ASSESSMENT OF WEATHER VARIABILITY IMPACT ON RICE YIELD IN SOUTH WESTERN NIGERIA

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ABSTRACT

The scientific evidence on rainfall and temperature variability with its significant impacts on rice yield is now stronger than ever. Rice, a cereal crop, which can be upland or low land type, serves as staple food in most parts of Nigeria. This study assessed the weather variability impact on rice yield in south-western states of Nigeria. Rainfall, temperature and rice yield data (1991 – 2007) in the six states of south-western Nigeria were collected from the Federal Ministry of Agriculture, Abuja and analyzed using ArcGIS 9.2 version. A geo-spatial variation maps showing rainfall, temperature and rice yields in the study were generated in order to assess the correlation of rainfall and temperature on rice yield in the south-western part of Nigeria. Geographical Information Systems (GIS) Kriging interpolation and other geospatial analysis technique were used to assess and map the spatiotemporal e values. Rice yield time series were correlated with temperature and rainfall time series for individual state. Linear regression analysis was carried to deduce the prediction of rice yields on rainfall and temperature variability. Correlation of rice yields with growing seasonal rainfall gave the highest of 0.403 (Lagos, Ogun, Ondo and Ekiti) and lowest of -0.215 (Oyo). Meanwhile, correlation of rice yields with growing seasonal temperature gave highest of 0.453 (Ogun and Oyo) and lowest of -0.012 (Ondo and Ekiti). Rice yield and rainfall relationship ranges between y = 0.007*x + 0.13 and y = 0.018* x -0.8714 while rice yield and temperature relationship ranges from y = 0.5*x – 12.52 and y = 0.7* x -18.6.The rice farmers can make better rice farming plan despite the varying weather condition. The Geographic Information Systems (GIS) data base created and maps generated in the study areas can be used by policy makers and climate change mitigation.

Keywords: Temperature, rainfall, rice yield, GIS, southwestern states.

INTRODUCTION

Weather describes current atmospheric conditions, such as rainfall, temperature, and wind speed, at a particular place and time (PCC, 2015). Weather variability can occur due to natural changes in the earth‘s orbit which may occur over time scales of thousands of years or sun which may affect the amount of incoming solar radiation. Generally weather factors such as rainfall and temperature are the most important influencing agricultural activities particularly in the tropical region. In Nigeria as a tropical country is characterized by dry and rainy seasons where the annual rainfall is less than the amount of the water that a crop well supplied with water would transpire during the growing season, the factors of rainfall and temperature among others, results to extreme and general scarcity of food in the country.

LITERATURE REVIEW

Weather variations has been discovered to have great impacts on agricultural activities such as crop and animal productions has shown by several studies carried out in different parts of the world by Intergovernmental Panel on Climate Change (IPCC) and other scholars (Haimson and Ennis, 2004; Adejuwon, 2005). According to Adejuwon (2005) rainfall can vary considerably even within a few kilometres distance and on different time scale, therefore it determines the crops that can be grown, the type of farming system, the sequence and timing of farming operations.

In Nigeria as a tropical country is characterized by dry and rainy seasons where the annual rainfall is less than the amount of the water that a crop well supplied with water would transpire during the growing season, the factors of rainfall and temperature among others, results to extreme and general scarcity of food in the country. Previous studies on the impact of rainfall variability on crop yield were focused on specific crops and make use of only statistical based technique in their analysis (Adejuwon and Odekunle, 2006) which is limited in its uses for prediction of crop yield. Another study by Osagie (2002) observed that over the period of 1961 to 1990 in the north east arid zone of Nigeria experienced a decline in annual rainfall leading to decline in millet based farming system. The zonal variability of rainfall, especially, is observed to bring about not only the difference in the type of crops cultivated but also the yield of such crop.

A study by Odekunle *et al.* (2007) reported that one undisputable causes of famine in South Western Nigeria is the poor growth of crops resulting from weather variability due to insufficient or untimely rainfall. Inter-annual rainfall variability refers to the distribution of rainfall within a year (Obasi, 2003). Inter–annual rainfall variations which is referred to as the distribution of rainfall within a period of a year (Obasi, 2003) has caused great stress to the farming activities, crop production and crop yield especially in the Guinea Savanna of Nigeria in the last decade (Adejuwon, 2004; Adejuwon and Odekunle, 2006). Some previous studies have also examined inter-annual rainfall variability in Nigeria and other part of West Africa (Awosika *et al.,* 1992; Obasi, 2003; Adejuwon, 2004) in which the plant growth, yield and productivity are affected. Awosika *et al.*, (1992) observed that the aggregate impact of drought on the economy of Nigeria in 1992 was bad from analysis of recent rainfall conditions in West Africa with resultant negative effects on production system and yield of crops that are grown. There is therefore the need for study and better understanding of spatio-temporal weather variability as little systematic research has focused on the distribution patterns of impacts of weather variability in terms of mapping its spatio-temporal impact using the modern Geographic Information Systems (GIS) techniques such as Kringing Interpolation techniques.

GIS is a computer-based technology that makes management, manipulation, displaying data or mapping, analysis and development of process easy. The GIS data base creates interactive maps of the crops production areas, areas harvested and the yield (Odekunle *et al.,* 2007) Kufoniyi, 2003). A common requirement of most rainfall or crop yield research is the assimilation of physical and biological data from many sources though building spatial-dominant models through GIS tools is frequently a time-consuming process (Kufoniyi, 2003 and 2004). This integrated type of GIS modeling system will allow agricultural producers and policy makers to know the impact of spatial-temporal variation in rainfall on crop yield for better management, productivity and profitability. This study thus aimed at using GIS Kringing interpolation technique to examine and map the spatio-temporal variation in weather impact on rice yield in south western Nigeria.

Rice (*Oryza sativa*) is an important annual crop in Nigeria. It is one of the major staple cereal crops which can provide a nation's population with the nationally required food security

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minimum of 2,400 calories per person per day (Akpokodje, 2001; FAO, 2001). Due to its increasing contribution to the capital calorie consumption of Nigerians, the demand for rice has been increasing at a much faster rate than domestic production and more than in any African country since 1970 (FAO, 2001). Rice is mainly grown in four major production ecosystems which are broadly defined on the basis of water regions; Irrigated rice, Rain field low land rice, Upland rice and deep water rice. In South western Nigeria, the local rice cultivated and produced in Yoruba land is commonly called Ofada (Olagunju, 2014). Its rise to eminence as a popular type of rice is associated with what has been described as its characteristic bold, short, mouth filling. Other varieties of rice like Igbemo and Kogi rice produced locally also fit the description of local Ofada rice (Olagunju, 2014).

METHODOLOGY

Study Area

The study area is south western Nigeria comparising of Lagos, Ogun, Oyo, Osun, Ondo and Ekiti states as shown in Figure 1. The six states lie between longitude 2^o31^1 and 6^o00^1 East and latitude 6^o21^1 and 8^o37^1 North (Agboola, 2004) with a total land area of 77,818 km^2. The study area is bounded in the East by Edo and Delta states, in the North by Kwara and Kogi states, in the West by the Republic of Benin and in the south by the Gulf of Guinea. The coordinates of the six states (Oyo, Ogun, Osun, Ekiti, Ondo, and Lagos) are presented in Table 1. Two distinct (dry and wet) seasons are dominant in the study area in which subsistence and small scale farming are practiced (Odekunle *et al.*, 2007).

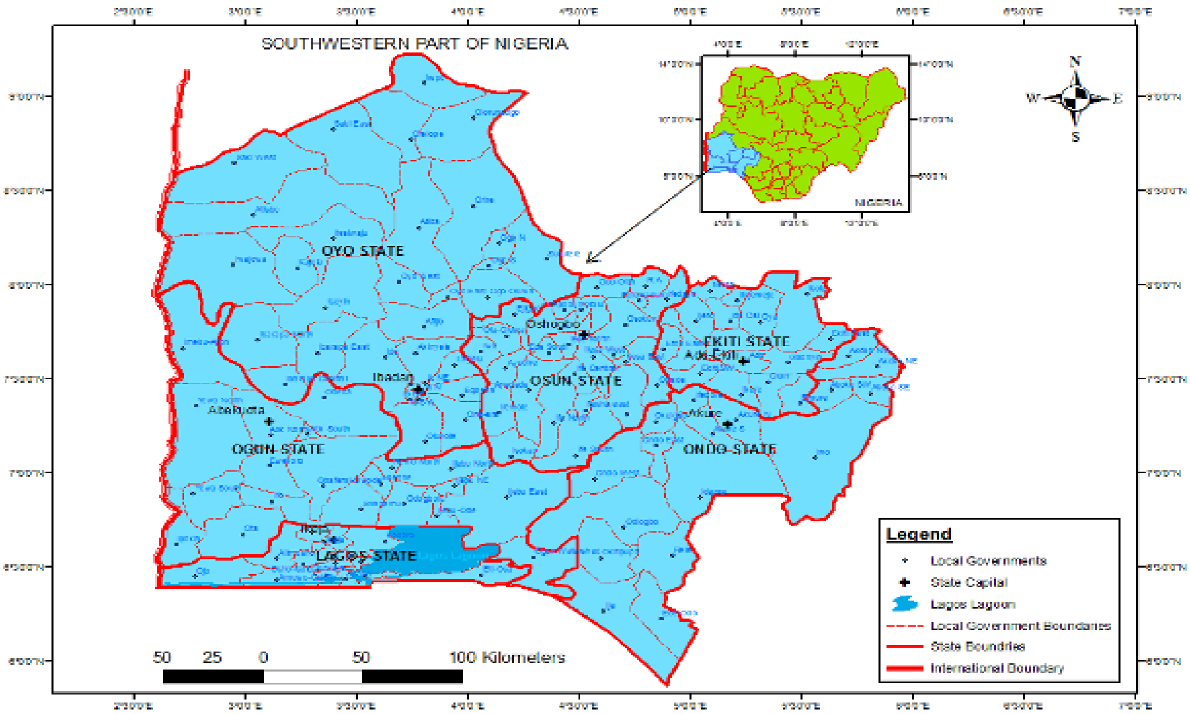

Figure 1: Map of the study areas (South Western, Nigeria)

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Table 1: Coordinates of South Western States

S/N	States	Latitude	Longititude
1	Oyo	8° 00' 00'' N	4° 00' 00''E
2	Osun	7° 30' 00'' N	4° 30'00''E
3	Ekiti	7°40' 00'' N	5° 15'00''E
4	Ogun	7° 00' 00'' N	3° 35' 00''E
5	Ondo	7°10' 00'' N	5° 05' 00''E
6	Lagos	6°35' 00'' N	3° 45' 00''E

Data Acquisition

Rainfall and temperature data for the six states of south western Nigeria from 1991 to 2007 were collected from the archives of the Nigerian Meteorological Services, Nigeria. The rainfall and temperature data used in this study consist of total annual rainfall and temperature for the period of 1991 to 2007. The rice yield data for the six states of south western Nigeria on annual basis on the other hand were obtained from Federal Ministry of Agriculture, Nigeria. The geographical maps of Nigeria used were downloaded from the internet by exploring. The annual rice yield data were also got obtained on the ratio of expected annual yield and exact annual yield.

Geospatial Analysis Methods

This analysis involved the use ArcGIS 9.2 to analyze annual temperature, rainfall and rice yield data geo-spatial variation using Kringing method of Interpolation. Existing Map of Nigeria in JP2 format was imported into the ArcGIS version 9.2 interfaces. This was done by making use of the adding data icon at the ArcGIS 9.2 interface. The Nigeria map was geo-referenced by correcting and updating the map with the correct coordinates. After importing the Nigeria map into the GIS interface, it was then pre-processed by geo-referencing, rectifying, updating and digitizing it. Geo-referencing was done by assigning the right coordinates to the study area map. Rectification was done to change the coordinates of the map from old coordinates to the newly assigned correct coordinates so as to register the map into ArcGIS version 9.2 internal environments in order to update the registered map. The map was after digitalized by carving out necessary features from an existing map. Southwestern part of Nigeria map, its states, states capitals, local governments and boundaries were edited out from the existing maps. Temperature, rainfall and rice yields values were recorded in the state capital attribute table. ArcGIS version 9.2 was used to develop the interpolated maps showing the variation of annual temperature, annual rainfall and annual crop yields at year intervals within the Southwestern part of Nigeria by performing kringing method of geo-spatial interpolation on the temperature, rainfall and crop yield values. The interpolated maps which served as the major outputs were then reclassified and post-processed by laying-out and exporting them. Laying out was done to give legend, scale bar, north arrow, grid lines, title and other map characteristic feature to the map. The interpolated maps were exported in TIFF formats. Figure 2 is a flow chart describing map interpolation process using kringing method of interpolation.

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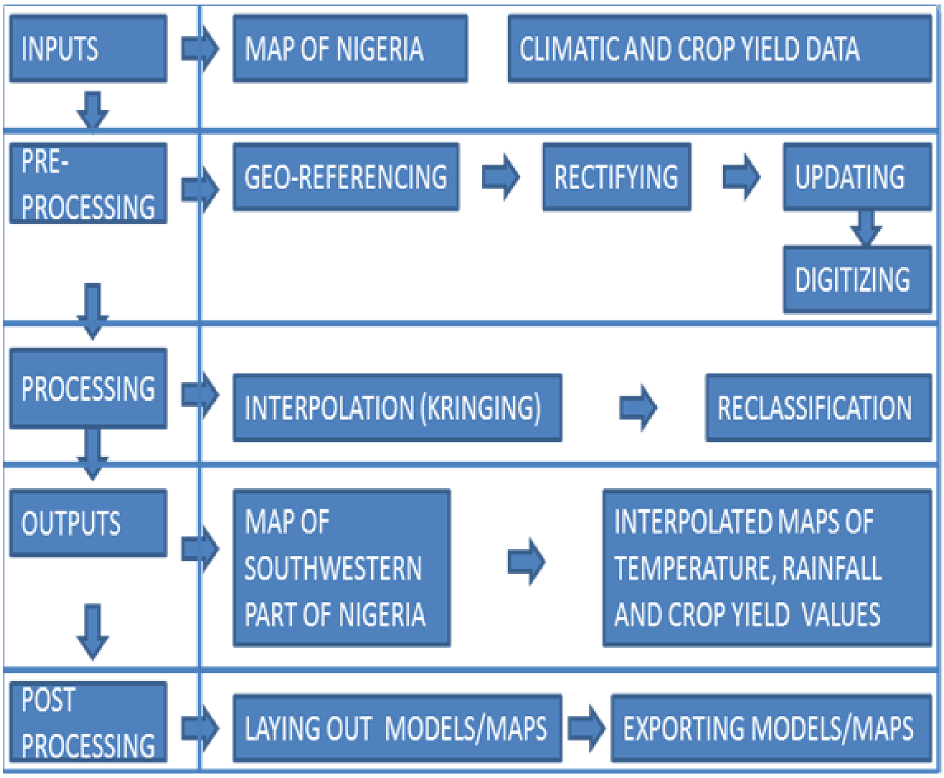

Figure 2: Flow Chart of Kringing Method of Interpolation

Variables Correlation and Prediction of Future Crop Yields

After ArcGIS version 9.2 has been used to produce the maps showing the geo-spatial variation of annual rainfall, annual temperature and annual rice yield, the inter-relationship that exist between these variables within their distributed areas and over the year intervals were then studied. Annual rice yield time series were correlated with annual temperature and annual rainfall time series for individual state. The correlation of these variables thereby helped in the prediction of future crop yields for each state in southwestern part of Nigeria. This was achieved by making use of the linear regression lines variables equations. Linear regression lines equations of annual temperature and annual rice yield were used to predict future crop yield value by making annual temperature to serve as the independent variable and vice versa. In the same way, future crop yield was deduced from rainfall values and the average of the total values was taken. Correlation of annual rainfall and annual temperature on rice yield was obtained by utilizing the linear regression equation on Arc GIS version 9.2 interfaces.

RESULTS

The mean rainfall variation maps as shown in Figure 3 gave the mean geo-spatial variation of rainfall and rice yield. The areas with dense red colour has the highest mean rainfall value range of (134.3–137.3) cm which cross across Ogun, Lagos, Ondo and Ekiti states while the area with dense green has the lowest mean rainfall value range of (107.6 – 110.5) cm which is mainly Ibadan. For mean rice yield geo-spatial variation map, the area with dense blue colour has the highest rice yield of (2.1 – 2.2) cm which across Lagos, Ondo and Ekiti states while the area with white colour has the lowest rice yield of (1.5 – 1.6) cm which is mainly Oyo state (Ibadan).

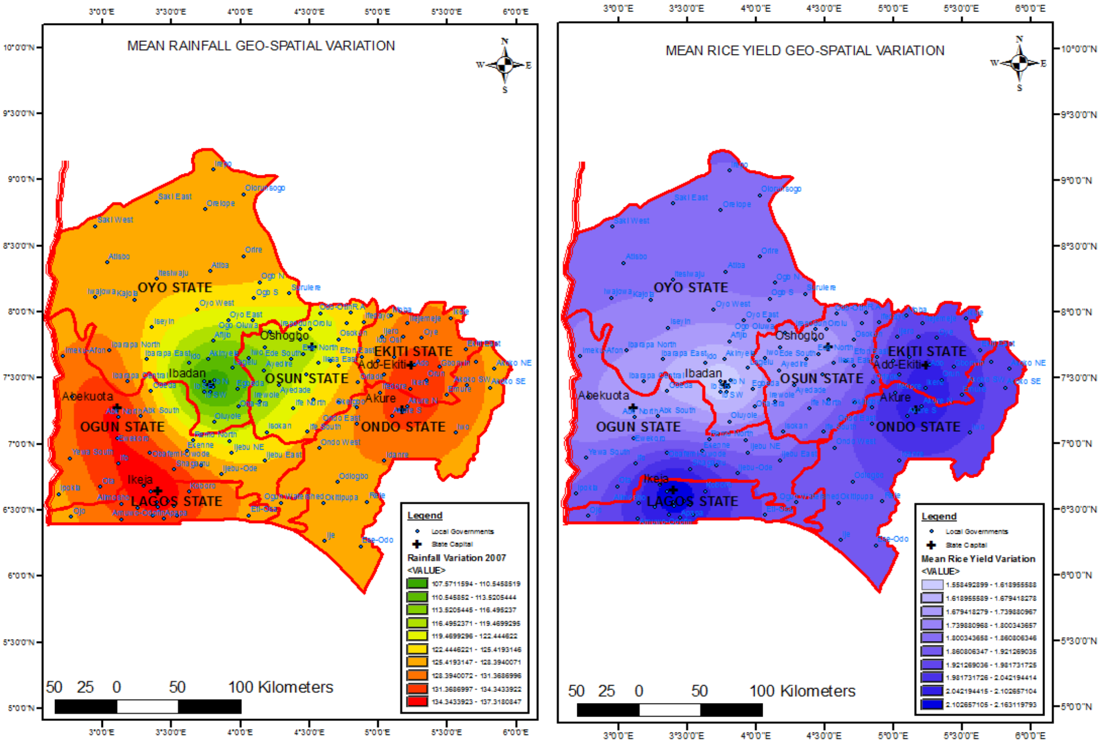

Figure 3: Maps of mean Geo-spatial Variation on Rainfall and Rice Yield

Maps showing mean Geo-spatial Variation of Temperature and Rice Yield

For mean temperature variation maps as in Figure 4 gave the mean geo-spatial variation of temperature and rice yield. The area with dense green colour has the lowest mean temperature value of (31.3cm – 31.4) °C which cross across through Ekiti and part of Ondo state while the area with dense red colour has the highest mean temperature value of (31.9 – 32.0) °C which is mainly in Ogun state. For mean rice yield geo-spatial variation map, the area with dense blue colour has the highest rice yield of (2.1 – 2.2) °C which cut across Lagos, Ondo and Ekiti states while the area with white colour has the lowest rice yield of (1.5 – 1.6) °C which is mainly Ibadan.

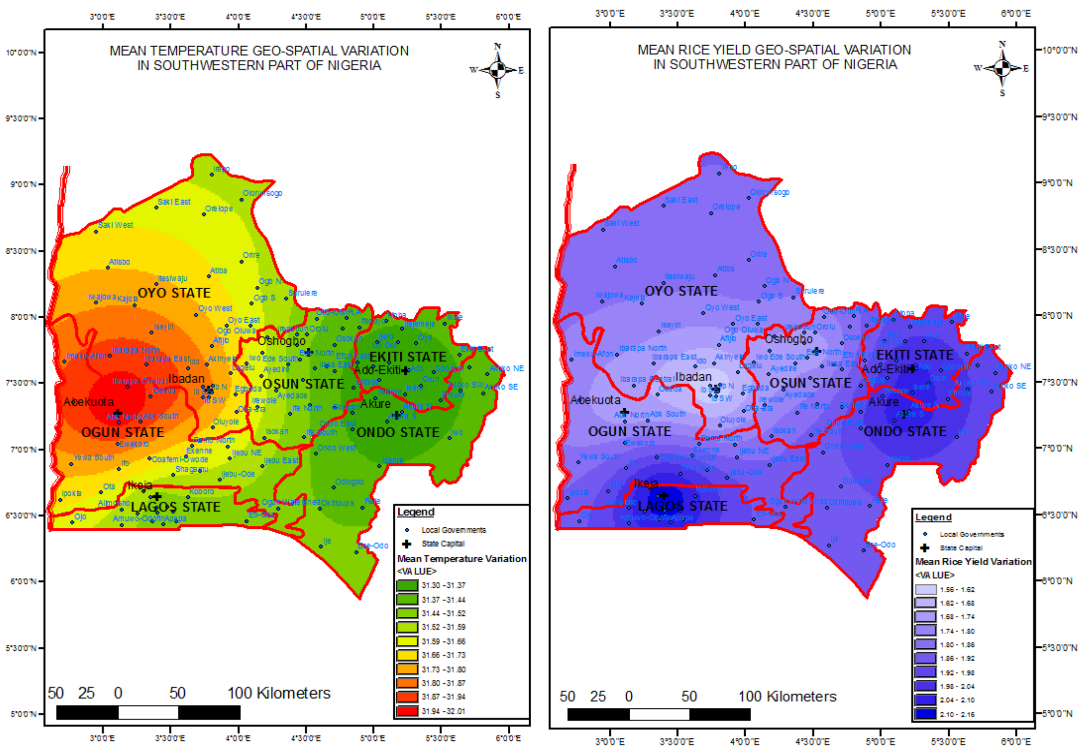

Figure 4: Maps of mean Geo- spatial Variation of Temperature and Rice yield

Correlation of Temperature and Rainfall on Rice Yield

The Correlation of rice with growing seasonal rainfall and temperature is as depicted in Table 2. For rice versus rainfall correlation, Ogun state has the highest correlation of 0.374 while there is negative correlation in Ekiti state of value -0.128. For rice versus temperature correlation, Osun state has the highest correlation of 0.448 while there is negative correlation in Ondo state of value -0.023.

Table 2: Correlation of rice yields with growing seasonal rainfall and temperature

S/N	States	Rice yield and R^s	Rice yield and T^s
1	EKITI	-0.128	-0.427
2	ONDO	-0.347	-0.023
3	OSUN	-0.238	0.448
4	OGUN	0.374	-0.081
5	OYO	0.065	-0.134
6	LAGOS	0.039	-0.146

R^s = *rainfall relationship*
T^s = *temperature relationship*

Table 3: Equation for future prediction of rice yield values in each state

S/N	States	Annual Rainfall, cm	Annual Temperature,℃
1	EKITI	Y= -1.455x + 152.3	Y= 0.023x+30.95
2	ONDO	Y= -1.455x + 152.3	Y= 0.023x + 30.95
3	OSUN	Y= -0.210x + 115.2	Y= 0.006x + 31.42

4	OGUN	Y= 0.667x + 92.91	Y= -0.025x + 32.73
5	OYO	Y= 0.081x + 108.7	Y= -0.011x + 31.87
6	LAGOS	Y= 0.769x + 120.4	Y=0.009x + 31.20

Y = Crop yield, X = Predicted year.

Table 4: Future prediction of rainfall and temperature values in each state from equations

S/N	STATES	Rainfall 2012 (cm)	Rainfall 2017 (cm)	Temperature 2012 (℃)	Temperature 2017 (℃)
1	EKITI	120.29	113.02	31.46	31.57
2	ONDO	120.29	113.02	31.46	31.57
3	OSUN	110.59	109.53	31.55	31.58
4	OGUN	107.58	110.92	32.18	32.05
5	OYO	110.48	110.89	31.63	31.57
6	LAGOS	137.32	141.16	31.40	31.44

Table 5: Equation for future prediction of rice yield values in each state

S/N	States	Rice yield and rainfall relationship	Rice yield and temperature relationship
1	EKITI	Y= 0.0087 * x + 0.85	Y= 0.28 * x - 6.5
2	ONDO	Y= 0.01 * x + 0.5	Y= 0.32 * x - 7.9
3	OSUN	Y= 0.0171 * x - 0.7714	Y= 0.6 * x - 17.7
4	OGUN	Y= 0 * x + 1.1756	Y= 0.0004 * x +1.16
5	OYO	Y= 0.008 * x + 1.22	Y= 0.267 * x - 6.43
6	LAGOS	Y= 0.012 * x + 0.04	Y= 0.8 * x - 23.48

Y= Rice yield, X = Rainfall or Temperature value

Table 6: Future prediction of rice yield values in each state for the year 2012 and 2017

S/N	States	Yield value in relation to Rainfall 2012 (tonnes)	Yield value in relation to Rainfall 2017 (tonnes)	Yield value in relation to Temperature 2012 (tonnes)	Yield value in relation to Temperature 2017 (tonnes)
1	EKITI	1.896	1.833	2.309	2.340
2	ONDO	1.703	1.630	2.167	2.602
3	OSUN	1.119	1.102	1.231	1.248
4	OGUN	1.176	1.176	1.17	1.172
5	OYO	1.104	1.147	1.015	1.999
6	LAGOS	1.688	1.734	1.640	1.672

DISCUSSION

Prediction of Future Annual Rainfall and Annual Temperature

The equation used for the future prediction of rainfall and temperature values for each state is as shown in Table 3. The dependent variables are annual rainfall, R and annual temperature, T, while the independent variable is the year represented with x and the value of x is got by subtracting the value of 1990 from the future year to be predicted i.e. (2012 – 1990) and (2017-1990) respectively. Table 4 shows the future prediction of annual rainfall and annual temperature in the study area states which was obtained by substituting the values of x obtained for each state in the equation. The value of experimental years, x obtained were 22

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and 27 years for the year 2012 and 2017, respectively for all the South Western states. From Table 4, under the annual rainfall values for the year 2012, Lagos states had the highest rainfall value of 137.32 cm while Ogun state had the lowest rainfall value of 107.58 cm. For the year 2017, Lagos state would have the highest annual rainfall value of 141.16 cm while Osun state would have the lowest annual rainfall value of 109.53 cm. For annual temperature values for the year 2012, Ogun states gave the highest annual temperature value of 32.180 ℃ while Lagos state gave the lowest annual temperature value of 31.398 ℃. For the year 2017, Ogun state would have the highest annual temperature value of 32.055 ℃ while Lagos state would have the lowest annual temperature value of 31.443 ℃.

Prediction of Future Annual Rice Yield

The result of equation used for the prediction of future annual rice yield and the values for future annual rainfall and annual temperature for each state were presented in Table 5. The dependent variable is annual rice yield represented with y while the independent variables are rainfall, *R* and temperature, *T*. The prediction of annual rice yield in the study area states was obtained by substituting the values of the predicted annual temperature and annual rainfall values for the year 2012 and 2017. For annual rice yield in relation to annual rainfall for the year 2012, Ekiti, Ondo and Lagos states had the highest annual rice yield values of 1.896, 1.703 and 1.688 tonnes, respectively while Oyo state had the lowest annual rice yield of value 1.104 tonnes. For the year 2017, Ekiti state would have the highest annual rice yield of value 1.833 tonnes while Osun state would have the lowest annual rice yield of value 1.102 tonnes. For annual rice yield in relation to annual temperature for the year 2012, Ekiti state had the highest annual rice yield value of 2.309 tonnes while Oyo state had the lowest annual rice yield of value 1.015 tonnes. For the prediction of year 2017, Ondo state would have the highest annual rice yield value of 2.6120 tonnes while Osun state would the lowest annual rice yield of value 1.17 tonnes as shown in Table 6.

CONCLUSIONS

From this study, it was discovered that the response of annual rice yield to weather changes varies from one state to another in the study area. The production and the annual yield of rice depend on the spatial temporal distribution, nature, variability and reliability of rainfall and temperature and this is visible in Ekiti and Ondo states having the highest mean annual rice yield value of 1.63 –1.90 tonnes, with the mean annual rainfall value of 113.02–120.29 cm and mean annual temperature values of 31.30 – 31.37 ℃. Annual rice yield and the amount of annual rainfall varied significantly from year to year and there was a significant relationship between annual rice yield and annual temperature or annual rainfall variability. It is visible in Ekiti and Ondo state because the higher the mean annual rainfall value, the higher the mean annual rice yield value. The Geographic Information Systems (GIS) data base created and maps generated in the study areas can be used by policy makers and climate change mitigation. The results of the study in terms of maps can also be used to help the rice farmers in order to make better rice farming plan despite the varying weather condition in terms of smart agriculture.

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