Application of Multi-Criteria Decision Making (MCDM) Model in Agro-climatic Zoning of Taraba State for Ofada Rice Production

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Abstract

Ofada is one of the rice varieties cultivated in Nigeria whose demand is increasing at both local and international levels because of its unique test and nutrient content. Ban on importation of rice into the country and population increase is major factors that push the need to increase local production of the variety so as to meetup with the growing demand. In regards to this, this paper applied Multi-Criteria Decision Making (MCDM) model in Agro-Climatic Zoning of Taraba State for Ofada rice Production. Climatic variables (1979-2017), Rice Yield (OFADA Variety), Digital Elevation Model (DEM), Landsat 8 (OLI) and Soil Texture map were the data used. Stepwise regression analysis between rice yield and the climatic variables were analyzed in SPSS and Minitab. MCDM was used to produce the Agro-climatic zoning with the help of Arc GIS 10.2. Results of the stepwise regression revealed that mean temperature is the critical climatic elements for local rice variety and accounted for 43.1% of the variation in Local Rice yield in the State while, June Rainfall, Minimum Temperature and Solar Radiation are the critical climatic variables for Ofada variety and accounted for 64.0% of the variation in yield of the variety. Result of the Ofada rice suitability map showed an area of 38.14%, 40.08%, 20.99% and 0.80% for highly suitable, suitable, moderately suitable and not suitable area respectively for the variety. Cultivation of rice should be encouraged in Highly Suitable and Suitable zones of the State while, alternative crops other than rice are recommended for the not suitable area. Information on latest crop cultivation method should be explained to farmers so as to reduce crop yield failure. Finally, application of Multi Criteria Decision Making (MCDM) a Remote Sensing and GIS tool should be employed in suitability zoning of other crops in the State.

Keywords: OFADA Rice Variety, MCDM, Agro-climatic, Landsat 8, DEM

INTRODUCTION

Ofada rice is one of the major rice variety cultivated in Nigeria, the variety is name based on the fact that it was produced and processed in a village called Ofada and other rice producing clusters of the South-West Nigeria (Gyimah-Brempong *et al.*, 2016; Adekoyeni *et al.,* 2012; Danbaba *et al.*, 2011 and NCRI/ARC, 2005). It was documented that the crop was first cultivated in Abeokuta, Ogun State and was introduced through missionary activities in 1850s to 1970s and it was then spread to Lagos area in Epe and Okitipupa; from there it was moved to Ogoja and Abakaliki provinces after the Second World War and further spread across the sahara, and to northern Nigeria via the Trans-Saharan trade (Selbut, 2003). Because of the unique taste and aroma of the variety which makes it more popular than other local varieties with distinct taste when cooked, the demand and consumption of the variety is increasing at both local and International level (Adekoyeni *et al.*, 2018). For example, it was observed that recently, the crop has become popular as special rice often served at parties and other status events by the elites; sold in fast food restaurants, and also in ½ kg boxes by marketers in Lagos, Ibadan, Abeokuta and other cities in the South West with spread effects to other parts of the country (Oyedepo *et at,*. 2018). Similarly, recent report by Premium Times (2019) documented that Ofada rice can now be packaged and sold to Nigerians in UK and USA in 1 kg or 2 kg bags like the old Uncle Bens rice.

Following the special attention and demand given to the rice variety, it is clear that there is a need for increase in production of the variety so as to meet up with the growing demand of the consumers. Although, several program and initiative were set by the Federal Government of Nigeria to improve Agricultural production especially rice; for example, the Anchor Borrowers Program (ABP) in 2015, Presidential Fertilizer Initiative (PFI) in 2016, Presidential Economic Diversification Initiative (PEDI) in 2017 and Food Security Council in 2018 (Toromade, 2018 and Iwuchukwu and Igbokwe 2012), but in spite of all these development, farmers in the country are still battling with some challenges among which are climate related issues. Actually, this is not surprising because technology alone cannot improve crop production, rather a period of favorable climatic condition interacts with Agricultural technology to improve crop yield, owing to the fact that, climate is very sensitive to agricultural production (Adebayo, 2000; Ayoade, 2005; Wassmann, 2010 and Odozi, 2014).

Climate is one of the major environmental factor affecting the growth and yield of crop. For instance, it was observed that, increase in temperature by 1.5 ^{O}C and 2.0 ^{O}C decrease flowering durations by 2.8 days and the maturity date by 11.0 days respectively, and also reduce yield of early and late mature rice varieties by 292.5 kg/ha and 151.8 kg/ha respectively in China (Yahui *et al.,* 2019). Furthermore, the amount and distribution of Precipitation, solar radiation, wind speed, temperature, relative humidity, and other climatic parameters affect and solely influence the global distribution of crops, its productivity and hence farmer's profit (Ayoade, 2005 and Stigter, 2004). In the same way, extreme weather conditions such as increasing concentration of greenhouse gases through its role in developmental stages of crops will negatively affect it's productivity and food self-sufficiency particularly rice production (Ajetomobi *et al.*,., 2011; Odozi, 2014 and Marie *et al.*,., 2019).

In Taraba State, study by Angela and Fidelis (2013) revealed that, rice farmers in the state are facing climate related challenges in their farm operation which include increase in temperature and attack by pest and diseases that resulted to poor yield. It is against this background that this study is design to examine the critical climatic factors affecting Ofada rice yield and map out suitable places for cultivation of the variety in the State.

Study Area

Taraba State was carved out of the former Gongola State on 27th August 1991 by the then regime of General Ibrahim Babangida. The State is one of the Nigerian thirty-six (36) state located in North-Eastern part of the country and has a coordinate of latitude 6º30' and 8º30' North of equator and longitude 9º00' and 12º 00' East of the Greenwich meridian (Figure 1). The area is made up of high plains which covered those parts of the Benue low lands lying above flood level but below 1000 foot contour line and include places around Karim Lamido, Jalingo, Sunkani and some part of Wukari while the high highlands are erosional in nature and are cut in sedimentary formations Udo (1978). River Benue is the major river in the state (Adebayo and Umar, 1999). River Donga and Taraba are the dominant river systems which flow across the Muri plains to drain the entire

State together with the minor ones, such as the Lamorde and Mayo Ranewo as displayed in Figure 1 (TYPA, 2009).

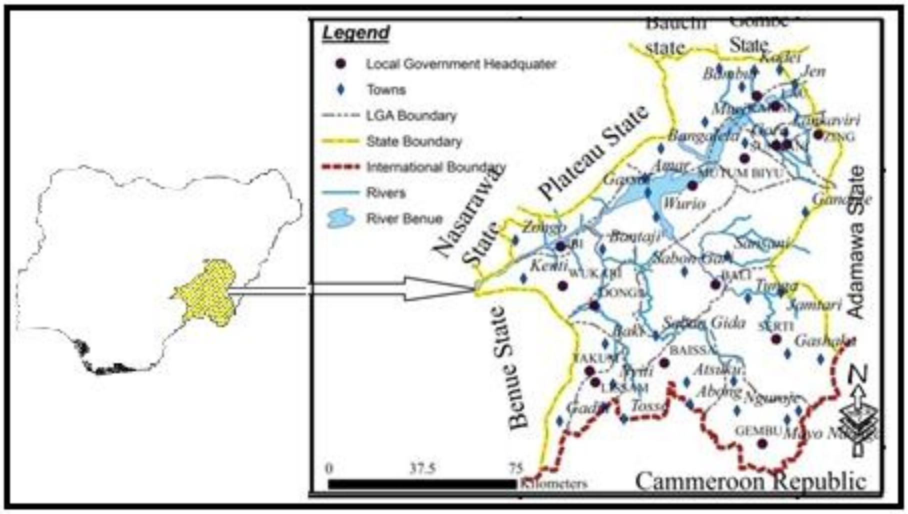

Figure 1: Map of Nigeria with Taraba State to the left. Study area to the right.

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

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

Types and source of Data

In this research work, six (6) different datasets namely; Climatic variables, annual rainfed Rice yield (Ofada Variety), Map of the study area, Geographical coordinate, Digital Elevation Model (DEM) Shuttle radar topographic mission (SRTM) and Soil texture maps were the data used in this research were used. All climatic data were collected from Upper Benue River Basin Development Authority (UBRBDA), Taraba State Agricultural Development Program (TADP) (Area, Zonal and Head office) in the State, Taraba State University Jalingo, Federal Polytechnic Bali, Nigerian Meteorology (NIMET) Ibi and worldCli-Global. Rice yield (Ofada Variety) data based on and LGAs, on the other hand, were collected from Taraba State Agricultural

Development Program (TADP) Area, Zonal and Head office in the State for the available years (2011-2017). Slope map of the State was produced from Digital Elevation Model (DEM) data of Shuttle radar topographic mission (SRTM) 30m resolution downloaded from USGS web site (glovis.usgs.gov). Soil Texture map of the State was extracted from the Nigerian Soil map produced by Soil Survey Division, Federal Department of Agricultural Land Resources (FDALR), Kaduna was downloaded from the European Digital Archive of Soil Maps **(**EuDASM) (2017).

Method of Data Analysis

The agro-climatic zoning method suggested by Adebayo (2000) and Ayoade (2005) was used in this study. The method integrates both heat and moisture climatic variables that were identified to be critical for the cultivation of rice in the Study Area. The method involves statistical techniques of stepwise multiple regression where rice yield is regressed with the critical climatic variables that are known to influence the yield of rice and the key predictor variables obtained from the regression analysis are then used as criteria to classify the State into agro-climatic zones suitable for cultivation of Rice.

Method of Extracting Criteria Maps for the Agro-climatic zoning

In an attempt to produce the map of the various selected criteria as layers for agro-climatic zoning of Taraba State for rice production, the selected criterion was analyzed and produced separately. For the selected Agro-climatic variables, the critical climatic variables influencing rice variety selected from stepwise multiple Regression analysis result were the identified climatic criteria for the zoning. Mean spatial climatic maps of Taraba state was used in criteria analysis. The Maps were scaled and reclassified into four (4) classes as highly Suitable, Suitable, Moderately Suitable and not suitable area. The suitability scale used was generated based on the nature and extent of the relationship between the climatic variables and rice yield obtained in the stepwise multiple regression and idea from experts. DEM as one of the criteria was processed then reclassified into four (4) different classes (highly Suitable, Suitable, Moderately Suitable and not suitable). In addition, Soil texture map of the study area was also reclassified into four classes (highly Suitable, Suitable, Moderately Suitable and not suitable). The method used by Getachew and Solomon (2015) and Joseph *et al.*, (2013) was adopted in scaling the soil texture and slope suitability zone for rice cultivation.

Application of weight on the selected criteria

Analytical Hierarchy Process (AHP)/Pair-wise Comparison Method (PCM) tested to be the most widely accepted method and the most reliable MCDM method that helps to measure the weight of criteria with respect to another was applied in this study (Getachew and Solomon, 2015 and Mu and Pereyra-Rojas, 2017). To apply the method in this research, four (4) major steps were followed; Development of AHP/PCM, Normalization of the criteria, calculation of the weight of each criterion and test of consistency index and ratio as also presented by (Mu and Pereyra-Rojas, 2017). The Pair-wise Comparison Method (PCM) designed by Saaty, (2012) was adopted in assigning scale and matrix computation of the selected criteria (Table 1). In assigning the scale, the stepwise regression result was used in determining the important of one variable to the other variable where high scale value represents high important and low scale value represents low important. Normalization is the next step after the PCM, in Normalization, row value of a criterion is divided by the column total of the criterion to obtain the overall or final priority (Mu and Pereyra-Rojas, 2017). The last step is the test of consistency, in AHP application, it is expected that there is a consistency in assigning weight among the criteria used, as such consistency test was used (Mu and Pereyra-Rojas, 2017). For the Pair-wise comparison consistency to be tested, consistency ratio tool was used to test the accuracy in Pair-wise matrix judgment. The acceptance level for the judgment is therefore presented as CR $\leq$ 0.10 (Saaty, 1977). The ratio is calculated using the equation below:

$$CR = {}^{CI}/_{RI}$$

Where CI = consistency index

RI = Random index (Table 1).

Consistency index, on the other hand, is calculated as; $CI = (\lambda\text{-}n)/(n-1)$

Where Lambda (λ) is the maximum Eigen value and n is numbers of criteria in the Pair-wise comparison.

Table 1: Saaty's Pair-wise comparison scale. Courtesy, Saaty (2012)

Numeric value	Verbal Judgment
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely important
Reciprocals	Values for Inverse Comparison

Table 2: Random Index (RI). Courtesy, Saaty (2012)

Order matrix	1	2	3	4	5	6	7	8	9	10
RI	0.0	0.0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Agro-climatic zoning for Cultivation of Rice based on the selected Climatic Variables

Agro-climatic suitability zones for the cultivation of different varieties of rice were produced after considering all the MCDM (AHP) steps presented above. In producing the suitability zones, the weighted overlay tool in the spatial analysis toolbox of Arc GIS 10.2 was used. All the selected climatic criteria for rice suitability maps were added into the Arc GIS environment using add data tool. The added layer of the selected criteria was then added into the weighted overlay environment together with their specific weight obtained from the AHP result and then run to produce the final output of the suitability map (Figure 3.4). Areas of the suitability classes were calculated in km^2 one after the other by highlighting the layer (Class) in the attribute table, reclassified the map to produce the area of the selected class.

Suitability zoning for Cultivation of Rice based on climatic variables, Soil, and Slope

To produce the suitability maps, AHP/PCM method was also applied to obtain the accurate estimate of each selected criterion for weighted overlay. The selected climatic variables, soil and slope of the State were overlaid using the same procedure of producing suitability zone explained in the last section above. In applying the method, the Agro-climatic Suitability zones produced in the last section above together with the soil and slope suitability map for rice cultivation were used as criteria for the zoning. All the criteria mentioned were then added into the Arc GIS environment, overlaid and the suitability classes were calculated.

Comparison of the Agro-climatic zones with NDVI

The final section is the comparison of the suitability map produced based on climatic variables, soil and slope of the Study area with the NDVI of the State in other to examine the impact of buildup area, water bodies and barren rock areas on the suitability map produced. To achieve this, present vegetation cover index of the study area was produced using Normalized Difference Vegetation Index (NDVI). In producing the NDVI, Landsat 8 OLI images were downloaded and process in Arc GIS by removing the no data background and mosaics all the images into one layer. The mosaic image was then processed and produced NDVI using Image analysis tool. In other to extract the study area from the NDVI layer, Taraba State shape file was used to extract Taraba State area from the NDVI layer using extraction by mask in arc toolbox. To classified the NDVI, the classes suggested by USGS and NASA was adopted. United State Geological Survey (USGS) and NASA Classified NDVI values into three classes based on the characteristics of surface features; Areas of barren rock, sand, or snow usually shows very low NDVI values of 0.1 or less, Sparse vegetation such as shrubs and grasslands or senescing crops is the second class with approximate value of 0.2 to 0.5 while areas with High NDVI value of approximately 0.6 to 1.0 represent dense vegetation. Following the aim of this study, NDVI of Taraba State was classified into three classes based on NASA method of grouping (Not Suitable class (0.1 or less), Highly Suitable class (0.2 to 0.5) and Moderately Suitable class (0.6 to 1.0).

To examine the effect of NDVI map on Agro-climatic zones for Ofada rice production, the two suitability maps were overlaid using Fuzzy overlay in the arc toolbox.

RESULTS AND DISCUSSION

Climatic Criteria maps

Result of the stepwise regression analysis between agro-climatic variables and Ofada rice yield identified three climatic elements (Minimum temperature, Solar Radiation and June rainfall) which are critical for the yield of the variety in the State (See Table 3). Table 4 displayed the scale used in assessing and producing the climatic criteria maps for suitability zoning of the selected rice variety. The scale of the criteria was produced based on the relationship between climatic variables and the selected rice varieties in the study area, reviewed related Literature and Professional advice.

Table 3: Stepwise Regression result between Ofada Variety and Climatic Variables

Predictor	Coef	SE Coef	T	R^2 (%)	R^2(adj)	R^2(pred)	VIF
Constant	13.119	6.171	2.13*				
Min. Temp	0.33836	0.09385	3.61**	40.70	38.42	33.31	1.009
Solar Rad.	-0.7836	0.2362	-3.32**	55.17	51.58	47.48	1.173
June Rain.	-0.0033	0.00137	-2.42*	63.98	59.45	53.06	1.164

** T-value is significant at 1%, * T-value is significant at 5%

Figures 2 showed the identified climatic criteria maps while Figure 3 on the other hand displayed the Soil texture and Slope maps which were also used in the Agro-climatic zoning of Taraba State for rice cultivation. The maps were produced based on the scale presented in Table 6.2. Soil texture and slope maps were used based on the fact that they play an important role in rice growth and yield. Soil texture and Slope of a place did not only determine the nutrient composition of a place but also determines the water retention capacity that will support the growth and yield of the crop.

The soil texture and Slope maps are classified into four different classes and the method used was adopted from (CSR/FAO, 1983; Joseph *et al.*,, 2013 and Getachew and Solomon, 2015) (Table 5).

Table 4: Scale of the idendified critical climate variable

	Highly Suitable	Suitable	Moderately Suitable	Not Suitable
Minimum Temperature (°C)	>20.5	19.1-20.4	17.1-19	<17.1
Solar Radiation (MJ/m^2)	19.5-20.5	20.6-21.0	21.0-21.5	>21.5
Rainfall in June (mm)	140-190	191-200	201-230	>230

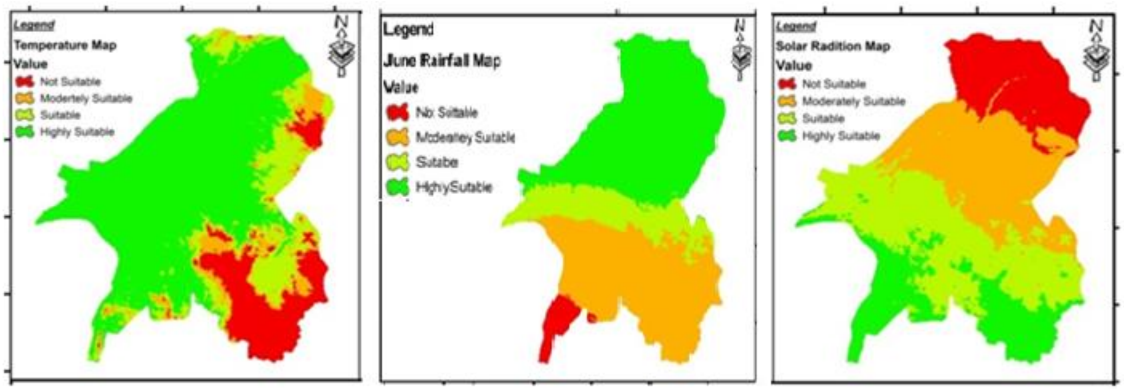

Figure 2: Identified Climate (moisture) criteria. These are temperature (left), rainfall (middle) and solarradiation (right).

Table 5: Scale of the Soil texture and Slope criteria

	Highly Suitable	Suitable	Moderately Suitable	Not Suitable
Soil Texture	Sandy Clay Loam, Clay Loam, Silt Loam, Silt Clay Loam	Sandy Clay, Sandy Loam	Loamy Sand, Massive Clay, Silt Clay	Sandy, Gravels
Slope (%)	<5	5-8	8-20	>20

Source: CSR/FAO, 1983; Joseph *et al.*,, 2013 and Getachew and Solomon, 2015.

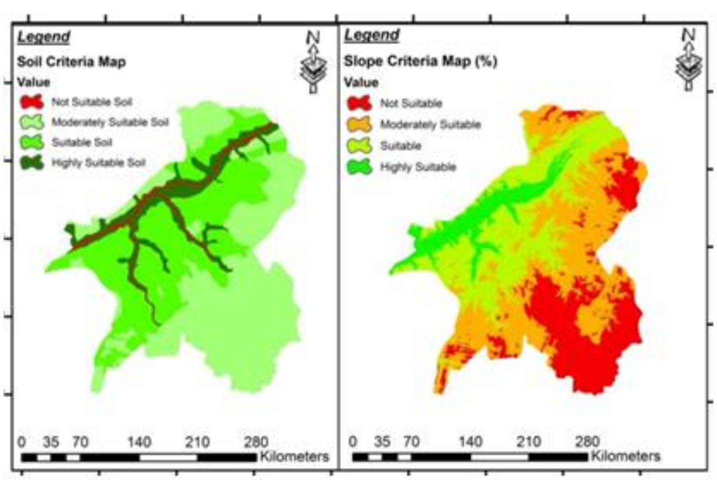

Figure 3: Soil and Slope Criteria Maps

Agro-climatic Zones for Ofada Rice cultivation based on Climatic Variables in the State

Table 6 and 7 present the Pair-wise and Normalized table of all the selected criteria for Ofada rice Agro-climatic zoning in the State. The tables revealed that the Minimum temperature has the highest weight of 66.87% followed by Solar Radiation with 24.31% and then June rainfall with 8.82%. The result clearly showed that Minimum temperature has a high influence on the Agro-climatic zoning map for Ofada rice variety followed by Solar Radiation and then June rainfall and also revealed in the stepwise regression result. In addition, the normalization table revealed that the process displayed a consistency ratio (CR) of 0.006061 which is within the PCM acceptance range and implies that, there is consistency in comparing the criteria.

An Agro-climatic zone for the cultivation of the rice variety is presented in figure 6.5. The map revealed that the highly suitable area for cultivation of the variety has a total land area of 27,883.48km^2 (47.15%) and include places such as Mutum Biyu, Sunkani, Amar, Gassol, Bantaji, Ibi, Wukari, Donga, Takum, Lissam, Nyiti, Baissa, and Sansani, while the Suitable area covered places like, Bambur, Karim, Muri, Lau, Jalingo, Bali, Gashaka and Tosso which covered a total area of 23,700.36km^2 (40.08%). The moderately suitable area, on the other hand, has a total land area of 12,414.45km^2 (20.99%) and places involved are; Zing, Pantisawa, Nguroje, Mayo Ndanga, Gembu, and Mai Samari while the not suitable places are Southeastern part of Pantisawa and some areas in Eastern part of Gashaka which covered an area of 471.09km^2 (0.80%) (figure 4). The highly suitable area for Ofada rice cultivation in the State is those places that have low June rainfall, Solar Radiation, and high Minimum temperature while places that are not suitable are places of low minimum temperature and high June rainfall and Solar Radiation. This analysis is based on the fact that minimum temperature has an appositive relationship with Ofada rice variety while June rainfall and Solar Radiation showed a negative relationship with the variety which clearly suggested that places with high minimum temperature are favorable for Ofada rice cultivation in the State.

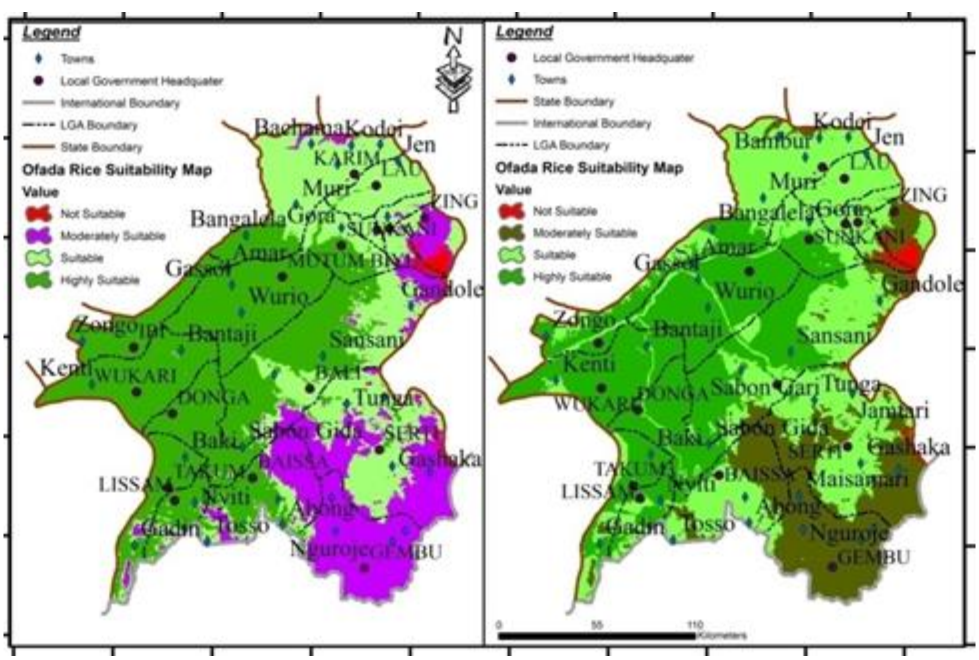

Figure 4: Ofada Rice Suitability maps. Left, based on climatic zones, right, based on climatic variables, soil and slope.

Table 6: Pair-wise Comparison matrix of the Selected Criteria for Ofada Variety

	Min. Temperature	Solar Radiation	June Rainfall
Min. Temperature	1.0000	3.0000	7.0000
Solar Radiation	0.3333	1.0000	3.0000
June Rainfall	0.1429	0.3333	1.0000
Total	1.4762	4.3333	11.0000

Suitability Zones for Rice cultivation based on Climatic Variables, Soil and Slope of the State

Table 8 and 9 showed the AHP/PCM based on the Agro-climatic variables, Soil Texture and Slope criteria. Result of the PCM revealed that Agro-climatic map has the highest weight, followed by Soil texture and then Slope. Suitability zones for the cultivation of Ofada rice variety are presented in Figure 6.10 The highly suitable areas for cultivation of Ofada rice variety include Sunkani, Mutum Biyu, Gassol, Amar, Wurio, Bantaji, Ibi, Wukari, Donga, Bali, Takum, Nyiti, Sabon Gida and Sansani. All these places covered a total land area of 22,554.74km^2 (38.14%) of the study area,

Table 7: Normalized Pair-wise Comparison Matrix and computation of criterion Weight

	Minimum Temperature	Solar Radiation	June Rainfall	Weight	Weight (%)
Minimum Temperature	0.677	0.692	0.636	0.669	66.87
Solar Radiation	0.226	0.231	0.273	0.243	24.31
June Rainfall	0.097	0.077	0.091	0.088	8.82

Maximum Eigen Value=3.00703, CI=0.003515, CR=0.006061

while not suitable areas which covered a small part of Southern Yorro has a total land area of 471.09km^2 (0.80%) of the State. The highly suitable places for the cultivation of Ofada rice variety in the State have met up with the major requirement (climate, soil, and slope) of Ofada rice variety in the State, while those places that are not suitable have an insufficient amount of the required determining factors. It can also be seen clearly from the result that, the highly suitable and suitable areas for cultivation of Ofada rice are places that have soil texture and plain terrain that will support the growth and yield of rice.

Table 8: Pair-wise Comparison matrix based on Agro-Climatic map, Soil and Slope maps

	Agro-climatic	Soil Texture	Slope
Agro-climatic	1.0000	3.0000	7.0000
Soil Texture	0.3333	1.0000	3.0000
Slope	0.1429	0.3333	1.0000
Total	1.4762	4.3333	11.0000

Following the result presented in this section, it is obvious that the Agro-climatic amount in the highly suitable and suitable Zones are favorable for the cultivation of all selected rice varieties and are considered to be the most critical climatic elements in rice growth and yield *(*Mayumi *et al.*, 2016; Sridevi and Chellamuthu 2015; Worou *et al.*,. 2012 and Powers, 2005). In addition, the zones are characterized by soil types that have high water holding capacity such as alluvial soil type which supports the growth and yield of rice (Tripathi, 2011). The zones are also characterized bysome percentage of clay soil content which has organic matter as one of the major requirements for crop development (Six, *et al.,* 2000). The highly suitable and suitable zones in the State are also characterized with plain/flat surface which allow even distribution and efficient infiltration of water and nutrient for rice growth and yield. Contrary to the highly suitable and suitable zones in the State is the not suitable zone which is characterized with steep slope or depression that allows water runoff and nutrient leaching through the process of soil erosion from heavy rain which also leads to crop damage, low nutrient intake and low water infiltration (Mayumi *et al.*,, 2016 and Husson *et al.*,. 2001). This explanation clearly suggested that the highland region of the State are those places that are difficult for rice cultivation because ofthe high undulation, scattered rock outcrops, and hills which affect crop management implementation leading to poor growth and yield of crops (Worou *et al.*,, 2012).

Table 9: Normalized Pair-wise Comparison Matrix and computation of criterion Weight based on Agro-Climatic map, Soil and Slope maps

	Agro-climatic	Soil Texture	Slope	Weight	Weight (%)
Agro-climatic	0.677	0.692	0.636	0.669	66.87
Soil Texture	0.226	0.231	0.273	0.243	24.31
Slope	0.097	0.077	0.091	0.088	8.82

Maximum Eigen Value=3.00703, CI=0.003515, CR=0.006061

Impact of NDVI on Agro-climatic suitability Zones for Ofada Rice production

Map of NDVI as a criterion is presented in figure 5 where three different classes was identified base on USGS and NASA classification of vegetation cover. The map revealed that, 51,747.64km^2 (87.50%) area of the State is occupied by sparse vegetation such as shrubs and grasslands or senescing crops while 1,511.39km^2 (2.56%) area is covered by dense vegetation and 5,879km^2 (9.94%) represent the buildup area, barren rock and water bodies. This result clearly showed that majority of the land area can be use for cultivation of crops because those area support plants growth which can equally support the growth of rice. The dense vegetation areas of the State were considered to be moderately suitable area for rice cultivation based on the fact that those areas can be preserved as game and forest reserved for purpose of environmental management.

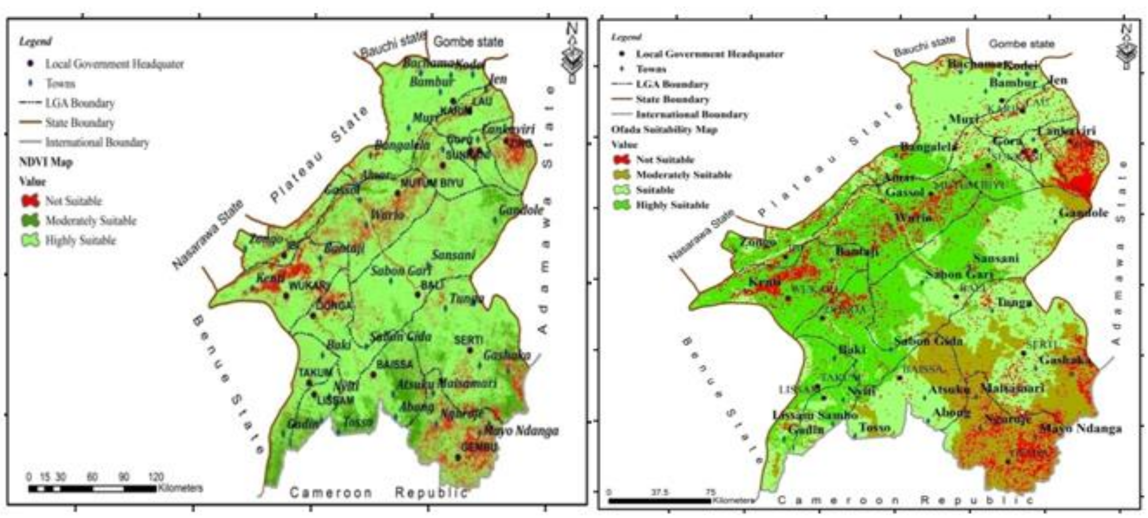

Figure 5: Left, NDVI suitability map. Right, Final Suitability Map for Cultivation of Ofada Rice Variety.

Result of analysis between Suitability map of Ofada and NDVI revealed that, the suitable area for cultivation of the variety reduced from 40.08% to 38.86% while the not suitable area increased from 0.80% to 10.79%, while the highly suitable area reduced from 38.14% to 32.88%. Following all these result presented, non-agricultural areas are mostly found on the on the suitability zone for cultivation of the variety.

CONCLUSION

Based on the results obtained from this work, it was concluded that, climatic elements such as minimum temperature, solar radiation and rainfall amount in June were critical to yield of Ofada rice in the State. In addition, over fifty percent of the study area are highly suitable and suitable for cultivation of Ofada rice in the State and include places such as Lissam, Takum, Donga, Wukari, Ibbi, Gassol, Serti, Karim, Lau, Sunkani, Mutum Biyu and Bali while a small fraction (10.79%) which include places around Gembu and Eastern part of Yorro and Zing LGA are not suitable for Ofada rice cultivation in the state. In addition, all the highly suitable and suitable zones are place high minimum temperature amount, favorable Solar radiation amount, favorable rainfall amount in June, suitable soil texture characteristics and plain or flat terrain which are all essential for the growth and yield of Ofada rice in the State. In addition, MCDM/AHP was test to be very vital in suitability study because it provides a means in which criteria are rank based on their contribution to rice yield which also helps in a weighted overlay.

References

Adebayo, A. A. (2000). Agro-climatic Classification of Adamawa State, Nigeria for Upland rice production. *The Nigerian Geographical Journal, New series*. Vol. 3 & 4, pp 83-97.

Adekoyeni, O. O., Akinoso, R., Malomo, O. (2012). Some Physical Properties and Yield of Ofada Rice. *J. Basic Appl. Sci. Res.* Vol 2(4):4098-4108.

Adekoyeni, O. O., Fagbemi, S. A. and Ismaila, A.R. (2018). Ofada Rice Identity, Physical Qualities and Processing Technology Options for Upgrading: A Review. *Annual Research & Review in Biology 23(2): 1-9.*

Ajetomobi, J., Abiodun, A., and Hassan, R. (2011). Impacts of Climate Change on Rice Agriculture in Nigeria. *Trop. Subtrop. Agro. Syst*. 14:613-622.

Angela, I. E and Fidelis, H. B. (2013). Effects of Climate Change on Rice Farming in Ardo Kola Combination and Ordered Weighted Averaging. *Informatica* 33(4):459-474

Ayoade, J. O. (2005). *Introduction to Agroclimatology,* Vintage, Publisher, Ibadan, Nigeria. Center for Soil Research (CSR)/ Food and Agricultural Organization (FAO) (1983). *Reconnaissance and Land Resource Surveys. 1: 250,000 Scale Atlas Format Procedures*, Centre for Soil Research, Ministry of Agriculture, Government of Indonesia, Bogor, and the United Nations Development Program and Food and Agriculture Organization

Danbaba, N., Anounye, J. C., Gana, A. S., Abo, M. E. and Ukwungwu, M. N. (2011). Grain Quality Characteristics of Ofada Rice (*Oryza sativa* L.); Cooking and eating quality. *Int. Food Res. Journal.* Vol 18, 629-634.

Fick, S.E. and Hijmans R.J (2017). Worldclim 2: New 1-km Spatial Resolution Climate Surfaces for Global Land Areas. *International Journal of Climatology.*

Getachew, T. A and Solomon, A. B. (2015) Land Suitability Analysis for Rice Production: A GIS Based Multi-Criteria Decision Approach. *American Journal of Geographic Information System*. Vol. 4(3): 95-104

Gyimah-Brempong, K., Michael, E., Johnson, Hiroyuki Takeshima, 2016. Rice in the Nigerian Economy and Agricultural policies. A publication of the International Food Policy Research Institute (IFPRI) www.ifpri.org/publication/ricenigerian- economy-and-ahricultural-policies

Husson, O., J. Castella, and N. H. D. Tuan (2001). Agronomic diagnosis and identification of factors limiting upland rice yield in mountainous areas of northern Vietnam. SAM Pap.Ser. 2 [Online] http://asia-uplands.org/Sam/Sam/pdf/SAMPS02_

Iloeje, N.P. (2001). *A new geography of Nigeria*. New Revised Edition. Longman Nigeria PLC. 200p.

Iwuchukwu, J .C. and Igbokwe, E.M. (2012). Lessons from Agricultural Policies and Programmes in Nigeria. *Journal of Law, Policy and Globalization.* Vol 5. pp 11-22

Joseph K., Njoroge J and Hunja M (2013). Suitability Analysis for Rice Growing Sites using a Multicriteria Evaluation and GIS Approach in Great Mwea Region, Kenya. *Springer Plus* 2013, 2:265.

Marie, M. E., Tianmei, W., Carolin, F. K., Britta, P. & Scott, F (2019). Rice production threatened by coupled stresses of climate and soil arsenic. *Nature Communications.* 10:4985. https://doi.org/10.1038/s41467-019-12946-4.

Mayumi, K., Yoshinori, Y., Yulius, B. P., Fransiscus, S. R., Akira, M., and Daigo, M. (2016). How Growth and Yield of Upland Rice Vary with Topographic Conditions: A Case of Slash-and-burn Rice Farming in South Konawe Regency, Southeast Sulawesi Province, Indonesia. *Tropical Agricultural Development.* 60（3）：162 －171，2016.

Mu, E. and Pereyra-Rojas, M. (2017), *Practical Decision Making*; Understanding the Analytic Hierarchy Process. *Springer Briefs in Operations Research*, DOI 10.1007/978-3-319-33861-3_2

National Cereal Research Institute (NCRI) and Africa Rice Centre (ARC) (2005). Definition of Ofada Rice Qualities through Varietal Identification and Testing. PrOpCom publication Monograph Series #26, Abuja, Nigeria; 2005.

Odozi, J. C. (2014). Rice Self Sufficiency and Farm households: The Role of Climate Change and Technology Response in Nigeria. *Journal of Poverty, Investment and Development.* Vol. 3. Pp 73-84

Oyedepo, J. A., Omotayo A. M., Elemo K and Oyedepo E. O. (2018). Mapping of Ofada Rice Production Areas For Rice Value Chain Development In South-West Nigeria. *FUW Trends in Science & Technology Journal.* Vol. 3 No. 2 pp. 564 - 569

Powers, R. F., Scott DA, Sanchez FG, Voldseth RA, Page-Dumroese D, Elioff JD, Stone DM (2005) The North American long-term soil Productivity Experiment, Findings from the first decade of research. *Forest Ecol Manage.* 220:31–50.

Premium Times (2019). "Rice production in Nigeria hits 15 million Tonnes" Thursday April 25th Premium Times News.

Saaty, T. L. (1977). A scaling method for priorities in Hierarchical structure. *Journal of Mathematical psychology*. 15 (3). 34-39

Saaty, T. L. (2012). *Decision Making for Leaders*; *The Analytical Hierarchy process for Decisions in a complex world.* Third Revised Edition. Pittsburgh: RWS Publications.

Selbut, R. L. (2003). A review and description of rice production systems in Nigeria. Ecosystems Development Organisation, WIS Partners Building, 5 Lugard road, Jos Plateau, Nigeria. https://www.odi.org/resources/do cs/3984.pdf

Six, J, Paustian, K., Elloitt, E.T., Combrink, C. (2000) Soil Structure and Soil Organic Matter, I.

Distribution of Aggregate size Classes and Aggregate Associated Carbon. *Soil Sci Soc Am J.* Vol 64, 681–689.

Sridevi V and Chellamuthu V (2015). Impact of weather on rice. *International Journal of Applied Research*; 1(9): 825-831

Stigter, C.J., (2004). The Establishment of needs for Climate Forecasts and other Agro-meterological Information for Agriculture by Local, National and Regional Decision-Makers and Users Communities. Pp. 73–86 in: Applications of Climate Forecasts for Agriculture. AGM-7/WCAC-1, WMO/TD-No.1223, WMO, Geneva.

TADP (2018). Taraba State Agricultural Production Data ('000MT) from 2012 to 2017.

Taraba Youth Progressive Association of Nigeria (TYPA) (2009). Report on Small Scale Environmental Studies in Taraba State.

Toromade, S. (2018). 5 agriculture initiatives by President's administration he wants you to know about. *Pulse NG News, 24 April*.

Tripathi, K. K., Ranjini W., Govila O. P., Vibha A (2011). Biology of *Oryza Sativa l.* (rice). Ministry of Environment and Forest Government of India.

Udo, R. K. (1978). *Geographical Regions of Nigeria*. Heinemann, London

Wassmann R, (2010). Advanced Technologies of Rice Production for Coping with Climate Change: 'no regret' Options for Adaptation and Mitigation and their Potential Uptake. Proceedings of the Workshop Advanced Technologies of Rice Production for Coping with Climate Change: 'No Regret' Options for Adaptation and Mitigation and their Potential Uptake held on 23-25 June 2010 in Los Baños, Philippines. IRRI Limited Proceedings No. 16. Los Baños (Philippines): International Rice Research Institute. 81p.

Worou, O.N., T. Gaiser, K. Saito, H. Goldbach, and F. Ewert (2012). Simulation of Soil Water Dynamics and Rice Crop Growth as Affected by Bunding and Fertilizer Application in Inland Valley Systems of West Africa. Agric. Ecosyst. Environ. 162: 24-35.