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

Olumuyiwa Idowu Ojo and Saheed Olabanjo Olawale

Department of Agricultural Engineering,
Ladoke Akintola University of Technology, Ogbomoso, Nigeria
Email: olumuyiwaojo@gmail.com

ABSTRACT
The scientific evidence of rainfall and temperature variability with their significant impacts on crops yield is now stronger than ever. It is even more so on cassava that serves as staple food in most parts of Southwestern Nigeria. Hence, this study, aimed at using Kriging interpolation and other geospatial analysis techniques to assess and map the spatiotemporal variation to investigate the relationship between the yield of cassava and temperature and rainfall for the period 17 years (1991 – 2007) in South Western, Nigeria. Data for an annual yield of cassava for all the time period were collected from the Federal Ministry of Agriculture, Nigeria, while data on the weather (temperature and rainfall) in the Southwestern states of Nigeria were obtained from the archives of the Nigerian Meteorological Services (NIMET) on an annual basis. ArcGIS (9.2 version) was used to analyze the annual temperature, rainfall and cassava yield data. Spatial variation maps were generated using Kringing method of Interpolation. Existing Map of Nigeria in JP2 format is imported into the ArcGIS software. The mean rainfall variation maps show the areas which cut cross across Lagos and part of Ogun states have the highest mean rainfall value range of 134.3 – 137.3 cm while the area having lowest mean rainfall value range of 107.6 – 110.6 cm. Mean cassava yield geospatial variation map show areas with the highest cassava yield of 16.9 – 17.8 tones with areas with the lowest cassava yield of 9.6 – 10.4 tonnes. For mean temperature variation maps, the area which cross cut across through Ekiti and part of Ondo states have the lowest mean temperature value range of 31.3 – 31.4 ^{0}C while areas, mainly in Ogun state has the highest mean temperature value range of 31.9 – 32.0 ^{0}C. Mean cassava yield geospatial variation map depicts the areas with the highest cassava yield of 16.9 – 17.8 tonnes, while the area with the lowest cassava yields of 9.6 - 10.4 tones. The results from these assessment and analysis will help cassava farmers so as to make better cassava farming plan despite the varying weather condition as to ensure smart agriculture.

Keyword*: GIS, Crop, Comparative Analysis, Temperature, Rainfall, Weather Variability*

Introduction
Cassava (*Manihot esculenta, crantz)* is a tuberous starchy root crop of the family *Euphorbiaceae* (Oriola and Raji, 2013). It is a popular crop worldwide. It is known for drought tolerance and for thriving well on marginal soils, a cheap source of calorie intake in the human diet and a source of carbohydrate in animal feed (Kordylas, 2007). It is believed to be originally native of South America. It grows well in areas with annual rainfall of 500-5000 mm and full sun, but it is susceptible to cold weather and frost (Agodzo and Owusu, 2002). A very wide range of cassava varieties is grown worldwide depending on the locality, but they are broadly classified into the sweet and the bitter varieties based on the level of the poisonous hydrogen cyanide (HCN) present in the tuber, they are also classified based on time to maturity (Oriola, 2013). According to Uthman (2011), Nigeria is the highest producer of the crop in the world with production level estimated at 49 million tonnes per year, this is a third more than the production in Brazil (The world's second largest cassava producer), and almost doubles the production of Indonesia and Thailand. Cassava is presently the most important food crop in Nigeria from the point of view of both the area under cultivation and the tonnage produced due to the fact that it has transformed greatly into high yielding cash crops, a foreign exchange earner, as well as a crop for world food security and industrialization. As a result of this there has been an unprecedented rise in the demand for cassava and its numerous products worldwide for both domestic and industrial applications (Adetunji and Quadri, 2011). The world import demand for cassava in 2004

stood at 25 million tonnes, while the local demand by poultry farmers alone was 400,000 tonnes. The 180 million litres yearly domestic demand for ethanol in Nigeria was met through importation in 2005 (Nigeriafirst, 2011). The Federal Government of Nigeria recent's directive that flour millers must substitute 10% of the wheat flour with cassava flour has also led to a surge in demand to the tune of 600,000 tons of processed cassava per day, apart from orders from abroad for semi-finished cassava products in the form of chips and pellets (Olukunle, 2005).

A geographic information system (GIS) is designed to visualize, store and analyze the information about the locations, topology, and attributes of spatial features. In GIS, location data and their map representations are dynamically linked so that any changes made in the databases are reflected immediately on its map presentation. The linkage between the map and databases makes GIS an ideal and strong tool for spatial data visualization and analysis (Bao *et al.,* 2006). According to David (1997) the use of GIS for this purpose involves the development of a GAM which requires immense quantities of spatial and temporal data, including geology, soils, census, aquifer properties, hydrograph, and land use. Weather variability is rapidly becoming the most important environmental challenge facing mankind as small temperature changes may seem inconsequential to the unwary, but only because small temperature shifts are often inconspicuous to people affecting urbanization which has been found to modify the city climate (Bryson and Ross, 2004). This problem includes the effects of the changes in physical land surface, which increases in roughness and wind speed. Furthermore, several human activities generate enormous particles into space that are capable of greatly modifying the solar energy incident on the earth's surface. Abnormal changes in temperature and rainfall, increasing frequency, intensity of droughts and floods have long-term implications on crop yield. Essentially, agriculture is the sector most affected by changes in climate patterns and will be increasingly vulnerable in the future. Especially at risk are developing countries like Nigeria, which are highly dependent on agriculture and have fewer resources and options to combat damages from weather variation (Bryson and Ross, 2004). According to Adejuwon (2004) intra-annual rainfall variability refers to the distribution of rainfall within a year. In the last decade, inter-annual rainfall variations are causes of great stress to the farming activities, crop production and crop yield in the Guinea Savanna of Nigeria. His study examined inter-annual rainfall variability in Nigeria and other part of West Africa. It affects the various aspects of plant growth and yields; consequently, alter crop productivity. According to a study by Awosika *et al.*, (1998) the aggregate impact of drought on the economy of Nigeria in 1992 was between 4 % and 6 % of the GDP. From an analysis of recent rainfall conditions in West Africa, FAO (2001) concluded that a long-term change in rainfall has occurred in the semiarid and sub humid zones of West Africa. Although, it may appear that little or nothing could be done to improve variability in rainfall since most of its causes are natural. Thus, there is need for in-depth study and understanding of spatiotemporal rainfall variability. Surprisingly, little systematic research has focused on the distribution patterns of the impacts of rainfall variability in terms of mapping its spatiotemporal impact using the modern GIS techniques such as Kriging interpolation technique. The Cost of using GIS applications in weather variability still slows the acceptance of this new technology. The applications of GIS in weather variability are relatively new (Kopp, 2004). Considering the effect of weather variability on Cassava yield and the difficulties associated with it, there is therefore the need for an integrated method of GIS modeling system, to allow agricultural producer as well as policy makers to know the impact of spatial temporal variation of weather on cassava yield for better management, productivity and profitability (Ayanlade & Odekunle 2009).

Methodology

Study Area

The study area is South western Nigeria, which consists of Lagos, Ogun, Oyo, Osun, Ondo and Ekiti states. According to Agboola (2004) the area lies between longitude $2^0 31^1$ and 6^0 00^1 East and Latitude 6^0 21^1 and 8^0 37^1 N with a total land area of 77,818 km^2 and a projected population of 28, 767, 752 millions in 2002. 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) of the South west Nigeria are shown in Table 1, Figure 1 shows the position of the study area in the map of Nigeria.

Table 1: Coordinates of South Western states. Source: (Agboola, 2004)

S/N	States	Latitude	Longitude
1	Oyo	8^0 00' 00'' N	4^0 00' 00'' E
2	Osun	7^0 30' 00'' N	4^0 30' 00'' E
3	Ekiti	7^0 40' 00'' N	5^0 15'00' E
4	Ogun	7^0 00' 00'' N	3^0 35' 00' E
5	Ondo	7^0 10' 00'' N	5^0 05' 00''E
6	Lagos	6^0 35' 00'' N	3^0 45' 00' E

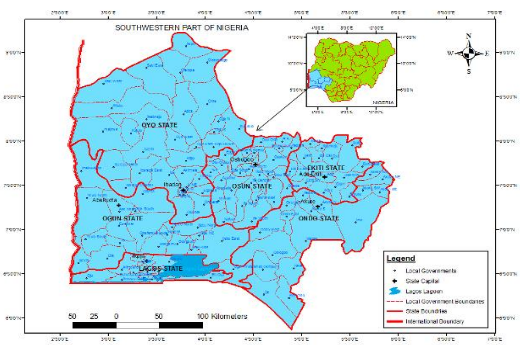

Figure 1: Map of the study area (South Western, Nigeria)

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. The rainfall and temperature data used in this study consist of annual rainfall and temperature, total for the period of 1991 to 2007. The cassava yield data for the six states of South western Nigeria on an annual basis on the other hand were collected from Federal Ministry of Agriculture, Nigeria. The annual cassava yield data were collected based on the ratio of expected annual yield and exact annual yield, while the geographical map of Nigeria used was downloaded from the internet by exploring.

Geospatial analysis

Geospatial analysis involved the use ArcGIS version 9.2 to analyze annual temperature, rainfall and cassava yield data geo-spatial variation by Kringing method of Interpolation. Existing Map of Nigeria in JP2 format was imported into the ArcGIS version 9.2 interfaces. The Nigeria map was being geo-referenced by correcting and updating the map with the correct coordinates. After which it was then pre-processed by geo-referencing, rectifying, updating and digitizing it. Geo-referencing was done by assigning the right coordinates to the Nigeria map. Rectification was done by changing the coordinates of the map from old coordinates to the newly assigned correct coordinates so as to register the map into ArcGIS internal environments and updating is re-adding the registered map, digitizing, the last face in map preprocessing done for editing/carving out necessary features from an existing map. Southwestern part of Nigeria map, its states, states capitals, local governments and boundaries were expunged out from the existing maps. Temperature, rainfall and cassava yields values were recorded in the state capital attribute table. ArcGIS version 9.2 was further 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 serve as major outputs were then reclassified and post-processed by laying-out and exporting them. The interpolated maps were exported in TIFF formats. Figure 2 is the flow chart describing map interpolation process using kringing method of interpolation.

Variables Correlation and Prediction of Crop Yields

Annual cassava yield time series were correlated with annual temperature and annual rainfall time series for individual states. The correlation of these variables helps in the prediction of cassava yields for each state in Southwestern part of Nigeria. Linear regression equations of annual temperature and annual cassava yield were used to predict crop yield value by making annual temperature to serve as the independent variable and vice versa. In the same way, future crop yield is extracted from rainfall values and the totals were averaged.

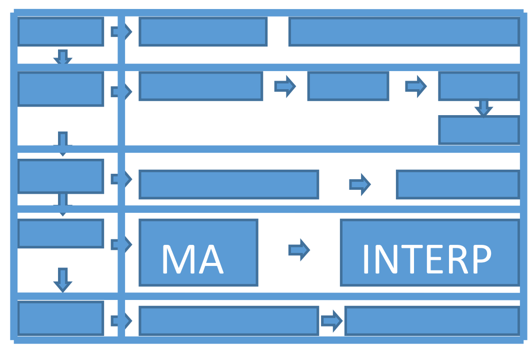

Figure 2: Flow Chart of Kringing Method of Interpolation

Results and Discussion

Mean Annual Rainfall and Mean Annual Cassava Yield Maps

Mean rainfall and mean cassava yield values were obtained by inputting the rainfall and cassava yield values for the 17 years on the GIS software. Figure 3 depicts the geospatial variation map generated for the mean annual rainfall and mean cassava yields of the study area. For mean annual rainfall variation maps, the areas which covers Lagos and part of Ogun states represent the area having the highest mean annual rainfall value ranges from 134.3 cm to 137.3 cm, while the area with the lowest mean annual rainfall value ranging from 107.6 cm to 110.6 cm. For mean annual cassava yield geospatial variation map, the area with the highest cassava yield ranges from 16.9 tonnes to 17.8 tonnes, while the area with the lowest cassava yield ranges from 9.6 tonnes to 10.4 tonnes. From the maps, the low mean annual yield of cassava in Oyo state was as a result of the low mean annual rainfall because cassava is a crop that needs constant water.

Mean Annual Temperature and Mean Annual Cassava Yield Maps

Mean annual temperature and mean annual cassava yield values were obtained by inputting the annual temperature and annual cassava yield values for the 17 years on the GIS mean icon at the statistical analysis field. Geospatial variation map of mean annual temperature and mean annual cassava yields of the study area is shown in Figure 4. For mean annual temperature variation map, the area across Ekiti and part of Ondo states represent the area having the lowest mean temperature value ranging from 31.3 ^{0}C to 31.4 ^{0}C while area mainly located in Ogun state, represents the area having the highest mean temperature value ranging from 31.9 ^{0}C to 32.0 ^{0}C. For mean annual cassava yields variation map, the area with dense blue colour represent the area having the highest cassava yield ranging from 16.9 tonnes to 17.8 tonnes while the area with white colour represent the area having the lowest cassava yield ranging from 9.6 tonnes to 10.4 tonnes. The low annual yield of cassava in Ibadan is as a result of the low mean annual rainfall which reduces the process of photosynthesis.

Correlation of Annual Rainfall and Annual Temperature on Annual Cassava Yield

Correlation of annual rainfall and annual temperature on cassava yield was obtained by utilizing linear regression equation on Arc GIS version 9.2 interfaces. Table 2 gave the correlation of cassava yield with rainfall and temperature respectively. The annual cassava yield is the dependent variable while annual rainfall and annual temperature is the independent variables respectively. The annual Cassava yield is represented by (Y) in the equation while the annual temperature and annual rainfall is represented by (x) in each case.

Table 2: **C**orrelation of cassava yield with rainfall and temperature

S/N	States	Cassava Yield and Rainfall Relationship	Cassava Yield and Temperature Relationship
1	Ekiti	Y= 0.05 * x + 9	Y= 1.6 * x – 33
2	Ondo	Y= 0.075 * x + 7	Y= 2.4 * x – 56
3	Osun	Y= 0.0857 * x + 4.1429	Y= 3 * x - 80.5
4	Ogun		Y= 0.24 * x + 7.46
5	Oyo	Y= 0.006 * x + 14.66	Y= 1.667 * x - 43.83
6	Lagos	Y= 0.05 * x + 4	Y= 12 * x - 363.2
		Y= 0.18 * x - 10.4	

Note: X= Rainfall or Temperature value

Prediction of Annual Rainfall and Annual Temperature

The equation used for future prediction of annual rainfall and annual temperature values for each state is captured in Table 3. The dependent variable is annual cassava yield represented with (y) while the independent variable is year represented with (x) and the value of x is gotten by subtracting the 1990 from the future years to be predicted (2012 – 1990) and (2017-1990) respectively, while Table 4 shows predictions of annual cassava yields in the study area which was obtained by substituting the values of x obtained for each state in the equation of each state. The value of x is 22 years for the year 2012 and 27 years for the year 2017 for all the South Western states. From Table 4, for annual rainfall values for the year 2012, Ekiti and Ondo states has joint highest rainfall value of 184.310 cm while Ogun state has the lowest rainfall value of 107.582 cm. For the year 2017, Osun state will have the highest annual rainfall value of 120.870 cm while Oyo state will have the lowest annual rainfall value of 110.887 cm. For annual temperature values for the year 2012, Ogun state has the highest annual temperature value of 32.180 º C, while Lagos state has the lowest annual temperature value of 31.398 º C. For the year 2017, Ogun state will have the highest annual temperature value of 32.055 º C while Lagos state will have the lowest annual temperature value of 31.443 º C.

Table 3: Equation for prediction of annual rainfall and annual temperature values

S/N	States	Annual Rainfall	Annual Temperature
1	EKITI	R= -1.455x + 152.3	T= 0.023x+30.95
2	ONDO	R= -1.455x + 152.3	T= 0.023x + 30.95
3	OSUN	R= -0.210x + 115.2	T= 0.006x + 31.42
4	OGUN	R= 0.667x + 92.91	T= -0.025x + 32.73
5	OYO	R= 0.081x + 108.7	T= -0.011x + 31.87
6	LAGOS	R= 0.769x + 120.4	T=0.009x + 31.20

Prediction of Future Annual Cassava Yield

For the prediction of annual cassava yield, the values for future annual rainfall and temperature were used. The equation used for the prediction of annual cassava yields for each state is shown in Table 5. The dependent variable is annual cassava yield represented with (y) while the independent variable is represented with (x), while Table 6 shows the predictions of annual cassava yields in the study area states which was obtained by substituting the values of the predicted annual temperature and annual rainfall values for the year (2012 and 2017).

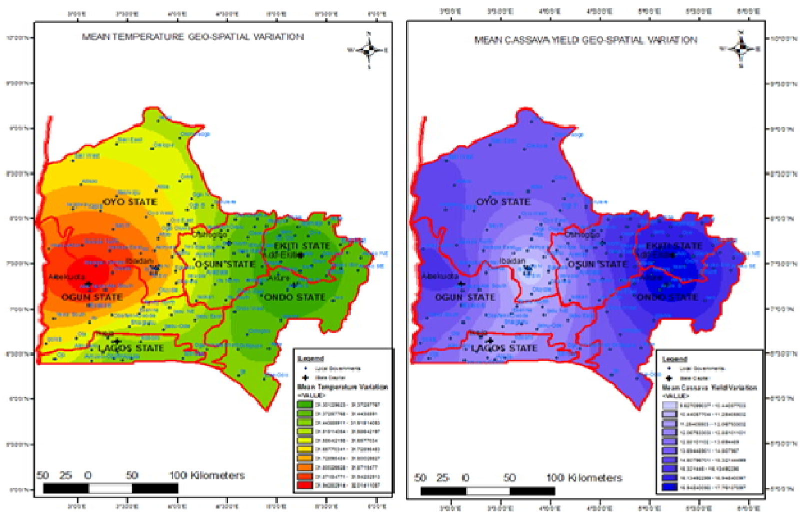

Figure 3: Geospatial variation map of mean annual rainfall and mean annual cassava yields

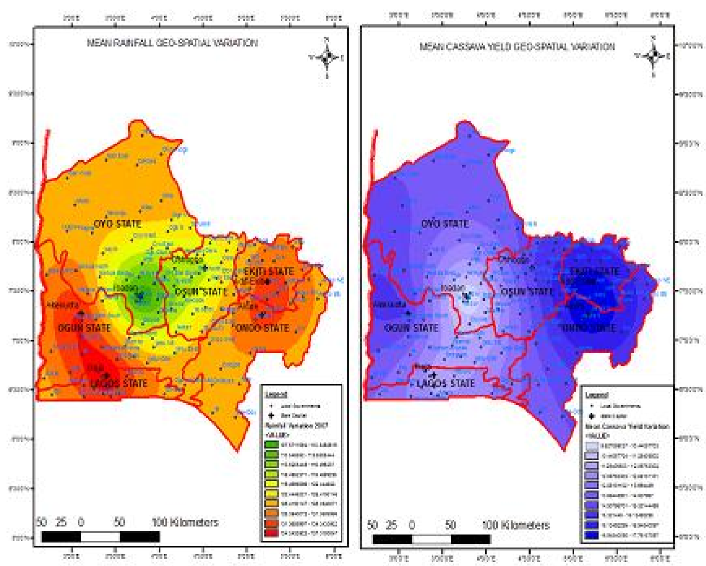

Figure 4: Geo- spatial variation map of mean annual temperature and mean annual cassava yields

Table 4: Prediction of Mean Annual Rainfall and Temperature Values

S/N	States	Rainfall (2012) in cm	Rainfall (2017) in cm	Temperature (2012) in ° C	Temperature (2017) in ° C
1	Ekiti	120.29	113.02	31.46	31.57
2	Ondo	120.20	191.59	31.46	31.57
3	Osun	119.82	120.87	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	31.39	31.44

For annual cassava yield in relation to annual rainfall for the year 2012, Osun state has the highest annual cassava yield of value 18373.5 tonnes, while; Ondo state has the lowest annual cassava yield of value 33.273 tonnes. For the year 2017, Lagos state has the highest annual cassava yield of value 1330.756 tonnes, while Ogun state has the lowest annual cassava yield of value 34.080

tonnes. For annual cassava yield in relation to annual temperature for the year 2012, Ogun state has the highest annual cassava yield of value 14.835 tonnes, while; Lagos state has the lowest annual cassava yield value of 4.7484 tonnes. For the year 2017, Ogun state has the highest annual cassava yield of value 14.8523 tonnes, while Lagos state has the lowest annual cassava yield of value 4.7403 tonnes.

Table 5**:** Equations for prediction of cassava yield values

S/N	States	Cassava yield and Rainfall Relationship	Cassava yield and Temperature Relationship
1	Ekiti	Y= 0.05 * R + 9	Y= 1.6 * T – 33
2	Ondo	Y= 0.075 * R + 7	Y= 2.4 * T – 56
3	Osun	Y= 0.0857 * R + 4.1429	Y= 3 * T - 80.5
4	Ogun	Y= 0.006 * R + 14.66	Y= 0.24 *T + 7.46
5	Oyo	Y= 0.05 * R + 4	Y= 1.667 *T - 43.83
6	Lagos	Y= 0.18 * R - 10.4	Y= 12 * T - 363.2

Note Y= cassava yield, R= Rainfall; T= Temperature value

Table 6: prediction of annual cassava yield values for the year 2012 and 2017.

S/N	STATES	Yield and Temp (2012)	Yield and Temp (2017)	Yield and Rainfall (2012)	Yield and Rainfall (2017)
1	Ekiti	10.5728	10.5786	156.264	147.827
2	Ondo	9.3592	9.3678	227.896	215.236
3	Osun	6.8469	6.8493	251.24	248.090
4	Ogun	14.8531	14.8523	33.279	34.080
5	Oyo	5.5814	5.5786	18373.5	141.018
6	Lagos	4.7484	4.7403	1284.6	1330.756

The results of the analysis and the maps produced show that weather variability brings about the differences in water availability which consequently affect the rate of cassava yield in South western part of Nigeria. For rainfall values for the year 2012; Ekiti and Ondo states have joint highest rainfall value of 184.310 cm, while Ogun state has the lowest rainfall value of 107.582 cm. For the predicted year 2017; Osun state will have the highest rainfall value of 120.870 cm, while Oyo state will have the lowest rainfall value of 110.887 cm. For temperature values for the year 2012; Ogun states has the highest temperature value of 32.180 ºC, while Lagos state has the lowest temperature value of 31.398 ºC. For the year 2017; Ogun state will have the highest temperature value of 32.055 ºC, while Lagos State will have the lowest temperature value of 31.443 ºC. Future annual cassava yield in relation to annual rainfall for the year 2012; Osun state has the highest annual cassava yield of value 18373.5 tonnes while, Ondo state has the lowest annual cassava yield of value 33.273 tonnes. For the year 2017; Lagos state has the highest annual cassava yield of value 1330.756 tonnes, while Ogun state has the lowest annual cassava yield of value 34.080 tonnes. For annual cassava yield in relation to annual temperature for the year 2012, Ogun state has the highest annual cassava yield of value 14.835 tonnes while; Lagos state has the lowest annual cassava yield value of 4.7484 tonnes. For the year 2017; Ogun state has the highest annual cassava yield of value 14.8523 tonnes, while Lagos state has the lowest annual cassava yield of value 4.7403 tonnes.

Conclusion

The mean geo-spatial variation of rainfall and cassava yield show that the area with moderately high rainfall has the highest cassava yield range of 16.9 to 17.8 tonnes and lowest cassava yield range of 9.6 to 10.4 tonnes, while mean geo-spatial variation of temperature and cassava yield show that the area with relatively low temperature has the highest cassava yield range of 16.9 to 17.8 tonnes and lowest cassava yield range of 9.6 to 10.4 tonnes in the study area which means that rainfall and temperature variables affect water availability and consequently affects cassava yields in the study area. Hence the production and the yield of cassava highly depend on the spatial-temporal distribution, nature, variability and reliability of rainfall and temperature. There was a significant relationship between cassava yield and temperature and rainfall variability. Cassava yield and the amount of rainfall varied from year to year. The high yields of cassava in Ekiti and Ondo state was as a result of heavy mean rainfall and also low mean temperature which allow water availability. The results from these assessment and analysis will help cassava farmers so as to make better cassava farming plan despite the varying weather condition as to ensure smart agriculture.

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