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APPLICATION OF ANALYTICAL HIERARCHICAL PROCESS (AHP) IN DEVELOPMENT OF SUITABILITY MODEL FOR RICE PRODUCTION IN TARABA STATE

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ABSTRACT

This research was aim at applying Multi-Criteria Decision Making (MCDM) in Agro-Climatic Zoning of Taraba State for rice Production. Climatic variables, Rice Yield, Digital Elevation Model (DEM), Land Sat 8 (OLI) and Soil Texture map were the data used. Climatic data of the state were analyzed over time and Space using trend and spatial analysis tools in excel and Arc GIS respectively, while correlation and stepwise regression analysis between rice yield and the climatic variables were analyzed in SPSS. Mean temperature, August and September rainfalls were identified to be the critical Climatic factors affecting the growth and yield of rice in the State. The highly suitable cover places such as; Lisasam, Takum, Donga, Wukari, Mutum Biyu and Bali while the suitable area occupy places like Serti, Lau, Sunkani, Jalingo and Lankaviri. Suitability map produced with NDVI showed that the highly suitable area for Rice cultivation reduced from 31.93% to 28.76%. In regards to this findings, cultivation of rice should be encourage in Highly Suitable and Suitable zones of the State while cultivation of alternative crops other than rice in not suitable area is very important in reducing the risk of crop failure. In addition, application of Multi Criteria Decision Making (MCDM) a Remote Sensing and GIS tool and NDVI plays a significant role in Agro-climatic suitability zoning, as such, the tools are recommended in Agro-climatic research.

Contribution/Originality: This study contributes to the Agricultural planning by determining the suitable area for cultivation of rice in Taraba State. Similarly, this paper contributes the first logical analysis that incorporates Agro-climatic statistical method and MCDM (AHP) method in designing a model for Agro-climatic suitability analysis.

1. INTRODUCTION

In Nigeria, rice is one of the major crops cultivated in the Country and it plays a very significant role in food security and provision of employment. Production of the crop recorded an improvement in recent years, but in spite of this development, there is a need for more efforts in its production because of some pressing issues. One of these issues is population increase; Nigerian Population is growing steadily. For example, the previous general census of the country in 1963 and 1991 recorded an increase from 60 million to 88.5 million people (48% increases). The population again increased from 88.5 million to 150 million in 2006 and further increase to the recent projected figure of over 190 million (National Bureau of Statistics (NBC), 2017; National Population Commission (NPC), 2017). Following this population trend, it is clear that the population is increasing at a steady rate and that will consequently increase the demand and consumption of food at both local and national levels. This issue therefore calls for an increase in food production especially rice to meet up with the growing domestic population, following the fact that, population increase is directly proportional to rice demand (Oladimeji, 2017; United Nation, 2017). In an attempt to increase rice production in Nigeria, there is a need for a reliable and accurate land evaluation technique for decision-making processes toward developing a land use policies that will support sustainable agricultural development (Elaalem, Comber, & Fisher, 2010).

Multi-Criteria Decision Making (MCDM) is a technique apply in GIS for Land use evaluation. The method has proven to be useful in different types of decision-making problems and the approaches taken to resolve the problem (Figueira, Greco, & Ehrgott, 2005; Ishizaka & Nemery, 2013; Janse, 2018). There are many different kinds of MCDM techniques used nowadays for solving various decision-making problems. Among them are; The Analytic Hierarchy Process (AHP) (Saaty, 1980), Analytic Network Process (ANP) (Saaty, 1996) and Technique for Order Preference by Similarity to Ideal Situation (TOPSIS) (Hwang & Yoon, 1981). However, among all these techniques used, AHP has received the most academic interest because of it related availability of user-friendly and commercially supported software packages and enthusiastic and engaged user groups, Huang, Keisler, and Linkov (2011); Hodgett (2016). AHP techniques are nowadays widely applied and used to solve various decision making, optimization and predictive problems (Majumder & Saha, 2016). The technique is an example of compensatory MCDM method which compares each alternative with the other alternatives with respect to each of the criteria and then finds the equivalent weight of importance for each of the alternatives which are derived by aggregating the individual importance of the alternatives found (Mrinmoy & Apu, 2016).

Following the relevance of this tool in land use analysis, this paper is design to apply the tool in developing an Agro-climatic model for rice production in Taraba State.

1.1. 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 6°30' and 8°30' North of equator and longitude 9°00' and 12° 00' East of the Greenwich meridian Figure 1.

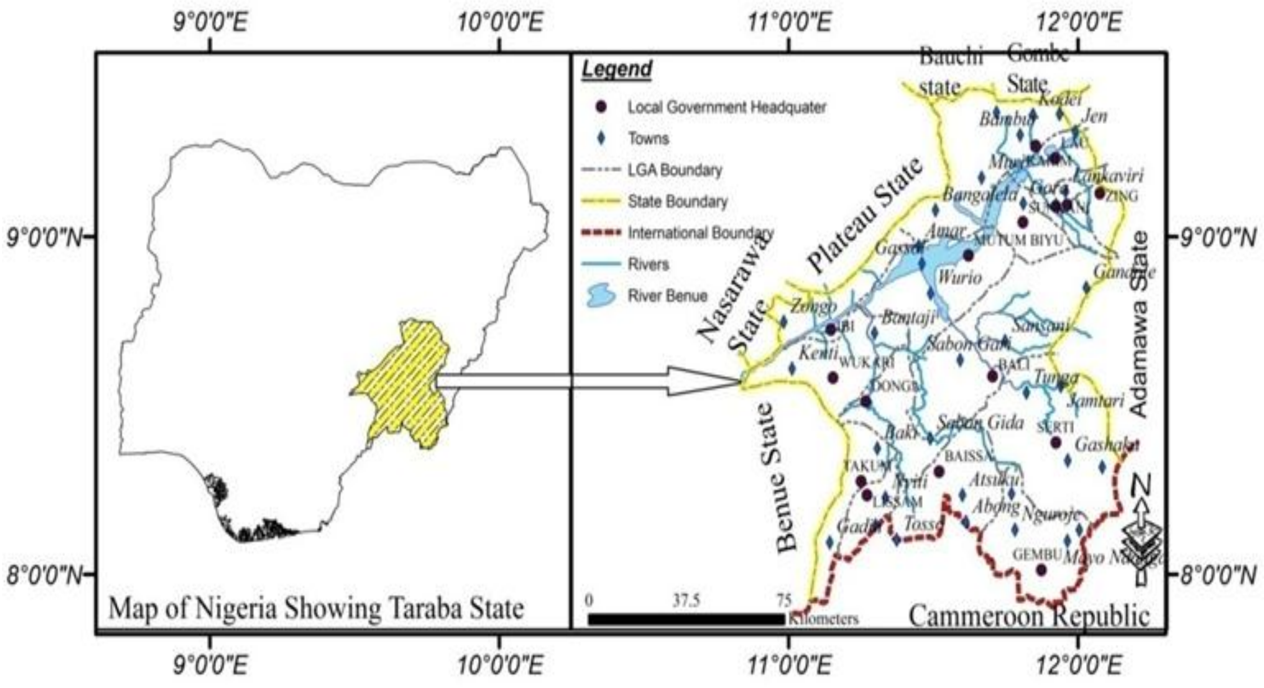

Figure-1. Tatraba State.

Source: Modified from Olalekan, Cao, Hamel, and Finnegan (2015).

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 & 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 (Udo, 1978).

Climate of the State is mainly influenced 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 & Abbas, 2011). Temperature during rainy season in Mambilla drops to as low as 15°C while the mean annual temperature around *Jalingo is about 28oC with maximum temperature varying between 30oC and 39.4oC and minimum temperatures range between 15oC to 23oC* (Emeka & 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.

1.2. Types and Source of Data

In this research work, six (6) different datasets namely; Climatic variables (1979-2017), annual rainfed Rice yield, Map of the study area, Longitude and Latitude, Digital Elevation Model (DEM) Shuttle radar topographic mission (SRTM) and Soil texture maps were the data used in this research were used. 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 (1979 to 2017) while, monthly and annual minimum temperature, maximum temperature, mean temperature, relative humidity, solar radiation and wind speed for the period 1979 to 2015 which is the longest period for which records of the variables are available in the State were obtained 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 and Nigerian Meteorology (NIMET) Ibi. Climate Forecast System Reanalysis (CFSR) is another daily and monthly climatic data source that was downloaded from the globalweather.tamu.edu website. 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 worldCli-Global Climate data version 2 (www.worldclim.org) produce by Fick and Hijmans (2017).

Rice yield data based on 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). The yield records were collected by the staff of TADP annually through a survey method called Crop Area Yield Survey (CAYS). In this survey method, rice yield records based on varieties and cultivated areas of rice farmers in each LGA of the State were collected, analyzed, summarized and recorded in tons per hectare.

Latitude and Longitude were collected using Google Earth, DIVA 75 GIS and Geographic Positioning System (GPS) while, 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). DEM was processed and mosaic to give comprehensive coverage of the study area and then was used to extract the study area with the help of a spatial analysis tool in Arc GIS 10.2. 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).

2. 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. In addition, the* Station-Year method used in section 3.3.2 above was also applied in this section. The statistical or empirical method used in this research was tested to be the best method in crop-climate analysis and was used by many authors in their respective studies (Adebayo, 2000; Adebayo & Adebayo, 1997; Dkhar, Feroze, Singh, & Ray, 2017; Govinda, 2013; Mahmood, Ahmad, Hassan, & Bakhsh, 2012; Tiamiyu, Eze, Yusuf, Maji, & Bakare, 2015).

2.1. 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 using Arc GIS 10.2. For the selected Agro-climatic variables, the critical climatic variables influencing different rice varieties selected from stepwise multiple 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). Criteria map of each selected variable was generated from interpolation maps produced and the world mean spatial climatic maps. The Spatial climatic maps were downloaded in raster format and were then added into the Arc GIS environment. Taraba State area was then extracted from the maps using extraction by mask in the Arc toolbox and was scaled and reclassified into four (4) classes as highly Suitable, Suitable, Moderately Suitable and not suitable area using reclassify tool in Arc toolbox. 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, related literature on rice climatic requirement for growth and yield as well as an idea from experts.

Digital Elevation Model (DEM) *data of Shuttle radar topographic mission (SRTM) 30m resolution as one of the criteria was* processed and mosaic using Arc GIS 10.2 package. The mosaic DEM and Taraba State Shape-file were added into the Arc GIS environment using the Add data icon and then extract Taraba State DEM using Extraction by Mask under Spatial Analysis tool in Arc toolbox. The extracted DEM was then reclassified using the Arc toolbox in Arc GIS were four (4) different classes (highly Suitable, Suitable, Moderately Suitable and not suitable) base on the pixel value of the reclassified DEM was produced. The pixel value was transformed into percentages were high percentage value represents highland and low percentage value represents low lowland area.

Soil texture map of Nigeria downloaded from European Digital Archive of Soil Maps (**EuDASM**) (2017) on the other hand was added to the Arc GIS environment, Georeference and Digitized. All the digitized layers with the same soil texture characteristics based on the soil requirement for rice production were selected and merged together as one class using merge tool in editor menu of the Arc GIS and was then reclassified into four classes (highly Suitable, Suitable, Moderately Suitable and not suitable). The method used by Getachew and Solomon (2015) and Joseph, Bosco, and Murage (2013) was adopted in scaling the soil texture and slope suitability zone for rice cultivation.

2.2. Application of MCDM (AHP/PCM) on the Selected Criteria Used

To produce the suitability zones for cultivation of rice, there is a need to assign a weight to each criterion so as to obtain an accurate estimate of the criterion on the suitability zone since the selected criteria have different contributions to rice yield. Analytical Hierarchy Process (AHP)/Pair-wise Comparison Method (PCM) as one of the methods of MCDM was 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 (Getachew & Solomon, 2015; Mu & 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. The reason for the scaling is to obtain the relative priority of each criterion with respect to each of the others. 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 & 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 & Pereyra-Rojas, 2017). For example, if Temperature is strongly more important than Rainfall and Rainfall is moderately important than Slope, this, therefore, showed that Temperature is very strongly more important than Slope. But in a situation whereby this relationship doesn't exist, then there is no consistency in the Pair-wise comparison, as such, you need to go back and repeat the Pair-wise comparison. 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.

RI = Random index Table 2.

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.

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).

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

2.3. 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. The Area of the reclassified layer (Class) was then converted into a polygon and was letter calculated using calculates area tool in spatial statistics toolbox. All these procedures were applied in producing suitability maps and calculation of areas of each selected rice variety. All the output maps produced in this section are referred to as the agro-climatic suitability maps for rice production based on the selected climatic variables in the study area.

2.4. 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. All the criteria mentioned were then added into the Arc GIS environment, overlaid and the suitability classes were calculated. 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.

2.5. Comparison of Rice Suitability 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 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). NDVI was used because it is the most common vegetation index used in vegetation analysis. 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 such as that found in temperate and tropical forests or crops at their peak growth stage. 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 compare the suitability map produce in the last step with NDVI map generated, the two suitability maps were overlaid using Fuzzy overlay in the arc toolbox.

2.6. Method of Statistical Analysis

Several statistical analyses were conducted in this research, these include simple mean, Regression, AHP and consistency ratio. Stepwise regression was used to examine the relationship and effect of climatic variables on the yield of rice in the study area.

Agro-climatic and rice yield data were correlated and regressed to examine the relationship between the climatic variables and yield of different varieties of rice as well as the effect of the climatic variables on rice yield. Consistency ratio was used in testing the consistency of the PCM in AHP. The regression models used in this research are presented below;

i. $Y= a+b_1x_1+ b_2x_2+ b_3x_3$ (Regression model)

Where:

Y = Rice yield.

X_1 = Mean Temperature, X_2 = August Rain and X_3 =September Rain.

a and b are constant.

3. RESULTS AND DISCUSSIONS

3.1. Climatic Criteria maps used in Agro-climatic Suitability Zones for Rice cultivation

Table 3 and 4 displayed the stepwise regression result and the scale used in assessing and producing the climatic criteria maps for suitability zoning. The climatic criteria were selected based on the result obtained from the stepwise regression result while the scale of the criteria was produced based on the relationship between climatic variables and the selected rice varieties in the study area. Figure 2 showed the identified climatic criteria maps.

Table-3. Stepwise regression result between faro 44 variety and climatic variables.

Predictors	Coef	SE Coef	T	R^2 (%)	R^2(adj)	R^2(pred)
Constant	-10.679	2.019	-5.289**			
Mean temp	0.464	0.073	6.371**	46.3	44.9	40.66
August Rain	0.004	0.001	3.413**	54.3	51.8	42.98
Sept. Rain	-0.003	0.001	-2.969**	60.1	56.8	45.40
July	0.002	0.001	1.991*	64.2	60.1	49.33

Note: ** T-value is significant at 1%.
* T-value is significant at 5%.

Table-4. Scale of the identified critical climatic variables.

Criteria	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 July	>280	231-280	210-230	<210

3.2. Soil Texture and Slope Criteria Maps Used in Suitability Zoning for Rice Cultivation

Figure 3 displayed the Soil texture and Slope maps which were used in the Agro-climatic zoning of Taraba State for rice cultivation.

The maps were produced based on the scale presented in Table 5.*Soil and Slope suitability maps of the State were also considered as criteria that were used in agro-climatic zoning of Taraba state for the cultivation of the rice varieties.* 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 map are classified into four different classes and the method used was adopted from* (CSR/ FAO, 1983; Getachew & Solomon, 2015; Joseph et al., 2013).

Table-5. Scale of the Soil texture and Slope criteria.

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); Getachew and Solomon (2015).

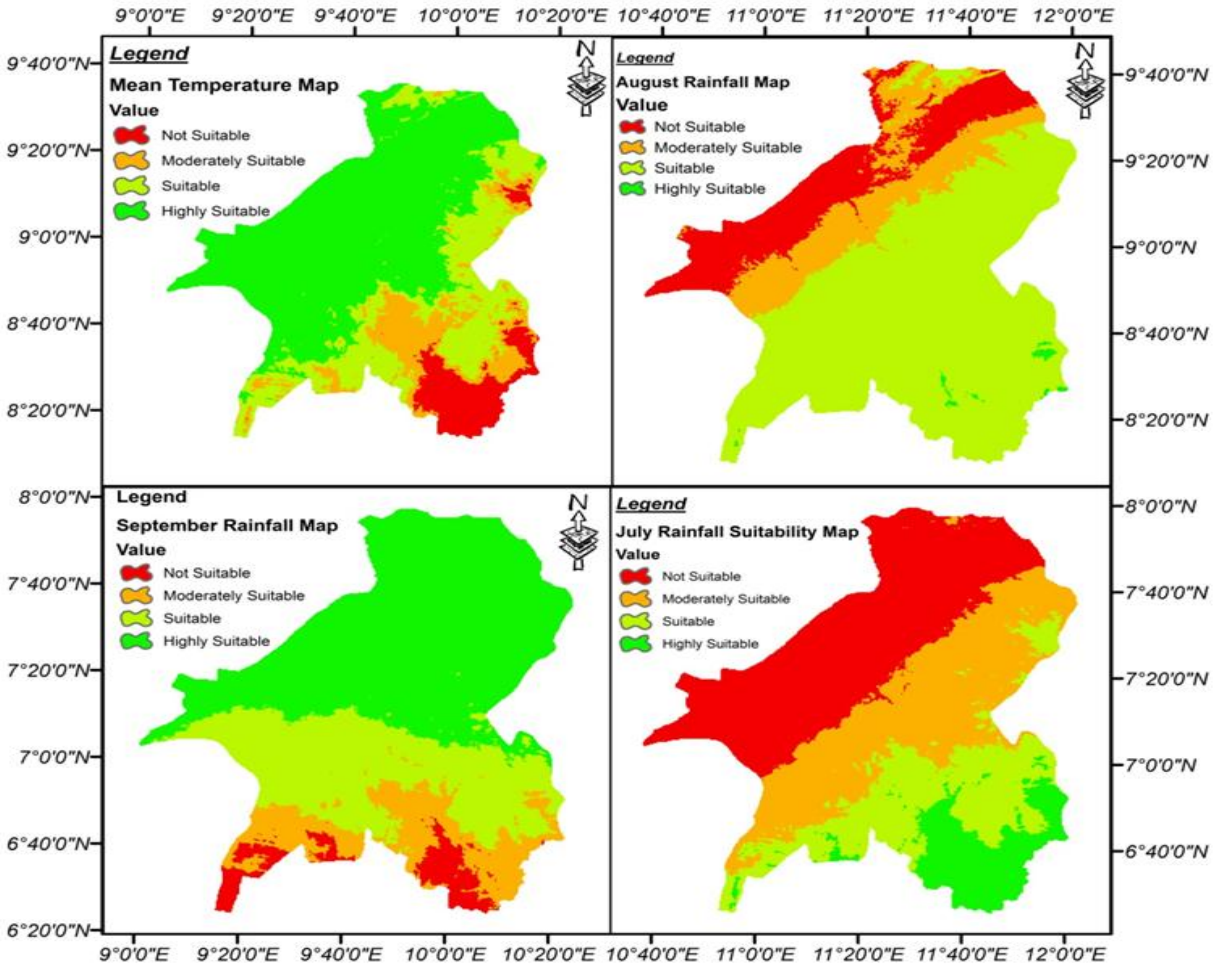

Figure-2. Identified climatic criteria.

Source: Modified from Fick and Hijmans (2017).

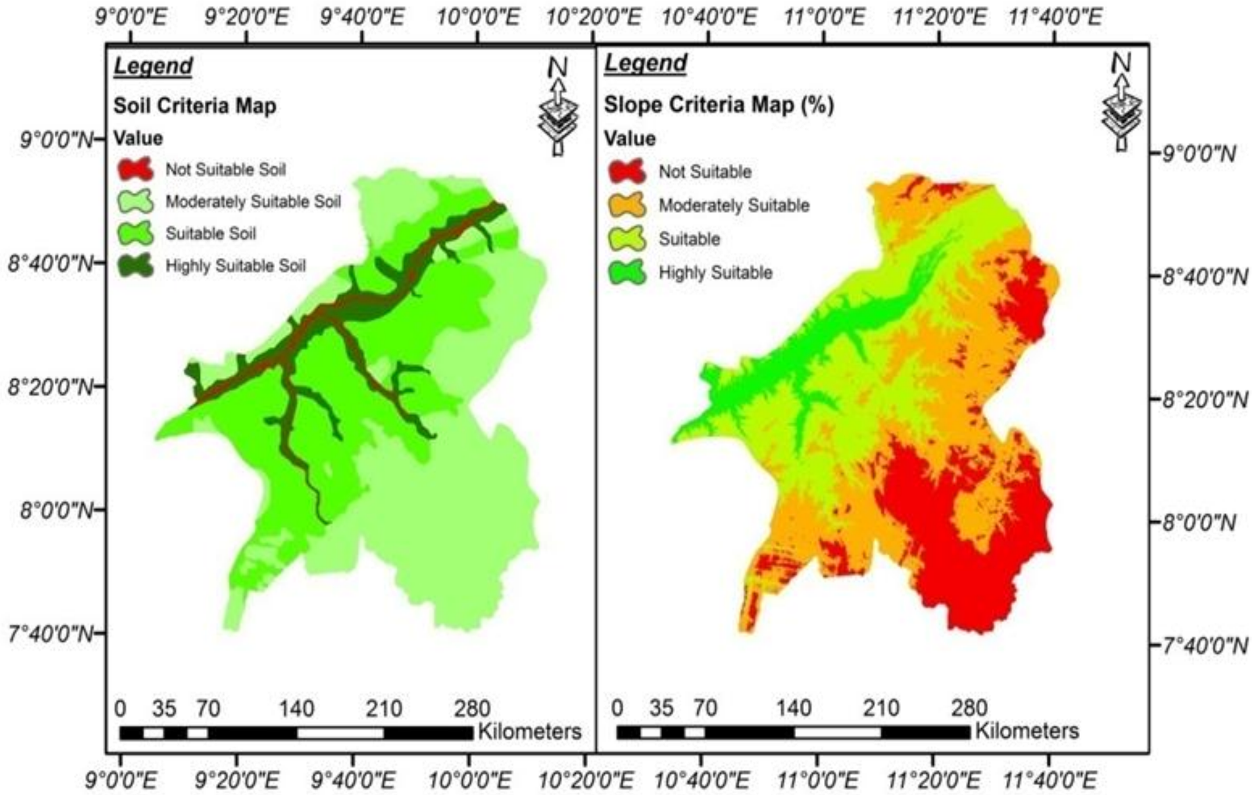

Figure-3. Soil and slope criteria maps.

Source: Modified from EuDASM, 2017 and glovis.usgs.gov.

3.3. Agro-Climatic Zones for Rice Cultivation Based on Climatic Variables in the State

The result of the PCM revealed that Mean Temperature has a weight of 61.33% followed by August rainfall with 21.91%, September rainfall with 10.93% and then July rainfall with 5.83% which explained that; mean temperature has a high contribution in producing the Agro-climatic zones for rice cultivation followed by August rainfall, September rainfall and then July rainfall Table 6 and 7.

Result of the suitability area based on Agro-climatic variables revealed that the highly suitable places for cultivation of the crop include; Wukari, Donga, Baki, Bantaji, Sabon Gari, Bali, Mutum Biyu, Sunkani, Jalingo, Lau, Gora, Muri and Bambur which covered a total land area of 20,846.17km^2 (35.25%), while the suitable area includes Ibi, Kenti, Zongo, Gassol, Amar, Karim, Zing, Takum, Lissam, and Baissa which covered an area of 26,861.03km^2 (45.42%). The moderately suitable places, on the other hand, has a total land area of 9,822.94km^2 (16.61%) 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 1,608.39km^2 (2.72%). In line to this result obtained, it is clear that the highland region of the State which includes Gembu, Mayo Ndanga and Nguruje are not suitable for the cultivation rice based on the fact that the area experience low mean temperature that is not suitable for rice growth and yield (Getachew & Solomon, 2015; Joseph et al., 2013) and high rainfall amount in the month of September which is not suitable for rice development at that stage (maturity stage of rice) (Buck, 2010; Oikeh et al., 2008; Teh, 1998). Unlike the not suitable zones, the highly suitable and suitable zone 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 rice (Joseph et al., 2013).

Table-6. Pair-wise Comparison matrix of the Criteria.

Criteria	Mean Temperature	August Rainfall	September Rainfall	July Rainfall
Mean Temperature	1.0000	3.0000	7.0000	9.0000
August Rainfall	0.3333	1.0000	3.0000	3.0000
September Rainfall	0.1429	0.3333	1.0000	3.0000
July Rainfall	0.1111	0.3333	0.3333	1.0000
Total	1.5873	4.6667	11.3333	16.0000

Table-7. Normalized pair-wise comparison matrix and weight of criteria.

Criteria	Mean Temperature	August Rainfall	September Rainfall	July Rainfall	Weight	Weight (%)
Mean Temperature	0.630	0.643	0.618	0.563	0.613	61.33
August Rainfall	0.210	0.214	0.265	0.188	0.219	21.91
September Rainfall	0.090	0.071	0.088	0.188	0.109	10.93
July Rainfall	0.070	0.071	0.029	0.063	0.058	5.83

Note: Maximum Eigen Value=4.12982
CI=0.04327
CR=0.04808.

3.4. Suitability Zones for Rice Cultivation Based on Climatic Variables, Soil and Slope Criteria

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.*

The suitability map for cultivation of rice revealed that the suitable area has the highest total land area of 30,734.02km² (51.97%) followed by the highly suitable area which occupied 16,975.87 km² (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 1,607.81 (2.72%) and covered places like Gembu, Mayo Ndanga, Nguroje and Mai Samari See Figure 4. All the highly suitable and the suitable area for cultivation of rice are place with relatively high temperature amount, favorable rainfall amount in August, September and July, good soil texture characteristics and plain or flat terrain which are all essential for the growth and yield of rice in the State.

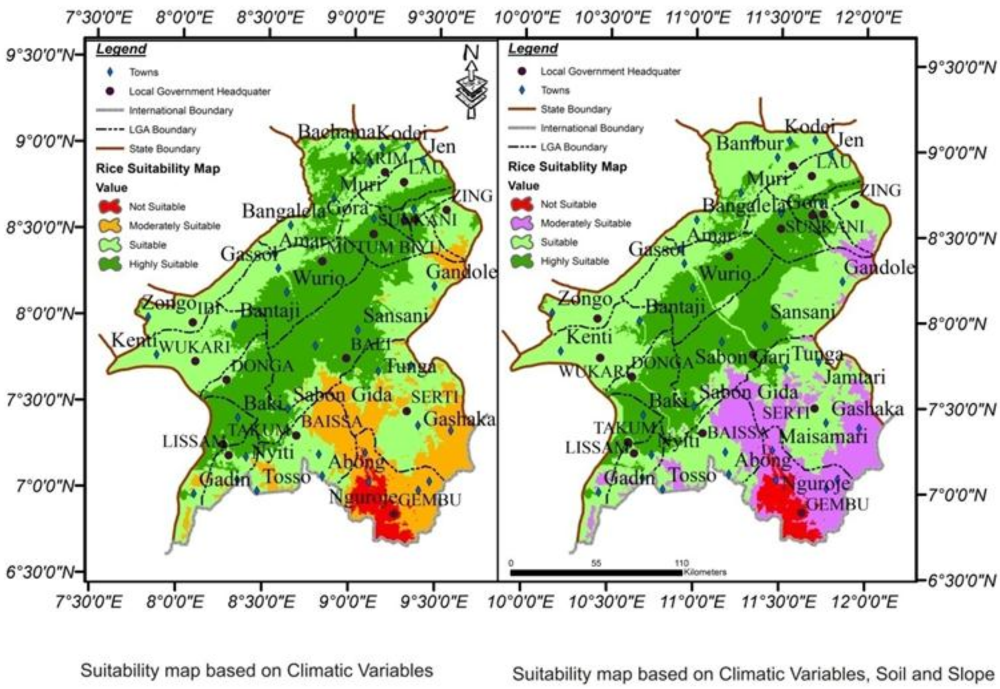

Figure-4. Rice suitability map based on the selected climatic variables.

Table-8. Pair-wise comparison matrix based on agro-climatic map, soil and slope maps.

Criteria	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

Table-9. Normalized pair-wise comparison matrix and computation of criterion weight based on agro-climatic map, soil and slope maps.

Criteria	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

Note: Maximum Eigen Value=3.00703
CI=0.003515
CR=0.006061.

The suitability map for cultivation of rice based on Agro-climatic, soil and slop of the area revealed that the suitable area has the highest total land area of 28,489.08km² (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.

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; Powers et al., 2005; Sridevi & Chellamuthu, 2015; Worou, Gaiser, Saito, Goldbach, & Ewert, 2012). *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, Ranjini, Govila, & Vibha, 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, Paustian, Elliott, & Combrink, 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 (Husson, Castella, & Tuan, 2001; Mayumi et al., 2016).

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).

3.5. Compare Agro-climatic Suitability Zone based on Climatic, Soil and Slope with the NDVI of the State

Map of NDVI as a criterion is presented in figure 7.20 where three different classes was identified base on USGS and NASA classification of vegetation cover. The map revealed that, 51,747.64km² (87.50%) area of the State is occupied by sparse vegetation such as shrubs and grasslands or senescing crops while 1,511.39km² (2.56%) area is covered by dense vegetation and 5,879km² (9.94%) represent the buildup area, barren rock and water bodies See Figure 5.

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. This is based on the fact that 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) based on the NDVI layer. Results of the analysis revealed that there is an increase of 5,879km² in not suitable area of the Agro-climatic suitability map produced.

This is based on the fact that, the NDVI map displayed not agricultural area of 5,879km² (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. Result of the analysis obtained after considering NDVI map of the study area revealed that, the not suitability area increases by 9.94% while the highly suitable area reduced from 28.71% to 26.56% while the suitable area reduced from 51.97% to 47.20% See Figure 6.

In all these analysis presented, it is clear that non agricultural land has reduced the areas that are suitable for cultivation of rice in the state, as such, NDVI plays a significant role on rice suitability mapping of the state. Following the steps and methods applied in this work, a simple model was designed to explain all the steps, methods and analysis applied in this work. The model is presented in Figure 7.

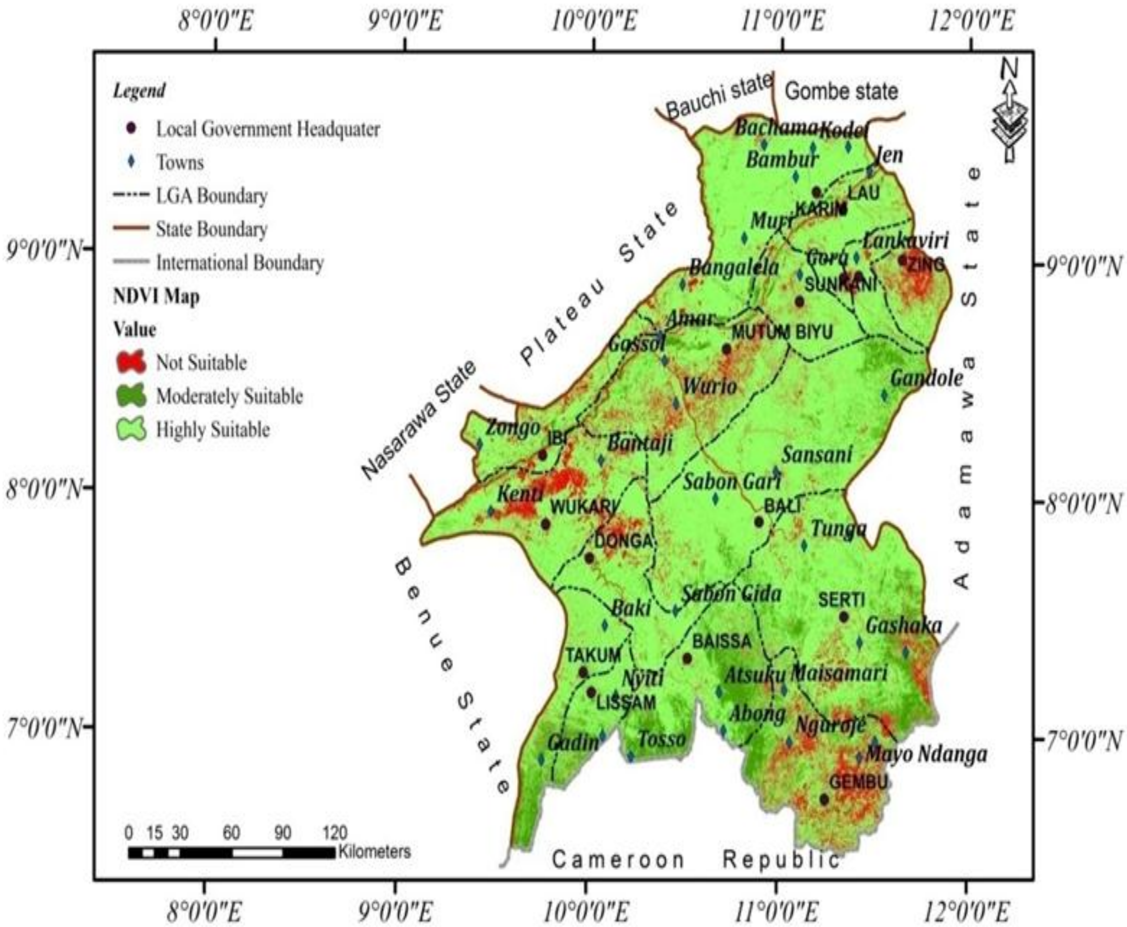

Figure-5. NDVI suitability map.

Source: Extracted from Landsat 8 (OLI) Images, 2018.

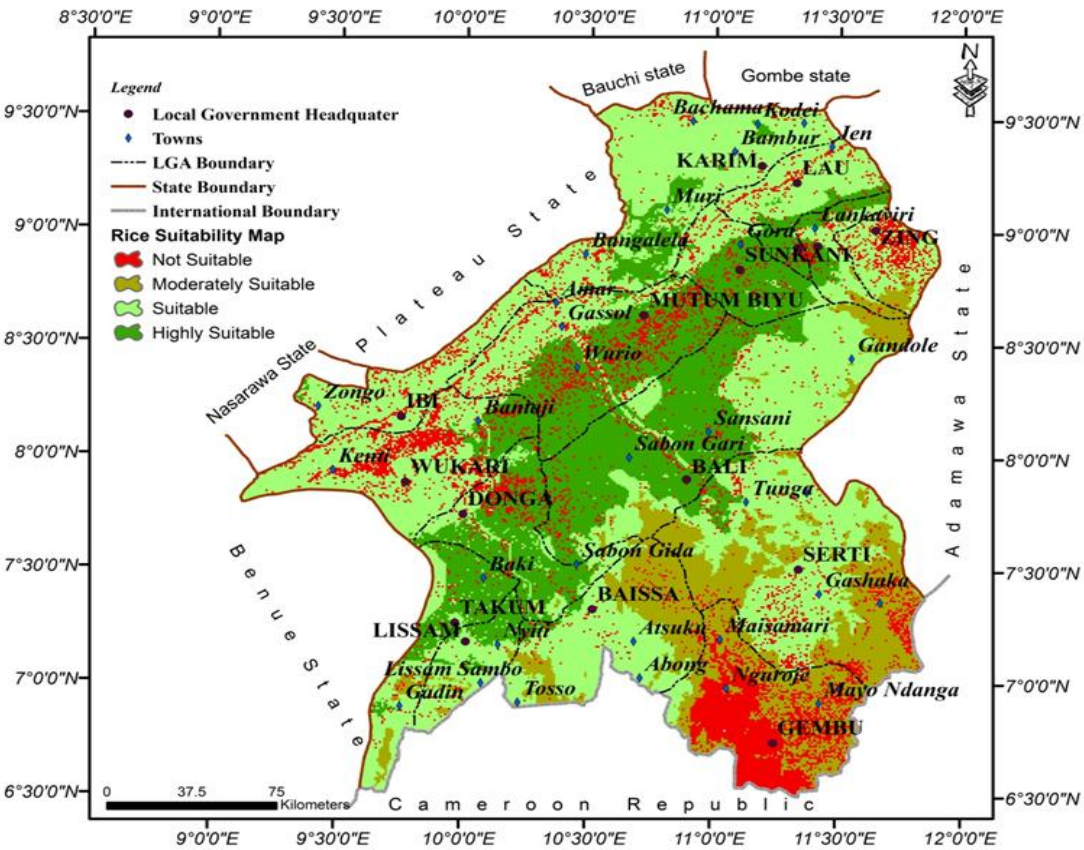

Figure-6. Final suitability map for rice cultivation in Taraba State.

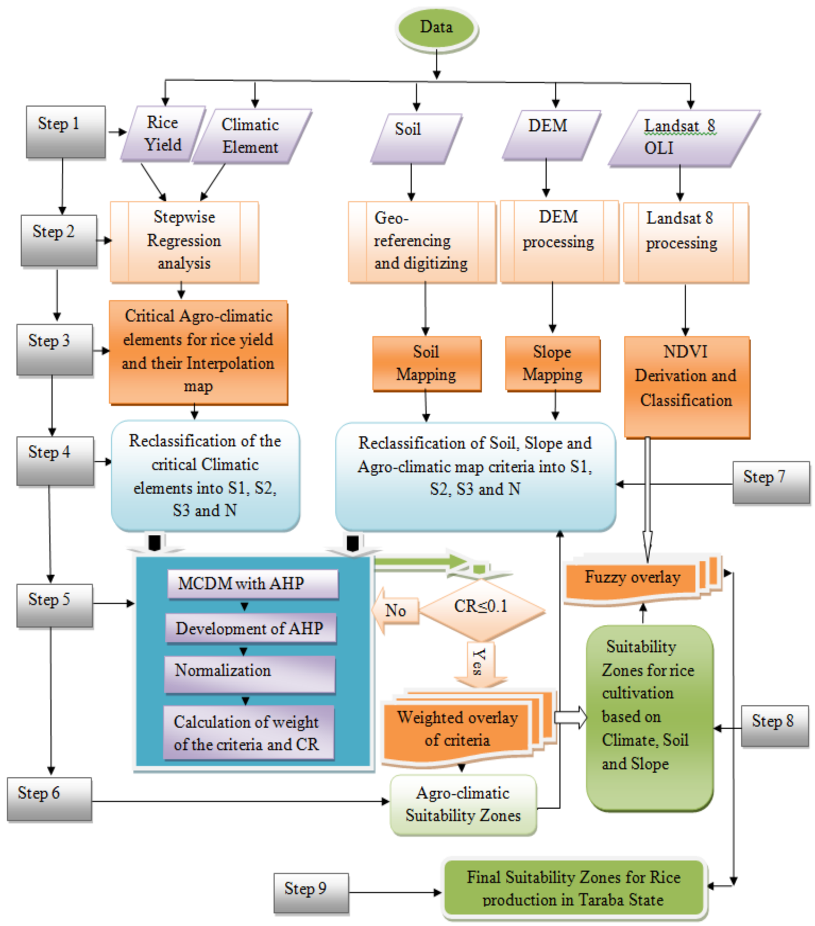

Figure-7. Suitability model for rice production in Taraba State.

4. CONCLUSION

Following the findings of this study, it was concluded that, Lissam, Takum, Donga, Wukari, Ibbi, Gassol, Serti, Karim, Lau, Sunkani, Mutum Biyu and Bali are suitable for cultivation of rice in the State and all the suitable areas for cultivation of rice are places 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 rice in the State. Unlike the Highly Suitable and Suitable Zones, the not suitable zone on the other hand include places such as, Gembu, Mayo Ndanga, Mai samari and Nguroje have low temperature amount that is not Suitable for cultivation of rice. In addition, MCDM/AHP was tested 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. Similarly, the Use of NDVI provides a means were by non agricultural land areas were extracted thereby reducing the level of exaggeration of Suitable agricultural land area.

5. RECOMMENDATIONS

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

ii. Cultivation of alternative crops other than rice in the not suitable zones is highly 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 compare to other parts of the State.

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

iv. Irrigation farming should also be motivated in places of insufficient rainfall distribution especially places along the major rivers in the State.

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