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APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM (GIS) AND MULTI-CRITERIA DECISION MAKING IN AGRO-CLIMATIC ZONING OF TARABA STATE FOR FARO 44 AND FARO 58 RICE PRODUCTION

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Abstract

This research was designed because of the need to improve Local rice production in Taraba State and the Country at large. The research was aim at applying Multi-Criteria Decision Making (MCDM) in Agro-Climatic Zoning of Taraba State for rice Production. *Climatic variables, Rice Yield (FARO 44 and FARO 58 Varieties), Digital Elevation Model (DEM), Land Sat 8 (OLI) images and Soil Texture map were the data used.* Stepwise regression analysis between rice yield and the climatic variables were analyzed in SPSS. MCDM was used to produce the Agro-climatic zoning with the help of Spatial Analysis Tool in Arc GIS 10.2. Result of the stepwise regression revealed that *Mean temperature, August and September rainfall were the critical climatic variables for cultivation of FARO 44 rice yield and accounted for 61% of the variance in the yield of the variety while Mean temperature, August and October rainfall were the critical climatic variables for cultivation of FARO 58 and accounted for 71.2% to the variation in yield of the variety. Result of the* FARO 44 suitability map showed an area of 31.93%, 48.17%, 13.11% and 6.78% for highly suitable, suitable, moderately suitable and not suitable area respectively for the cultivation of the variety, while highly suitable, suitable, moderately suitable and not suitable area for cultivation of FARO 58 covered an area of 31.49*%, 48.61%, 12.58% and 7.33% respectively.* Suitability map produced with NDVI showed that, agro-climatic suitability area for FARO 44 and 58 reduced from 31.93% to 28.76% and 31.49% to 28.35% for FARO 44 and 58 respectively. Cultivation of rice should be encouraged in Highly Suitable and Suitable zones of the State while, alternative crops other than rice should be recommended for the not suitable areas. 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) and GIS tool should be employed in suitability zoning of other crops in the State.

***Key words**:* Multi-Criteria Decision Making, Spatial Analysis Tool, Agro-climatic Zoning, Taraba State, FARO 44, FARO 58 and Rice Production

1. Introduction

Rice plays a very significant role in sustaining national food security as well as creation of employment and income in Nigeria (Saliu et al., 2015). It is one of the major crops cultivated in the nation covering 3.7 million hectares of land (10.6%) out of the total arable land area of 70 million hectares (Akinbile, 2010). Production of the crop showed an improvement in recent years, for example in 2011, 2012, 2013 and 2014, it production stand at 4.2, 4.4, 4.7 and 4.8 respectively, in 2017, the production increase significantly from 5.5 in 2016 to 5.8 million metric tons (Teliat, 2015 and Daniel, 2018). However, in spite of this development, the production has not been able to satisfy the demand of it consumers, instead the country import to close the demand gap (Onu, Obike, Ebe, and Okpara, 2015 and Uche & Joshua, 2017).

Although, several programs and technological efforts were set by the Federal Government toward improving the production of the crop in the past. These include Government initiative to increase rice production through the promotion of New Rice for Africa (NERICA) variety, Agricultural Development programs, use of pesticide and Herbicide, which led to an appreciable increase in rice output (Adebayo, 2000 and FAO, 2013).Despite these technological development, the average national yield of the crop remained low when compared with the potential yield of the rice seed varieties (Abo et al, 2009).

In spite of the fact that technology improves crop production but that does not reduce the impact of weather on crop, instead a period of favorable weather interacts with technology produce higher yield of crop (Adebayo, 2000 and Ayoade, 2005). This is based on the fact that climate is very sensitive to all stages of crop production; from land clearing and preparation, through crop growth and management to harvesting, storage, transportation and marketing of the product (Ayoade, 2005). For instant, 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 as well as their productivity and also determine the types of crop a farmer cultivate, the yield of the crop and hence farmers' profit (Ayoade, 2005 and Stigter, 2004).

In addition, the amount of Sunlight, temperature, moisture and carbon dioxide (CO_2) determines seed germination, the time emergence of plant, the rate of growth of roots, stems, and leaves and flower development. They also determine when plant produces flowers, and consequently the filling of grain or the expansion of fruits (David and Mark (2007).In Taraba State, study by Angela and Fidelis (2013) revealed that, rice farmers in the state are facing serious climatic challenges which include stunted rice growth, wide spread of pest and diseases, difficulties in predicting rice planting period, drying and withering of rice seedlings, delayed rainfall and too much heat which evaporates water from rice plant.

In the same vein, Jifin (2017) reported that, climate affect agricultural production in the state in many aspects of farming activities which includes; change in agricultural pattern, pests and disease attack on crops, crop failure and poor harvest. So far, from this reports examined on rice production in some rice producing areas across the Nation, there is a clear indication that Agro-climatic condition of a place determines the quality and quantity of the crop yield. Since rice cultivation has a dependency relationship with climatic factors at different level and places, there is therefore a need to delineate suitable zones for the purpose of efficient production of the crop (Ayoade, 2005). In regards to this, Multi-Criteria Decision Making (MCDM) a Geographical Information System (GIS) based tool which is important in finding solutions to decision-making problems characterized by multiple alternatives that can be evaluated by means of decision criteria, and was also recognized as a relevant tool in future land use planning (Jankowski et al. 2001; Ceballos-Silva and L'opez-Blanco, 2003; Drobne and Lisec, 2009; Yu et al, 2011 and Getachew and Solomon, 2015). Following the relevance of this tool in land use analysis, this research is design to apply the tool in evaluating the Agro-climatic condition of Taraba State for cultivation of FARO 44 and 58 varieties

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2. Study Area

Taraba State State is one of the Nigerian thirty-six (36) state located in North-Eastern part of the country and has a coordinate of latitude $6^{o}30^{\prime}$ and $8^{o}30^{\prime}$ North of equator and longitude $9^{o}00^{\prime}$ and 12^{o} $00^{\prime}$ East of the Greenwich meridian (Figure 1).

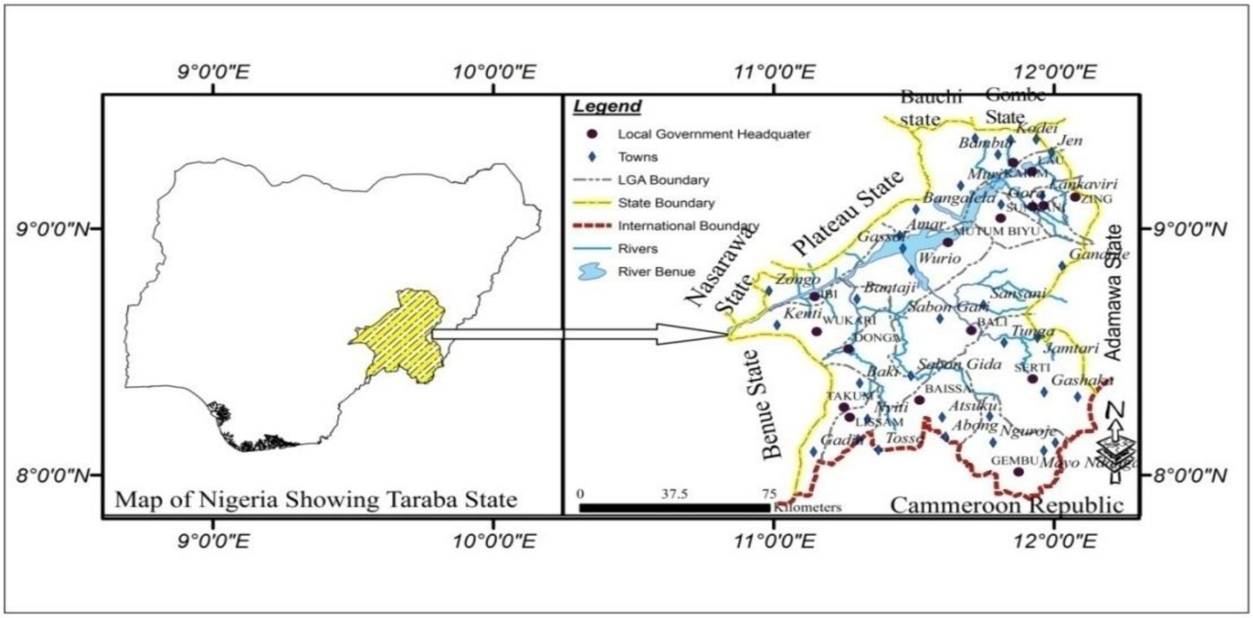


Figure 1: Study area

The Study 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 (TYPA, 2009).

Climate of the State is mainly influenced the rain-bearing south-west air mass and the north-east trades. 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 type are found on the flooded plains of rivers 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.

3. Materials and Method

Climatic variables, annual rainfed Rice yield (FARO 44 and FARO 58 Varieties), Map of the study area, Digital Elevation Model (DEM) Shuttle Radar Topographic Mission (SRTM), Landsat 8 Operational Land Imager (OLI) images and Soil texture maps were the data used in this Study. Annual rainfall, monthly rainfall, dry spell, onset date of rain, cessation date of rain, Length of Rainy Season (LRS), seasonality index and hydrological ratio were extracted from the daily, monthly and annual rainfall for a period of 38 years while, monthly and annual minimum temperature, maximum temperature, mean temperature, relative humidity, solar radiation and wind speed were obtained from Upper Benue River Basin Development Authority (UBRBDA), Taraba State Agricultural Development Program (TADP) (Area, Zonal and Head office) in the State, Federal Polytechnic Bali and Nigerian Meteorology (NIMET) Ibi. Mean spatial climatic map of monthly rainfall, minimum temperature, maximum temperature, solar radiation, and wind speed were also used in this study. Maps of these variables were downloaded from world Cli-Global Climate data version 2 (www.worldclim.org) produce by *Fick and Hijmans (2017).*

Rice yield data based on varieties (FARO 44 and FARO 58 varieties) and LGAs, on the other hand, were collected from Taraba State Agricultural Development Program (TADP) in the State. Latitude and Longitude were collected using Geographic Positioning System (GPS) while, LandSat 8 Operational Land Imager (OLI) images and Digital Elevation Model (DEM) data of Shuttle radar topographic mission (SRTM) 30m resolution were downloaded from USGS web site (glovis.usgs.gov). The data were processed and mosaic to give comprehensive coverage of the study area and then was used to extract the study area. 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)

3.1 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 to 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 the selected rice varieties.

3.2 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, each selected criterion was analyzed and produced separately. For the selected Agro-climatic variables, the critical climatic variables influencing different rice varieties selected from stepwise Regression analysis result were the identified climatic criteria for the zoning. This is based on the fact that they were identified to be the critical climatic factors influencing the growth and yield of rice in the State, as such, they are recommended to be the only climatic criteria that were used in the Zoning as also suggested by Adebayo, (2000) and Ayoade, (2005). The selected criteria 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 regression, related literature on rice climatic requirement for growth and yield as well as expert's Idea. Soil texture map of Nigeria Geo-reference and Digitized and 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.

3.3 Application of MCDM (AHP/PCM)

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 same procedure was applied to the entire criterion. To obtain the exact weight and rank of each criterion, the average of each row was calculated and the values were ranked based on Hierarchy. 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 (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 since the tool indicates the likelihood that the matrix judgments were reasonable consistent and are generated randomly. 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 and RI = Random index (Table 2).

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

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

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

Source: Saaty (2012)

Table 2: Random Index (RI)

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

Source: Saaty (2012)

3.4 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. 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.

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

In this section, the method used in producing the agro-climatic zone for the cultivation of the selected rice varieties based on climatic variables, soil, and slope of the study area was explained. To produce the 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. The suitability map produced in this section was then referred to as the suitability zones for the cultivation of selected rice varieties based on climatic variables, soil, and slope of the Study area.

3.6 Agro-climatic zones and NDVI

The final section is the application of the suitability map produced with the NDVI of the State in other to examine the impact of build up area, water bodies and barren rock areas on the suitability map produced. The essence of extracting those areas is to understand the actual suitable area for rice cultivation. This is based on the fact that, some of the suitable zones produced were overlaid on build up area, water bodies and barren rock areas and that will be an exaggeration if all those areas are included in the suitable zone. 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 processed and produced NDVI using Image analysis tool. 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).

4. Results and Discussions

4.1 Climatic Criteria maps used for Agro-climatic Suitability Zones for Rice cultivation

Table 1, 2 and 3 displayed the regression result and scale used in assessing and producing the climatic criteria maps for suitability zoning of the varieties. 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. Figures 2 showed the identified climatic criteria maps.

Table 1: Stepwise Regression result between Faro 44 Variety and Climatic Variables

Predictor	Coef	SE Coef	T	R^2 (%)	R^2(adj)	R^2(pred)	VIF
Constant	-11.508	2.312	-4.98**				
Mean temp	0.50128	0.08379	5.98**	46.44	45.03	40.39	1.027
August Rain	0.0044	0.001285	3.44**	54.26	51.79	42.85	1.143
Sept. Rain	-0.0026	0.0009975	-2.59*	61.44	58.23	46.98	1.163

Table 2: Stepwise Regression result between Faro 58 Variety and Climatic Variables

Predictor	Coef	SE Coef	T	R^2 (%)	R^2(adj)	R^2(pred)	VIF
Constant	-8.029	2.972	-2.70*				
Mean Temp	0.3513	0.1044	3.36**	38.56	36.37	30.53	1.306
August Rain	0.007772	0.001702	4.57**	63.89	61.22	56.23	1.304
October Rain	-0.0039	0.001524	-2.57*	71.19	67.87	64.63	1.027

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

Table 3: Scale of the identified critical Climatic Variables

	Highly Suitable	Suitable	Moderately Suitable	Not Suitable
Mean Temperature (°C)	>27.1	25.9- 27	24.5- 22.4	<22.4
Rainfall in August (mm)	>300	251-300	245 – 250	<245
Rainfall in September (mm)	100-200	201-290	291-310	>310
Rainfall in October (mm)	100-150	151-200	201-250	>250

Source: Computed by author 2018.

Table 4: 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

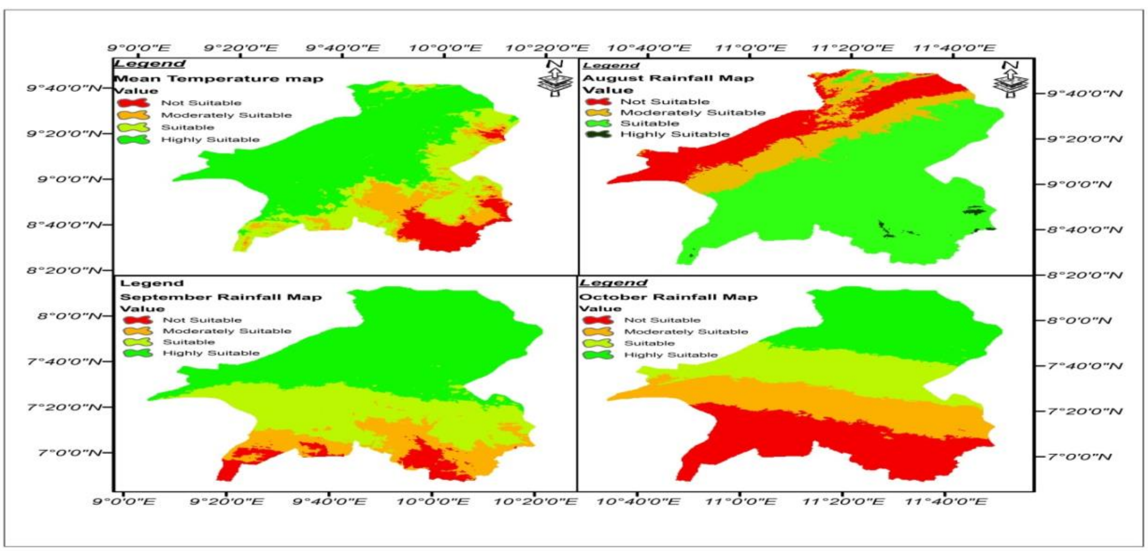


Figure 2: Identified Climatic Criteria

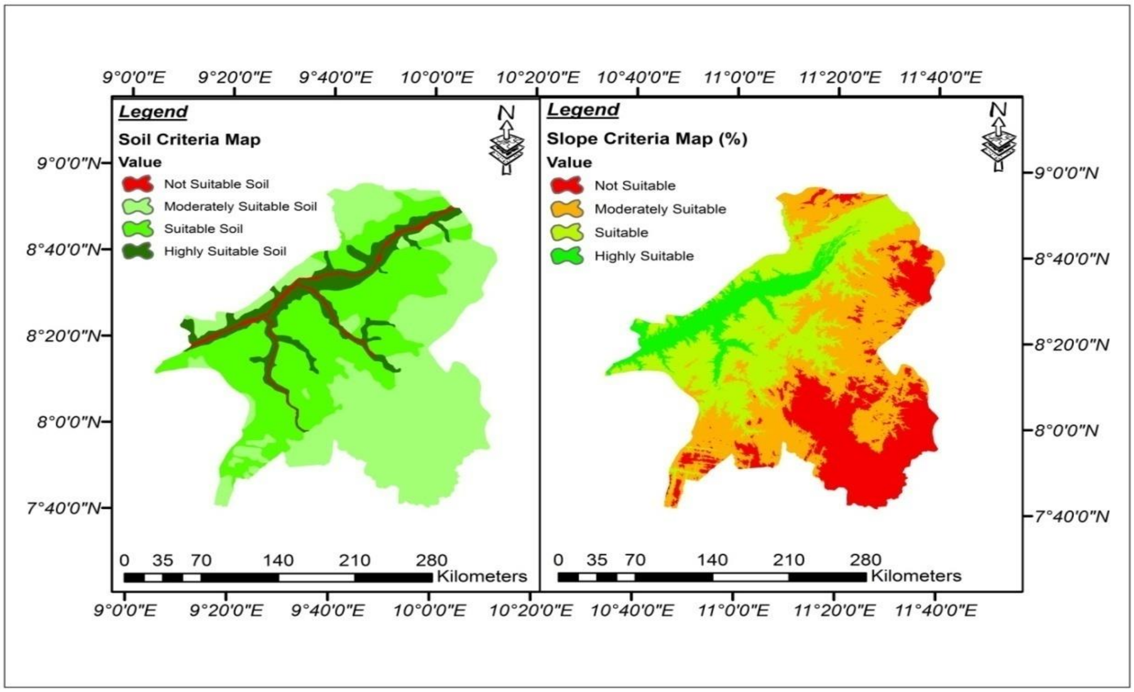


Figure 3: Soil and Slope Criteria Maps

4.2 Agro-climatic Zones for FARO 44 Rice cultivation based on Climatic Variables

The result of the Pair-wise comparison matrix presented in Table 5 and 6 displayed the weight of the selected Agro-climatic variables that are significant for growth and yield of FARO 44 rice variety which was used for the production of the Agro-climatic zone for the cultivation of FARO 44 rice variety in the State. Result of the matrix revealed that Mean Temperature has the highest weight of 74.82% followed by August rainfall with 18.04% and then September rainfall with 7.14%. This result clearly suggested that; the mean temperature has the high contribution in producing the Agro-climatic zones for FARO 44 rice cultivation followed by August rainfall and then September rainfall. Agro-climatic zones for the cultivation of FARO 44 rice variety is presented in Figure 4. Result of the suitability area revealed that the highly suitable places for cultivation of the variety include; Wukari, Donga, Baki, Bantaji, Sabon Gari, Bali, Mutum Biyu, Sunkani, Jalingo, Lau, Gora, Muri and Bambur which covered a total land area of 22.792.11km^2 (38.54%), while the suitable area includes Ibi, Kenti, Zongo, Gassol, Amar, Karim, Zing, Takum, Lissam, and Baissa which covered an area of 24,576.42km^2 (41.56%). The moderately suitable places, on the other hand, has a total land area of 7,755.80km^2 (13.11%) and covered places such as; Serti, Eastern part of

Gashaka and some places in southern part of Pantisawa in Yorro LGA, while the not suitable places include; Gembu, Mayo Ndanga, Nguroje and Mai Samari which has a total land area of 4,014.20km^2 (6.79%). This Agro-climatic zone clearly showed that the highland region of the State that includes Gembu, Mayo Ndanga and Nguruje are not suitable for the cultivation of FARO 44. This is because the area experience low mean temperature that is not suitable for rice growth and yield (Getachew and Solomom, 2015 and Joseph *et al.*, 2013). In addition, the area has a high rainfall amount in the month of September, which coincides, with the maturity stage of FARO 44, which required low or no rainfall (Buck, 2010 and WARDA, 2005). Unlike the not suitable zones, the highly suitable and suitable zones for the cultivation of FARO 44, on the other hand, are those places with favorable mean temperature of 22-30^{O}C and favorable rainfall amount in the months of August and September, which is sufficient for growth, and yield of FARO 44 rice variety (Joseph *et al.*, 2013).

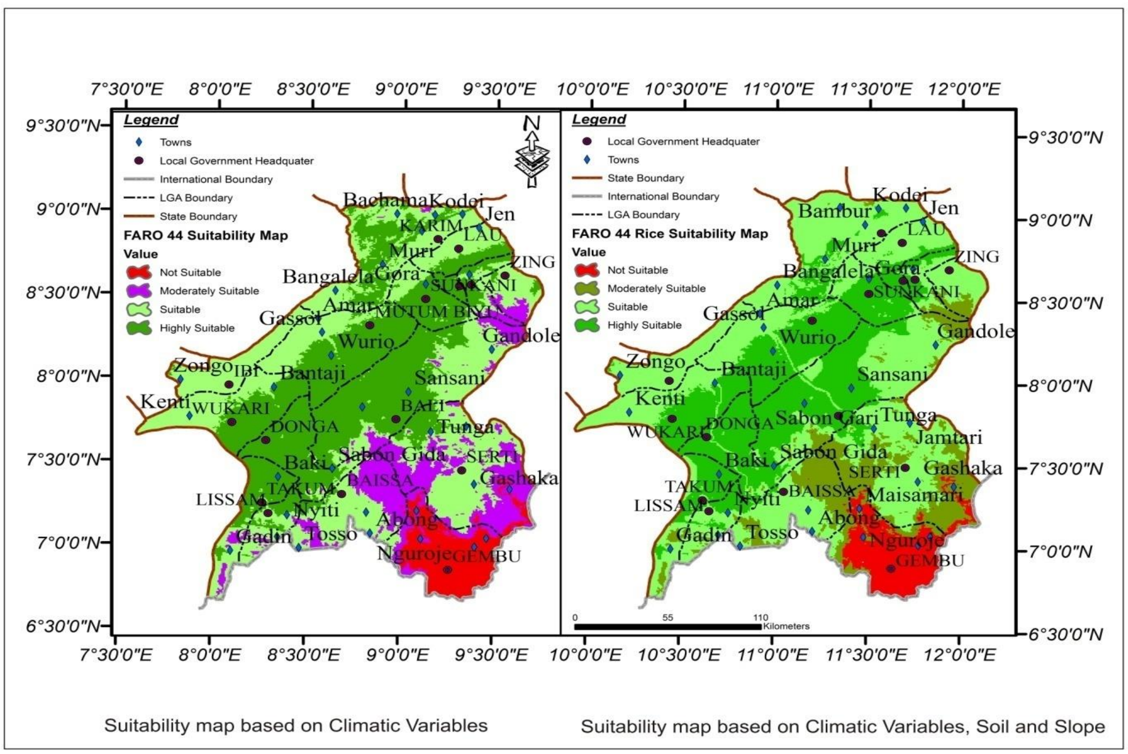


Figure 4: FARO 44 Rice Suitability Map based on the selected Climatic Variables

Table 5: Pair-wise Comparison matrix of the Criteria based on FARO 44 rice Variety

	Mean Temperature	August Rainfall	September Rainfall
Mean Temperature	1.0000	5.0000	9.0000
August Rainfall	0.2000	1.0000	3.0000
September Rainfall	0.1111	0.3333	1.0000
Total	1.3111	6.3333	13.0000

Source: Authors data analysis, 2018.

Table 6: Normalized Pair-wise Comparison Matrix and computation of criterion Weight for FARO 44 Rice

	Mean Temperature	August Rainfall	September Rainfall	Weight	Weight (%)
Mean Temperature	0.763	0.789	0.692	0.748	74.82
August Rainfall	0.153	0.158	0.231	0.180	18.04
September Rainfall	0.085	0.053	0.077	0.071	7.14

Maximum Eigen Value=3.02928
CI=0.014639
CR=0.025239

4.3 Agro-climatic Zones for FARO58 Rice cultivation based on Climatic Variables in the State

The Pair-wise Comparison Matrix and Normalized computation of the selected criteria for the cultivation of FARO 58 were presented in Table 7 and 8. The result revealed that Mean Temperature has the highest weight of 74.82% followed by August rainfall amount with 18.04% weight and then October rainfall with 7.14%. In addition, the result also showed a Consistency ratio (CR) of 0.02524, which clearly implies that there is consistency in PCM of the selected Agro-climatic variables and the weight, was appropriately computed. Agro-climatic zones for the cultivation of FARO 58 rice variety is presented in figure 5. The result revealed that the highly suitable zone includes places such as; Karim, Muri, Lau, Jalingo, Sunkani, Mutum Biyu, Wurio, Bantaji, Wakari, Donga, Takum, Baki, Sabon Gari, Bali and Sansani which covered a total land area of 22,530.74km^2 (38.10%) of the State while the suitable area has a total land area of 24,836.13 (42.00%) and include places such as; Bachama, Bangalela, Ibi, Zongo, Takum, Lissam, Baissa, Atsuku, Abong, Zing and Gandole. The moderately suitable zone on the other hand covered places such as; Sert, Pantisawa and Chappel hundu which have a total land area of 7,437.55km^2 (12.58%) while the not suitable area includes places such as; Gembu, Mayo Ndanga, Nguroje, and Mai Samari, and it covered a total land area of 4,334.11km^2 (7.33%). The highly suitable and suitable places for the cultivation of FARO 58 rice variety were identified based on the fact that they are places with a mean temperature range of 21-33^{O}C which are suitable for rice cultivation (Getachew and Solomom, 2015 and Joseph *et al.*,, 2013). In addition, the places have August rainfall amount >250mm which is sufficient to support the growth and yield of rice in the State.

Table 7: Pair-wise Comparison matrix of the Selected Criteria for Faro 58 Variety

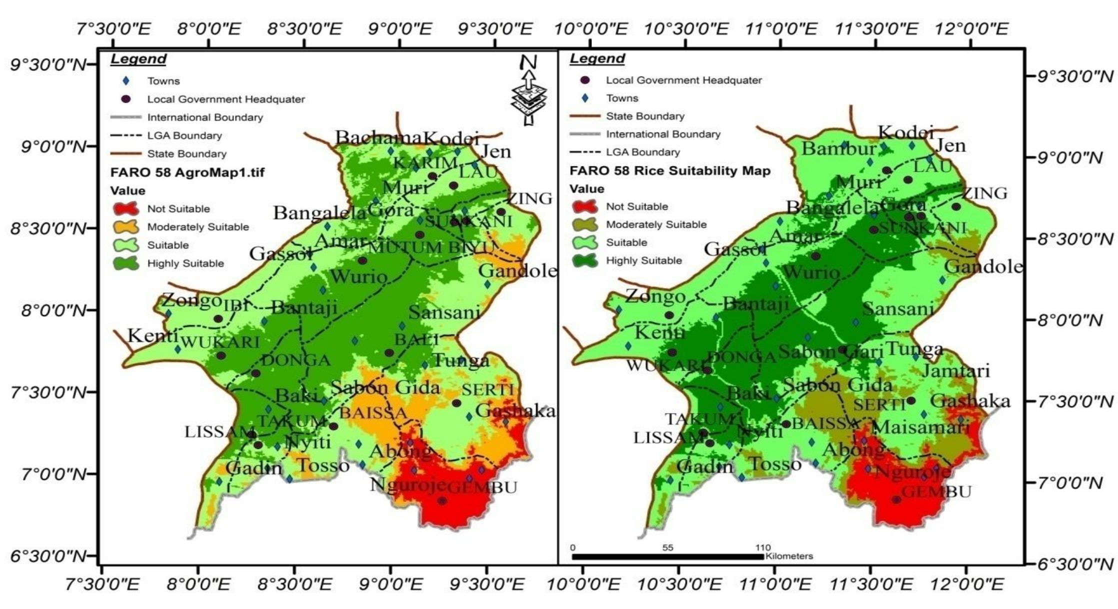
	Mean Temperature	August Rainfall	October Rainfall
Mean Temperature	1.0000	5.0000	9.0000
August Rainfall	0.2000	1.0000	3.0000
October Rainfall	0.1111	0.3333	1.0000
Total	1.3111	6.3333	13.0000

Source: Authors data analysis, 2018

Table 8: Normalized Pair-wise Comparison Matrix and computation of criterion Weight for Faro 58 Variety

	Mean Temperature	August Rainfall	October Rainfall	Weight	Weight (%)
Mean Temperature	0.763	0.789	0.692	0.748	74.82
August Rainfall	0.153	0.158	0.231	0.180	18.04
October Rainfall	0.085	0.053	0.077	0.071	7.14

Maximum Eigen Value=3.02928
CI=0.01464
CR=0.02524



Suitability map based on Climatic Variables

Suitability map based on Climatic Variables, Soil and Slope

Figure 5: FARO 58 Rice Suitability Map based on the selected Climatic Variables

4.4 Suitability Zones based on the Climatic Variables, Soil and Slope of the State

Table 9 and 10 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.

Table 9: 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

Source: Authors data analysis, 2018.

Table 10: 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
Source: Author's data analysis, 2018

Suitability zones for FARO 44 and 58, on the other hand, are presented in figure 4 and 5 respectively. The suitability map for cultivation of FARO 44 revealed that the suitable area has the highest total land area of 28,489.08km^2 (48.17%) followed by the highly suitable area which occupied 31.93% of the total land area of the State and include places such as; Muri, Jalingo, Sunkani, Mutum Biyu, Wurio, Bantaji, Wukari, Donga, Sabon Gari, Sansani and Bali. The not suitable area, on the other hand, has the smallest fraction of 6.78% and covered places like Gembu, Mayo Ndanga, Nguroje and Mai Samari. All the highly suitable and the suitable area for cultivation of FARO 44 are place with relatively high temperature amount, favorable rainfall amount in August and September, good soil texture characteristics and plain or flat terrain which are all essential for the growth and yield of FARO 44 in the State .In the case of FARO 58 suitability map, the highly suitable area include places such as; Muri, Jalingo, Sunkani, Mutum Biyu, Wurio, Bantaji, Wukari, Donga, Takum, Baki, Sabon Gida, Sabon Gari, Bali and Sunkani which covered a total land area of 18,620.94 (31.49%) while the suitable area for the cultivation of the variety has a total land area of 28,748.20km^2 (48.61). The moderately and not suitable area, on the other hand, covered a total land area of 12.58% and 7.33% respectively. The high suitable and suitable area for cultivation of FARO 58 rice variety are recognized to be the favorable places for cultivation of the variety based on the fact, they have sufficient mean temperature amount and also relief nature that is efficient in water and nutrient distribution and moderate rainfall amount in the months of August and October which favor cultivation of the variety in those places.

With respect to the two suitability maps above (FARO 44 and 58), it is clear that those places that are highly suitable and suitable for the cultivation of the varieties are places with an optimum climatic requirement for growth and yield of the two varieties. In addition, the soil texture and relief nature of those places are favorable to the growth and yield of the varieties.

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, soil types that have high water holding capacity such as alluvial soil type, which supports the growth and yield of rice (Tripathi, 2011), characterize the zones. 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).

4.6 Suitability Zones and NDVI of the State

Map of NDVI as a criterion is presented in figure 6 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 moderately suitable area for rice cultivation. This is because those areas can be preserved as game and forest reserved for purpose of environmental management. To compare the suitability maps produce and NDVI, the two different layers were overlaid to examine the impact of the NDVI layer on the Agro-climatic suitability maps produced, and also to assess the major suitability area affected by the not agricultural land use (none vegetation area) of the NDVI layer. Results obtained from the analysis revealed that there is an increase of 5,879km^2 in not suitable area of all the Agro-climatic suitability map of the selected varieties of rice produced in section 8.3. This is because the NDVI displayed not agricultural area of 5,879km^2 (9.94%), as such, the not suitable area will increase while the other suitability classes will reduce base on the spread and area where the not agricultural area occupied.

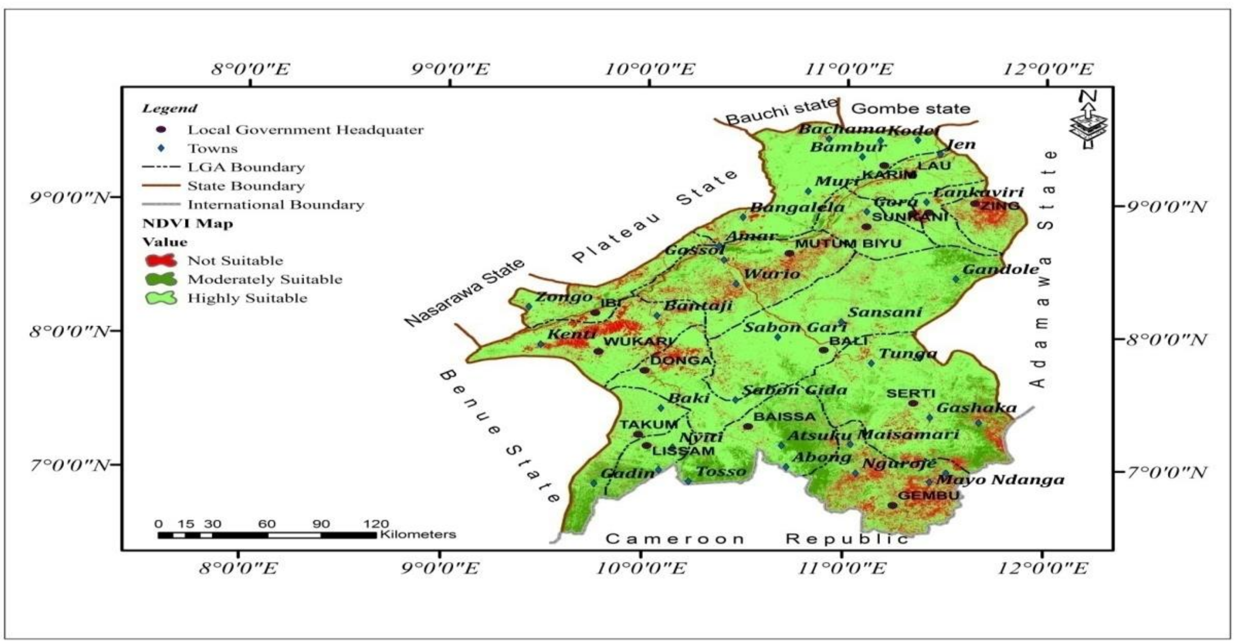


Figure 6: NDVI suitability map

According to the result on the suitability map for FARO 44 and 58 rice suitability, the two varieties showed a similar pattern of increase and decrease in not suitable and other suitability classes. The not suitability area increases with 9.94% while the suitable area reduced from 31.93% to 28.76% and 31.49% to 28.35% for FARO 44 and 58 respectively (Table 11, Figure 7 and 8).

Table 11: Suitability Area for Rice Cultivation after NDVI

	Not Suitable		Moderately Suitable		Suitable		Highly Suitable	
	(Km2)	(%)	(Km2)	(%)	(Km2)	(%)	(Km2)	(%)
FARO 44 Variety	8,779.70	14.85	7,177.74	12.14	26,171.07	44.25	17,010.02	28.76
FARO 58 Variety	9,006.27	15.23	6,953.22	11.76	26,415.96	44.67	16,763.08	28.35

Source: Authors data analysis, 2018

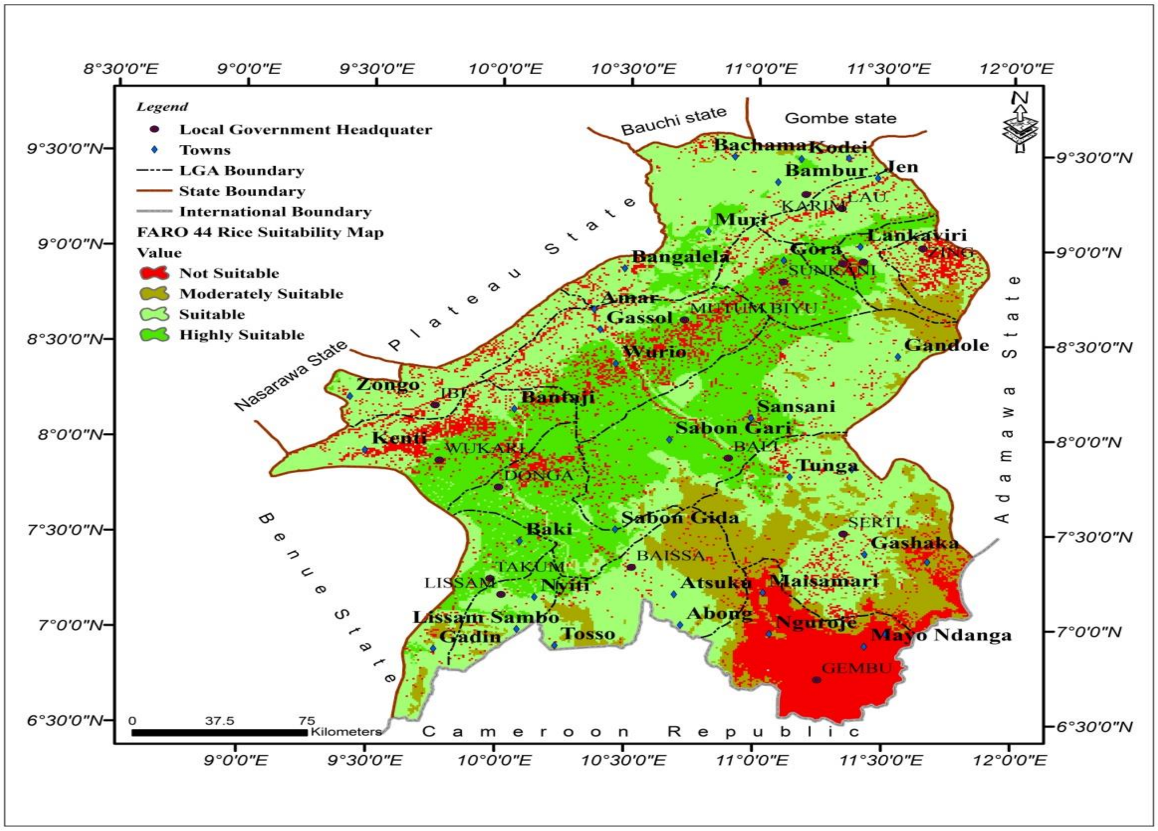


Figure 7: Final Suitability Map for Cultivation of FARO 44 Rice Variety

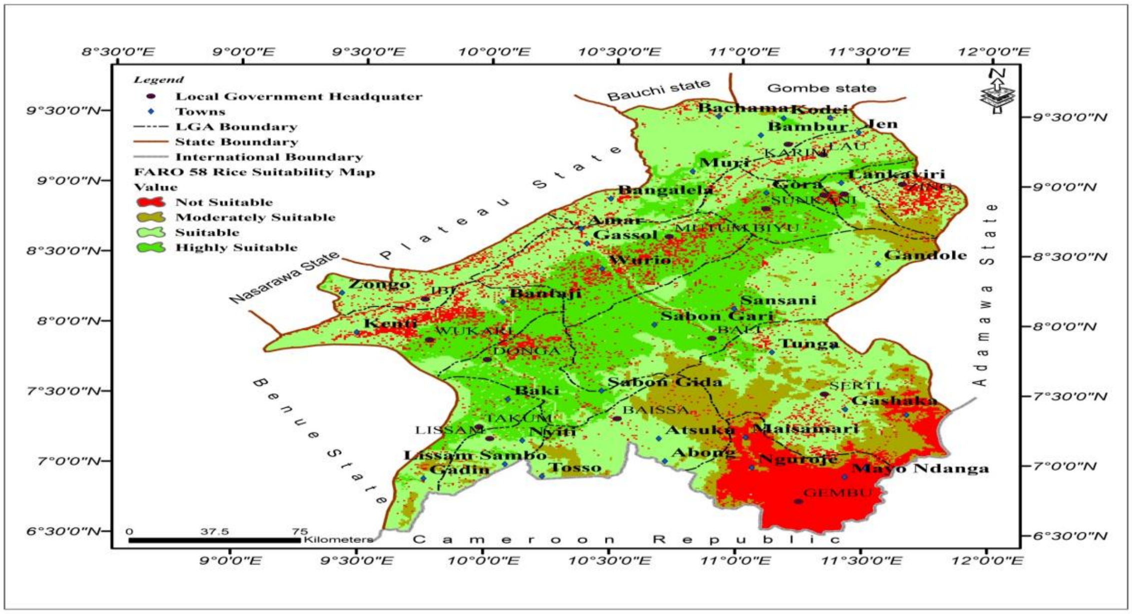


Figure 8: Final Suitability Map for Cultivation of FARO 58 Rice Variety

5. Conclusion

Following the result obtained from this work, it was concluded that places like; Lissam, Takum, Donga, Wukari, Gassol, Ibbi, Mutum Biyu, Bali, Serti, Karim, Lau, Sunkani, Jalingo and Lankaviri are suitable for cultivation FARO 44 and 58 and the covered over fifty percent of the State. While places like; Gembu, Nguroje, Mayo Ndanga and small eastern part of Zing LGA are not suitable for cultivation of the Varieties. It was also concluded that Mean temperature, August, September and October rainfall are the critical climatic factors affecting the growth and yield of the varieties. Furthermore, it was discovered that, MCDM/AHP is 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.

6. Recommendations

i. Most of the farmers in the study area engaged in small scale farming as such, Government and NGOs should help in providing the necessary agricultural input required by the farmers in a subsidy rate that can be affordable by the average farmer.

ii. Cultivation of FARO 44 and 58 rice should be encouraged in Highly Suitable and Suitable zones of the State since those areas have sufficient amount of the critical climatic elements that determine growth and yield of rice in the State.

iii. Cultivation of alternative crops other than rice in the not suitable zones was recommended as that will help in reducing the risk of crop failure. For example, cultivation of a crop that has low Mean temperature requirements should be encouraged in Sardauna LGA and other southern Highlands since they have low mean temperature compared to other parts of the State.

iv. Diversification of occupation is another suggestion to farmers especially in the not suitable area where there are other alternative occupations.

v. Extension service should be motivated because it would go a long way in enlightening farmers on the latest development in agricultural activities.

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