nigeria for sustainable maize production.

Study Area

South west Nigeria is made up of six states namely; Ekiti, Lagos, Ogun, Ondo, Osun and Oyo. It extends over a surface area of about 76,851km², with an estimated population of 27,581,993 and population density of 359/km² (Macmillan, 2007). The south west region of Nigeria is located between latitudes 6⁰ and 9⁰ north of the Equator, and longitudes 3⁰ and 6⁰ east of the Greenwich Meridian (see Figure 1). The climate of Southwestern region of Nigeria is dominated by the influence of two major wind currents, just like any other parts of Nigeria. The wind currents are the tropical maritime (mT) air mass and the tropical continental (cT) air mass.

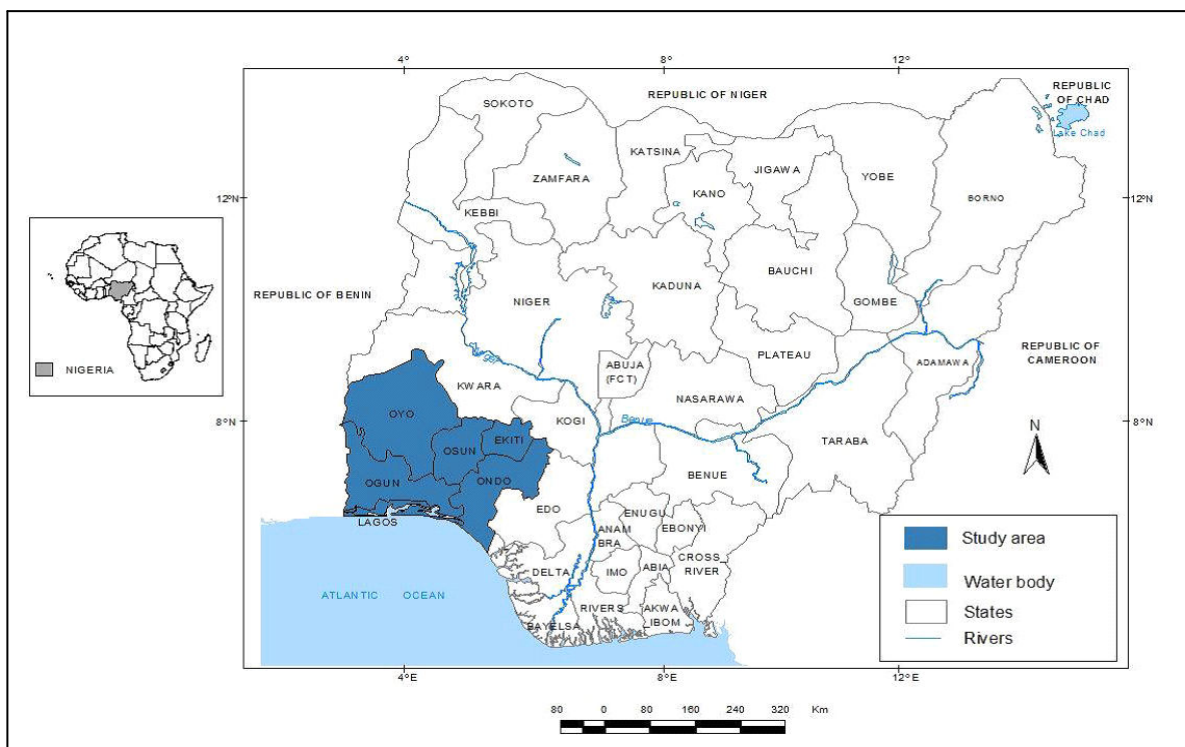


Figure 1: Study Area

Source: Modified After Ministry of Urban Development, Ibadan, Oyo State.

Materials and Methods

Meteorological data and maize yield data were utilized in this study. The meteorological data used is rainfall data (mm) for three states of Ondo, Oyo and Ogun. Data on the yield (Mt/Ha) of maize were collected from the office of Agricultural Development Programmes (ADP) of each state mentioned above. The rainfall data were collected from the Nigerian Meteorological Agency (NIMET) Oshodi, Lagos. Maize yield data were available for a period of 19 years (1996-2013) for Ondo and Ogun States and 23 years (1990-2013) for Oyo States respectively while data on rainfall were also available for a period of 23years as above.

The rainfall data collected on monthly basis was partitioned on annual basis to match the yield of maize data which was collected on annual basis. Descriptive, inferential and

geospatial analytical methods were used in analyzing and interpreting the obtained data. The Standardized Rainfall Anomaly Index (SAI) was employed and Pearson moment correlation analysis was used to study strength in relationship between the dependent variable (maize) and the independent variable (rainfall). Simple regression analysis was used to determine the % level of rainfall influence on maize yield. Point data of rainfall amount and maize yield collected were interpolated to reveal the spatial distribution pattern of rainfall and maize yield in the study area using Inverse Distance Weighted (IDW) method in Arc GIS 10.2.

Results and Discussion

Annual pattern of rainfall amount of the study area is displayed in table 1. While the year 1991 recorded the highest annual total rainfall

amount in Ondo State, the least was observed in 1990 (see figure 2). The Coefficient of variation (CV) showed that annual rainfall amount is highly heterogeneous. In Ogun State the year 2011 recorded the highest annual rainfall while year 2001 received the

least and the CV revealed that rainfall amount is highly variable. Similarly, in Oyo State, year 2011 receives the highest rainfall amount but the least was observed in 1994. The CV also revealed that rainfall amount in Oyo State is highly heterogeneous.

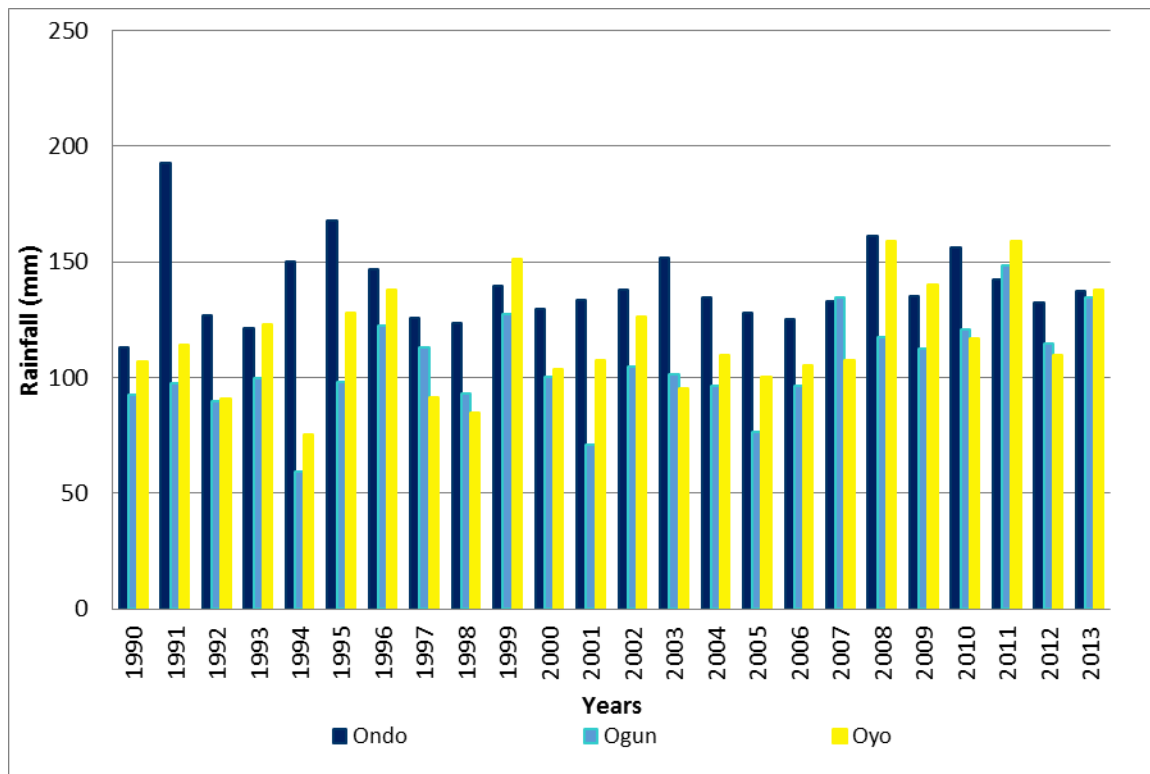


Figure 2: Mean Annual Rainfall in the Study Area 1990-2013

Table 1: The Pattern of Annual Rainfall Amount (mm) 1990-2013

Year	Ondo State				Ogun State				Oyo State			
	Total	Mean	SD	CV	Total	Mean	STD	CV	Total	Mean	STD	CV
1990	1357.4	113.12	88.36	78.11	1111	92.58	76.15	82.25	1283.9	106.99	86.62	80.96
1991	2310.2	192.52	161.97	84.13	1173.1	97.76	79.75	81.58	1369.3	114.11	82.59	72.38
1992	1520.2	126.68	137.52	108.55	1076.7	89.73	89.59	99.87	1088.6	90.72	80.41	88.64
1993	1453.6	121.13	98.69	81.48	1193.6	99.47	78.41	78.83	1478.1	123.18	112.69	91.49
1994	1799.6	149.97	106.25	70.85	712.2	59.35	52.24	88.01	905.9	75.49	74.97	99.31
1995	2015.1	167.93	141.85	84.47	1177.5	98.13	80.27	81.80	1534.7	127.89	97.75	76.43
1996	1760.3	146.69	101.05	68.89	1471.6	122.63	112.66	91.87	1653.7	137.81	96.54	70.05
1997	1506.1	125.51	97.69	77.84	1354.9	112.91	83.63	74.07	1097.1	91.43	70.61	77.23
1998	1484.6	123.72	118.66	95.91	1118.4	93.20	88.79	95.28	1018	84.83	73.87	87.08
1999	1671.7	139.31	112.36	80.66	1530.4	127.53	109.48	85.84	1814.9	151.24	136.23	90.07
2000	1555.3	129.61	115.64	89.22	1201.9	100.16	95.44	95.29	1244.5	103.71	86.50	83.41
2001	1600.7	133.39	118.05	88.49	849.2	70.77	77.70	109.80	1289.7	107.48	103.95	96.72
2002	1655.7	137.98	117.27	84.99	1253.1	104.43	99.08	94.89	1515.3	126.28	103.97	82.34
2003	1819.3	151.61	153.86	101.49	1214.7	101.23	105.38	104.11	1143	95.25	69.72	73.20
2004	1617.2	134.77	103.41	76.73	1153.3	96.11	89.46	93.08	1314.2	109.52	85.88	78.42
2005	1533.4	127.78	125.65	98.33	917.5	76.46	66.47	86.94	1204.2	100.35	79.67	79.39
2006	1498.9	124.91	93.06	74.50	1157.2	96.43	87.35	90.58	1260.1	105.01	94.56	90.05
2007	1596.8	133.07	109.89	82.58	1615.7	134.64	135.07	100.32	1290.6	107.55	110.20	102.47

2008	1930.9	160.91	139.52	86.71	1408.7	117.39	119.92	102.16	1905.4	158.78	128.63	81.01
2009	1621.3	135.12	113.08	83.69	1351.1	112.59	93.46	83.01	1542.2	140.20	104.09	74.25
2010	1872.9	156.08	133.78	85.72	1450.7	120.89	120.96	100.06	1399.7	116.64	117.02	100.32
2011	1706.9	142.24	120.05	84.40	1777.6	148.13	222.91	150.48	1908.92	159.08	155.50	97.75
2012	1591	132.58	88.19	66.51	1375.4	114.62	118.59	103.47	1318.1	109.84	91.41	83.22
2013	1648.95	137.41	100.73	73.30	1614.15	134.51	166.50	123.78	1654.31	137.86	128.72	93.37

Source: Authors' Computation, 2016

The annual pattern of maize yield in the study area is reflected in table 2. Ondo and Ogun States have no record keeping of maize yield between the year 1990 and 1995. The highest yield of 2.86 ton/ha was observed in year 2011 at Ondo State followed by Oyo State with 2.03 ton/ha recorded in year 2013 and 1.56 ton/ha in Oyo State, during year 2002. During this period the least of 1.86ton/ha occurred in 1997 in Ondo State and this was followed by Ogun State with 1.25ton/ha in 1999 and lastly by Oyo State with 1.23ton/ha in 2009.

Table 2: Maize Yield (mt/ha) 1990-2013 (ton/ha)

Years	Ondo State	Ogun State	Oyo State
1990	NA	NA	1.45
1991	NA	NA	1.51
1992	NA	NA	1.66
1993	NA	NA	1.53
1994	NA	NA	1.30
1995	NA	NA	1.53
1996	2.05	1.54	1.44
1997	1.86	1.40	1.28
1998	1.89	1.36	1.37
1999	1.932	1.25	1.57
2000	1.92	1.42	1.69
2001	2.10	1.50	1.70
2002	2.19	1.56	1.78
2003	2.08	1.45	1.87
2004	2.12	1.42	1.88
2005	2.13	1.35	1.79
2006	2.23	1.32	1.28
2007	2.18	1.32	1.35
2008	2.40	1.40	1.32
2009	2.35	1.40	1.23
2010	2.35	1.41	1.37
2011	2.86	1.40	1.51
2012	2.61	1.35	1.75
2013	2.20	1.35	2.03

Source: Authors' Computation, 2016

*NA = Not Available

Table 3 shows the dry and wet years in the study area, which indicated the departure in long term established rainfall mean in more than half (58.33%) of the 24 years under consideration. These anomalies in rainfall can significantly influence maize yield in the study area and subsequently affect the income of the farmers in the long run (see table 1). The dry and wet years experienced in each of the three locations are on the negative and positive sides of the graph, respectively.

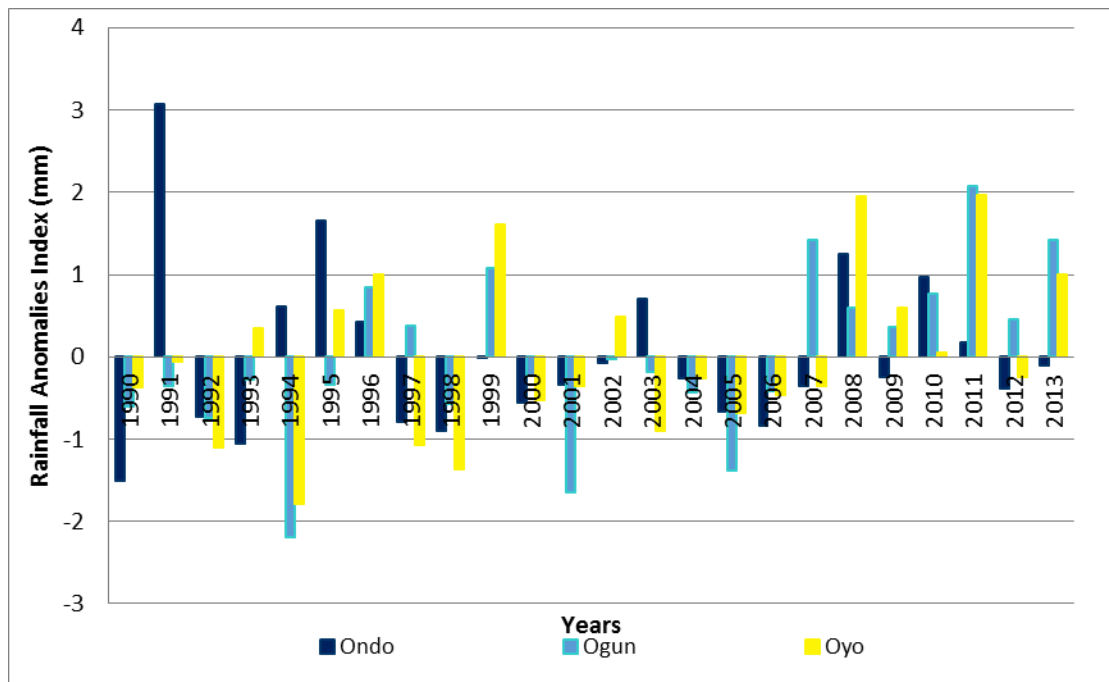


Figure 3: Pattern of Rainfall Anomaly Index in the Study area

Table 3 gives the descriptive analysis of maize yield in the study area. It shows that there are no significant variations in annual yield of maize in the three states considered.

Table 3: Descriptive Analysis of Maize Yield in the Study Area

	Mean	Std. Deviation	Std. Error	CV
Ondo State	2.1915	.25493	.06009	11.63
Ogun State	1.4000	.07784	.01835	5.56
Oyo State	1.5672	.24840	.05855	15.85

Source: Authors' Computation, 2016

Table 4 shows that the variation in maize yield between Ondo State and Ogun State is significantly different because the p-value (0.001) < than 0.05. Also, the variation in maize yield in Ondo State and Oyo State is significantly different because the p-value (0.001) < than 0.05. On the other hand, the variation in maize yield in Ogun State and Oyo State is not significantly different because the p-value (0.053) > than 0.05. It is not surprising because it was noted earlier that both Ondo and

Oyo states received more rainfall than Ogun State. The implication is that Ogun State is the driest of the 3 states. Hence maize yield/ha is least in the state.

Table 4: Multiple Comparison of Maize Yield in the Study Area

(I) States	(J) States	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Ondo State	Ogun State	.79150*	.07012	.001	.6222	.9608
	Oyo State	.62428*	.07012	.001	.4550	.7935
Ogun State	Ondo State	-.79150*	.07012	.001	-.9608	-.6222
	Oyo State	-.16722	.07012	.053	-.3365	.0020
Oyo State	Ondo State	-.62428*	.07012	.001	-.7935	-.4550
	Ogun State	.16722	.07012	.053	-.0020	.3365

*. The mean difference is significant at the 0.05 level.

Source: Authors' Computation, 2016

Table 5 shows the result of the correlation between rainfall and maize yield in the study area.. The table revealed that maize yield and rainfall amount in both Oyo and Ondo States exhibited very strong positive relationships ($r = 0.755$ and $r = 0.552$) at 99% confidence level respectively. All things been equal, this indicates that increase in rainfall brings about increase in maize yield and vice versa.

Table 5: Association between Maize Yield and Rainfall

States	Variables	Maize Yield
Ondo State	Rainfall Amount	0.552*
Ogun State	Rainfall Amount	0.341
Oyo State	Rainfall Amount	0.755**

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Source: Author's Computation, 2016

However, the table revealed that maize yield and rainfall amount in Ogun State exhibited a mild positive relationship ($r = 0.341$), which is not statistically significant.

Table 6 further displayed the relationship between maize yield and inter-annual rainfall variability. The relationship is still strongest in Ondo State. In Ondo State, for every 1% increase in rainfall amount, there is 0.018% increase in maize yield. In Ogun State, for every 1% increase in rainfall amount, there is 0.001% increase in maize yield. In Oyo State, for every 1% increase in rainfall amount, there is 0.002% increase in maize yield.

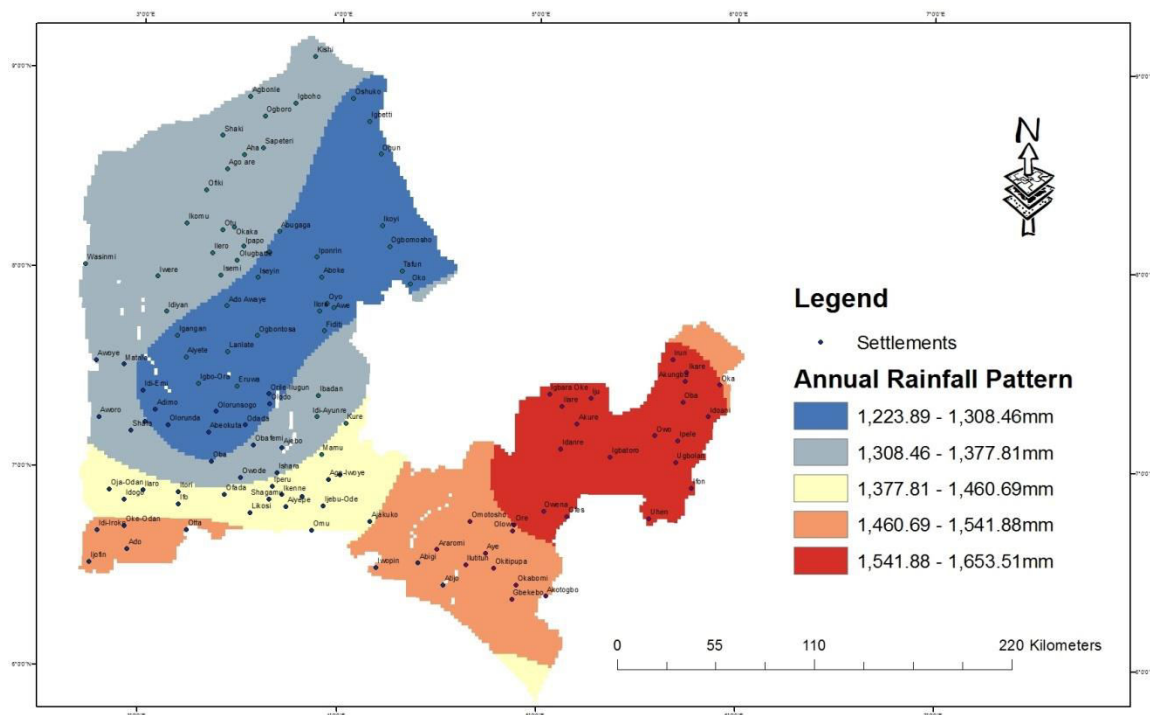
Table 6: Relationship between Inter-annual Rainfall Variability and Maize Yield

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
Ondo State	(Constant)	1.320	.772		1.337	0.2
	Rainfall	.018	.006	0.352	1.506	0.152
Ogun State	(Constant)	1.504	.105		14.302	.000
	Rainfall	.001	.001	.243	1.004	.330
Oyo State	(Constant)	1.799	.055		32.484	.001
	Rainfall	.002	.000	.755	5.402	.001

a. Dependent Variable: Maize Yield

Source: Authors' Computation, 2016

To shed more light on the impacts of inter-annual rainfall variability on the yield of maize, the spatial pattern of mean annual rainfall amount in the study area is presented in Figure 4. The mean annual rainfall amounts in the three locations were interpolated using the universal kriging method in ArcGIS 10.2.

**Figure 4:** Spatial Distribution Pattern of Rainfall in the Study Area

Source: Authors' Computation, 2016

Figure 5 shows the result of the kriging analysis to indicate a variability in maize yield/ha which is about 0.79 ton/ha from the Southeastern part to the Southwestern part of the study area.

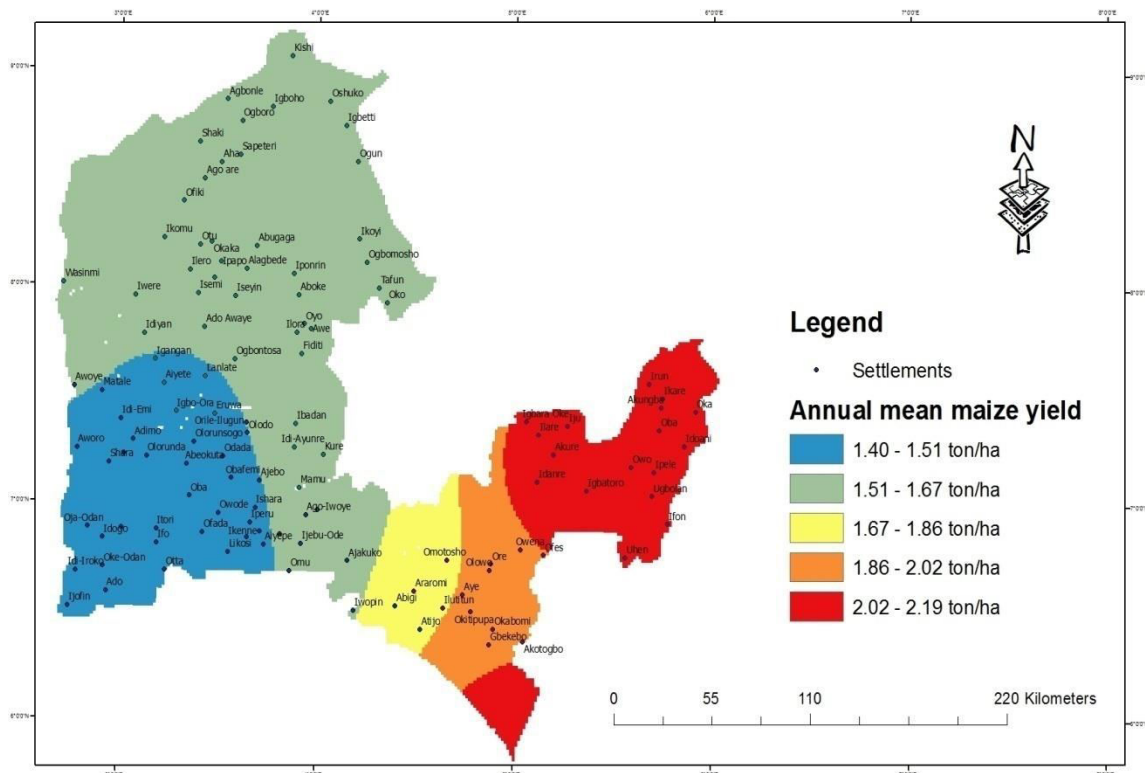


Figure 5: Spatial Distribution Pattern of Annual Mean Maize Yield in the Study Area (1996-2013)

Source: Authors' Computation, 2016

Conclusion and Recommendations

The study revealed that the inter-annual rainfall variability in the three states of Ondo, Ogun and Oyo is very high as no year under the period of study recorded CV that was less than 66.51%. Hence, it can be concluded that the effective determinants of inter-annual changes in maize crop yield in the study area is high inter-annual rainfall variability. The highly inter-annual variability in rainfall amount recorded in the three locations was attributed to the number of rainy days, intensity and duration of rainfall amount received in any particular year during the period of study.

From the foregoing discussions, inter-annual rainfall variability has a direct influence

on maize yield. Thus it can be recommended that other factors such as seed type, on set and cessation of rainfall, number of maize farmer in the three states and soil nutrient among others should be considered along with rainfall amount for a more robust methodology in maize yield determinant in the south-western Nigeria for a sustainable maize production in the area.

Maize growth should be monitored to identify the most critical phase of maize growth to various climatic factors and rainfall in particular.

References

- Adejuwon, J.O. (2004). "Crop Yield Response to Climate Variability in the Sudano-Sahelian Ecological Zones of Nigeria in South-Western Nigeria". In AIACC Report of Workshop for Africa and Indian Ocean Island. Dakar, Senegal, pp.15
- Adebayo, A., Abdulhamid A.I., Ati F.O. and (2011). Effect of climate on the growth and yield of sorghum in Wailo, Ganjuwa Local Government Area, Bauchi State. *Research Journal of environmental and earth sciences* 3(5): 469-472
- Ajetomobi, J. and Abiodun, A. (2010). "Climate Change Impacts on Cowpea Productivity in Nigeria". *African Journal of Food, Agriculture, Nutrition and Development* 10(3): 2258 - 2271.
- Awosika, L., Ojo, O. and Ajayi, T. (2004), "Implications of Climate Change and Sea Level Rise on the Niger Delta, Nigeria" – Phase 1.A report for the United Nations Environmental Programme OKAPIS/UNEP, 92 pp.
- Building Nigeria's Response to Climate Change (BNRCC), 2008: 2008 Annual Workshop of Nigerian Environmental Study Team (NEST): The Recent Global and Local Action on Climate Change, held at Hotel Millennium, Abuja, Nigeria; 8-9th October, 2008.
- Chi-Chung, C., McCarl, B.A. and Schimmelpfennig, D. (2004). "Yield Variability as Influenced by Climate: A Statistical Investigation". *Climatic Change*, 66: 239-261, 204.
- CIMMYT (Centro Internacional de Mejoramiento de Ma. z y Trigo) (2001). CIMMYT 1999–2000 in 'World Facts and Trends. Meeting World Maize Needs: Technological Opportunities and Priorities for The Public Sector'. In Pingali, P. (ed) *Centro Internacional de Mejoramiento de Ma. z y Trigo: Mexico D.F.*
- Ezedimma, F.O.C. (1986). "Crop Science". In Youdeowei, A., Ezedinma, F.O.C and Onazi, A. (eds) *Introduction to Tropical Agriculture*. Longman Essex.
- Hodder, B.W. (1980). *Economic Development in the Tropics*. Methuen, London.
- IPCC (Intergovernmental Panel on Climate Change), 2008. Africa (Chapter Ten). *Climate Change 2008: Impacts, Adaptation, and Vulnerability. Report of Working Group II of the Intergovernmental Panel on Climate Change*, Geneva. <http://www.ipcc.ch> Accessed 23 April 2017.
- Macchi, M. (2008) 'Indigenous and Traditional Peoples and Climate Change: Issues Paper', Geneva: International Union for the Conservation of Nature.
- Macmillan (2007). *Atlas of the World Geography*, Macmillan Learning, London.
- Mortimore, M.J. and adams, W.M. (2001). "Farmers' Adaptations, Change and Crisis in the Sahel". *Global Environmental Change*, 11(49-57)
- Molua E. & Lambi CM (2006). Assessing the impact of climate on crop water use and crop water productivity: The CROPWAT analysis of three districts in Cameroon. CEEPA Discussion Paper No. 33, Centre for Environmental Economics and Policy in Africa, University of Pretoria.
- Rudolf, W. and Hermann, W. (2009). "Climate Risk and Farming Systems in Rural Cameroon". Institute of Development and Agricultural Economics. University of Hannover, Germany, pp. 21-24.