Agro-Climatic Land Suitability Mapping for Sugarcane Production in Parts of Adamawa State, North-Eastern Nigeria

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Abstract

In this paper, agro-climatic conditions were used in mapping out suitable sites for sugarcane production in the southern parts of Adamawa State, North-Eastern Nigeria. In search of more areas to diversify sources of revenue for the state, the researchers ventured into the aspect of sugarcane production to look for additional sites, different from the ones being cultivated presently. From the literatures reviewed in the course of this study, no work has been carried out on specifically mapping areas that will be suitable for sugarcane production in the State. Therefore, to fill this gap, this work was conceived. The study covers eleven Local Government Areas with total area of about 20,739 Km.^{2} Data on rainfall, temperature, relative humidity, sunlight, soil, relief and drainage were transformed into spatial datasets and integrated in the process of Weighted Sum overlay in ArcGIS 10.2 and in line with the FAO guidelines on suitability analysis for the sites selection. Four classes of suitability were arrived at, which are Most suitable, Moderated suitable, Marginally suitable and Not suitable sites for sugarcane cultivation. The result from this study revealed significant information on site selection for sugarcane cultivation in the study area. The results show that, most suitable areas cover a total area of about 850 Km^2 (4% of study area), moderately suitable areas cover about 10,978 Km^2 (53%), marginally suitable areas cover about 6,248 Km^2 (30%) and not suitable areas 2,664 Km^2 (13%). Thus, combining the areas that are most suitable and moderately suitable gives about 11,828 Km^2 (57%) as total land that could support optimum growth and yield of sugarcane crop in the study area. This area is substantial enough to produce sugarcane in a quantity that can boost the economy of the State and the country at large. Therefore, the government of the State should key in to this potential area of economic diversification by inviting stakeholders in the area of sugarcane production to look into this finding with the aim at promoting sugarcane production as one of the major sources of income to the State.

Keywords: agro-climatic, site suitability, sugarcane, suitability analysis, spatial data

1. Introduction

To explore and of course search for more source of income for Adamawa state in addition to the ones been cultivated presently, this work considered the area of sugarcane cultivation. Presently, one of the largest Nation's sugarcane refining companies is located in the study area at Numan on about6,750 hectares of land (Dangote Sugar Refinery, 2018). This work seeks to find out if there are other areas, especially in the southern parts of the state that could be suitable for the cultivation of sugarcane. This quest informs the conception of this work believing that information provided in the end will lead to clear mapping out of agro-climatic land suitability for the production of sugarcane crop in the study area.

Weighted Sum Overly of ArchGIS 10.2 was adopted for the study for its reliability in providing relatively accurate result of land suitability analysis (Esri, 2016). This methodology combines all the parameters used as basic agro-climatic requirement for sugarcane cultivation to identify areas that meet all or otherwise the requirements.

However, there are several studies on sugarcane and other crops, but none attempted to carry out mapping out of agro-climatic land suitability for sugarcane cultivation in the study area. A detailed soil survey and characterization of Vertisols of Numan in Adamawa state have been carried out to provide soil-based information in order to boost sugarcane production and also to serve as a yard stick to the immediate community in the area. This study was carried out by Zata *et al.* (2013) in their work: "a detailed soil survey and characterization of some usterts inNortheastern Nigeria." They carried out field survey, following some scientific steps to obtain the data used for the study. A total area of about 5000 ha covering both fallow and cultivated vertisols was selected for the research. All the morphological, physical and chemical properties including the micro-nutrients were carried out. Land evaluation vis-à-vis land capability classification, land suitability classification and soil fertility capability classification were also carried out respectively using the data obtained from this research. Some simple correlation analysis was carried out in order to study the relationship between cation-exchange capacity (CEC) and Clay; CEC and organic matter. Also, predictive regression analysis was carried out to be able to determine how the soils of the study area will behave in the future. The results of the research showed that the soils were generally dark grey to dark greyish brown in colour with a general clayey texture and strong prismatic structure. Five soil mapping units were identified in the study area and these were: Calcic Chromusterts (SVM1); Entic Haphlusterts (SVM 2); Eutric Chromusterts (SVM 3); Natric Chromusterts (SVM 4) and Typic Pelluderts (SVM 5). SVM= Savannah Vertisols mapping unit. This study is somehow related to the present one, for it identified some soils that will be good for sugarcane production.

Yahya & Adebayo (2015) carried out a study on "Assessment of land use /land cover changes in the Savannah Sugar project area, Adamawa state, Nigeria". Landsat satellite images from Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+), acquired from the United States Geological Survey (USGS) archives, and topographic maps from the Nigerian Survey Departments for different dates were used. They adopted Algebraic and Markov (in IDRISI) for data analysis. Map algebra was employed to determine image differential from an earlier year and the latter, while the Markov method provides a change matrix with change trajectories. This was done with IDRISI software. The results of the study showed that cropland has highest increase gained from vegetation, bare surface, built up, marshes, and water in that order. This is followed by bare surface which gained from vegetation, cropland, water built-up and marshy land. The largest decrease was vegetation which gave out to cropland, bare surface, marshes, built up, and water. It was concluded that, land cover changes are tending towards bare soils and marshes as indices of environmental degradation, primarily because of increased human activities, particularly agriculture, animal grazing, and the increased construction of paved roads and settlements.

Binbol *et al.* (2006) in their study "influence of climatic factors on the growth and yield of sugar cane at Numan, Nigeria" useddaily records of rainfall, relative humidity, maximum and minimum temperatures, evaporation, wind velocity and sunshine hours for the 20-year period (1981–2000) collected from the meteorological station (No. 0911.35; 9° 34' N, 11° 58' E; 144 m mean sea level) of the Agronomy Division of Savannah Sugar Company Limited (SSCL). The nature and extent of the relationship between sugar cane yield and climatic variables at each stage of growth was examined using correlation analysis, while stepwise multiple regression analysis was employed to determine the combined effect of the climatic elements on sugar cane yield. Results from the correlation analysis showed that several of the climatic factors studied significantly affect the growth and yield of sugar cane.

In their study, Girei & Giroh (2012) "analysis of the factors affecting sugarcane (*saccharum officinarum*) production under the out growers' scheme in Numan Local Government Area Adamawa State, Nigeria," used questionnaires, administered to 120 respondents which was the main source of data collection for the research work and this was complemented by oral interview amongst other sources. Simple random sampling method was used, where respondents were selected from each of the six (6) zones of Savanna Sugar Company Limited estates comprising of 40 farmers. Out of these, a sample of 20 respondents was randomly selected from each site, giving a total of 120 farmers selected for the study. The main tools for data analysis were descriptive statistics such as mean, percentages and frequency distribution and budgetary technique for analysis of cost and benefit associated with sugarcane production. The results of the study indicated that the cost of production of sugarcane per hectare which consist of both the total variable cost (TVC) and total fixed cost (TFC) per hectare were and ₦ 20,959.00, accounting for 85.48% and 14.52% of the total cost of production. The gross farm income was ₦ 38, 625.83 while the NFI was ₦ l7, 666.83/ha. Similarly, the return/naira invested in the production of sugarcane by the out-grower farmers was ₦ 0.84 implying a positive return of 84 Kobo on every ₦1.0 invested, showing that production is profitable in the short run.

Of all the works (published) reviewed, there is no one that attempted to assess suitable lands for the cultivation of sugarcane covering the present area of study (Southern part of Adamawa State). However, few researchers worked on sugarcane cultivation, but failed to either identify suitable agro-climatic sites for the crops production or only cover smaller areas in the state. For instance, Zata and Mustapha (2013), identified some soils that will support the crop in their work, but narrowed their work on Numan local government area of the state. Nevertheless, the data used in their work failed to include climatic factors in their evaluation. Binbol *et al.* (2006) also monitored the influence of climatic factors on sugarcane production in the state, but failed to specify some suitable site for the production of the crop. Yahaya & Adebayo (2015) also worked on sugarcane production in the state, but their work was more of assessing the changes that are taking place in the land cover/land uses as it affected cultivation of sugarcane in Savannah Sugar Company Limited in Numan.

However, there are several other works on agricultural land suitability evaluation carried out on Adamawa state and other countries of the world, done on different crops. Some of such are the works of Ikesemoran and Hajjatu (2009) who worked on yam and rice; Jerry, Gadiga and Mshelia (2014) on irish potatoes; Kefas and Zemba (2016) worked on Cassava and Mshelia and Zira (2015) who worked on wheat. The listed works were also on agricultural land suitability evaluation, but are not on agricultural land suitability mapping for sugarcane production in the southern parts of Adamawa state. Nevertheless, Jamil *et al.* (2017) and Mustafa *et al.* (2011) carried out land suitability analysis in some regions in India, but climatic factors were not used much as criteria for their analysis.

2.0 Materials and Methods

2.1 Study Area

Adamawa state is one of the states in north eastern Nigeria with its capital Yola. It is one of the largest states in the country and occupies about 36,917 square Kilometres. It is located between longitudes 11ºE and 14ºE and latitudes 7ºN and 11ºN. The State has common boundaries with Taraba State in the south-west, Gombe state in the north-west and in the north with Borno state. In the eastern part, the State shares an international boundary with the Republic of Cameroon (Adebayo & Tukur, 1999). However, the study area, that is the southern parts of the Adamawa State consists of only eleven (11) Local Government Areas and lies between latitude 7ºN and 11ºN (Figure 1).

Adamawa state is characterised with varied rainfall ranging from 700mm in the north-western part to 1600mm in the southern part. By and large, the mean annual rainfall is less than 1000mm in the central part of the state. This region includes, Song, Gombi, Shelleng, Guyuk, Numan, Demsa, Yola and part of Fufore Local Government Areas (LGAs). Northern strip and southern part have over 1000mm in the other hand. This variation of the annual rainfall amount is as the result of the altitudes of the stations.

2.2 Data Source

The Climatic data used include: Rainfall, Temperature, Sunlight, and Relative Humidity (RH); Soil, Relief and Drainage of the study area where also incorporated for the analysis. Therefore, their source varied. Data on rainfall, temperature, sunlight and RH were obtained from Nigerian Meteorological Agency (NiMet), Global Weather Data for SWAT (GWDS) and NASA Prediction of Worldwide Energy Resources (POWER). The data from GWDS were from 1979 to 2014 (35 years). NASA POWER data also covered a period of 35 years, which is from 1982 to 2017. All the climatic data were in numeric forms which were later processed into spatial datasets for this work. Dataset on soil type were obtained from Global Soil Survey and NRCS (Natural Resources

Conservation Service) map of 2005 from United State Department of Agriculture (USDA). However, Relief and drainage of the study area where extracted fromhttp://data.biogeo.ucdavis.edu/data/diva/ alt/NGA_Alt.zip was the source used to obtain the related data. These data were in JPEG formats and imagery and *added* (imported) in the Arc Map environment where they were *georeferenced* and captured for used in the study.

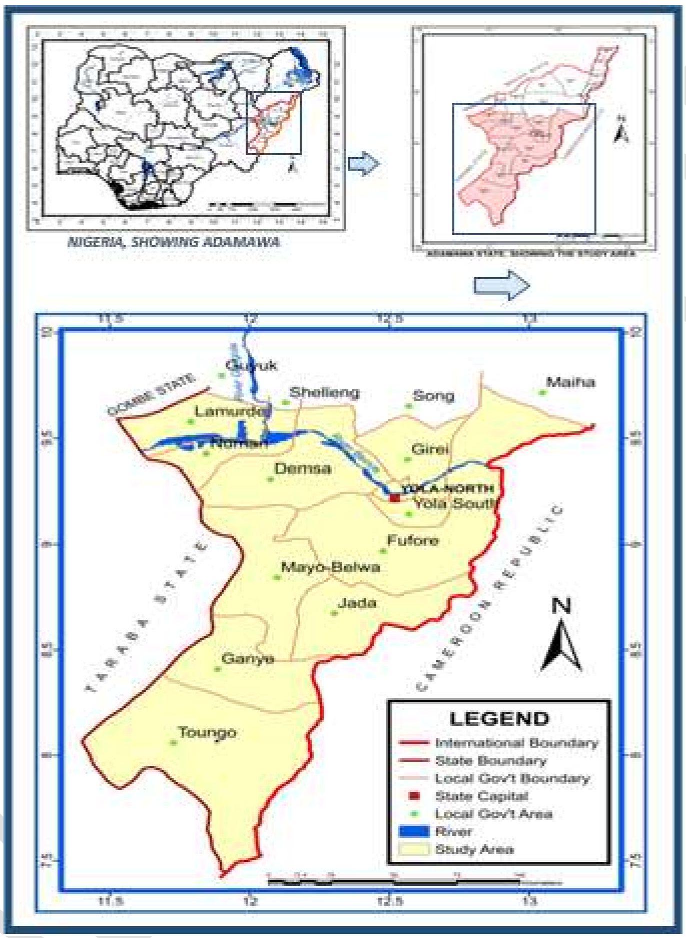

Figure 1: Location of the Study Area (Source: NETAFIM, 2019)

2.3 Preparation and Creation of Criteria Maps

The four climatic data used in this work, were analysed in the Microsoft Excel to produce tabular datasets for use in the Arc Map (ArcGIS 10.2) environment. Averages for each point (coordinate) in the study area captured for the period of 35 years were computed. Subsequently, the tables were added in the Arc Map environment, where the *Display XY Data* command, was used to display the values computed for all the points. These points and their values for each dataset were displayed across the study area automatically. In order to produce a spatial representation of the datasets over the study area, *interpolated* command was used on each of the climatological dataset. Therefore, on each dataset, a map was produced showing various units depending on the range of values computed and they served as criteria used for further analysis. The other three physical data (soil, relief and drainage) which were in form of thematic maps for soil and drainage, and imagery for relief were geo-referenced following their retrieval from the sources stated early to come up with compatible datasets for used in ArcGIS environment (see Appendix 1)

2.4 Reclassification of Dataset

The climatic datasets having been produced through the process called interpolation in ArcGIS environment are automatically in form of raster map were also used for further analysis. However, the physical data needed were converted into raster maps by digitising them. Therefore, various units on the physical datasets (maps) were digitised as polygons. In ArcGIS environment, attribute table was created for the dataset so that more information on the data is recorded on the table. For instance, the various temperature regions have their attribute tables produced and each region's value recorded against it on the table.

All the datasets were further reclassified for integration in the weighted sum overlay process. Reclassification here was carried out so that on each dataset's attribute table, areas that meet the required condition for sugarcane cultivation were reassigned value **1**, while areas that do not were given **0** (see Table 1 for requirement). The datasets which were initially having various units shown by different colours now changed to two (2) units, that is areas that are suitable and areas that are not suitable for sugarcane cultivation in the study area. These two units were depicted with green colour for areas that are suitable and red colour for areas that are not suitable. It was these analysed agro-climatic parameters (reclassified datasets), that were integrated to come up with the final result (See Appendix II).

2.5 Weighted Sum Overlay and Sum Output

Weighted Sum is a process of data analysis, which works by multiplying the values of designated field for each input raster by the specified weight. It then sums (adds) all input raster datasets together to create an output raster (Esri, 2016). Weight here, means importance attached to a criterion, which could be in percentage or ratio. For this study, the value of 1 was assigned to each of the reclassified dataset used, signifying that equal importance were given to each.

The seven reclassified criteria were integrated through the process of W*eighted Sum* overlay This process could be expressed mathematically as follows:

Weighted Sum output = *wightedSum (weighted Sum Table[Criteria 1, Value *weight Value], [Criteria 2, Value*weight value], [Criteria 3, Value*weight value].....[Criteria N, Value*weight value])*(Esri, 2016)

2. Results and Discussions

The analysed datasets shown in Figures 9 to 15. (appendix II) are the reclassified datasets. They display the areas that are suitable and areas that are not suitable for sugarcane growth on each criterion used for study. The area coverage for each unit of suitability on the maps is computed and the result displayed in Table 2. This is the transformation of the initial criteria datasets used for this study, from multi-units' maps to di-unit maps showing only areas that are suitable with value 1 (green in colour) and areas that are not suitable with value 0 (red in colour) for sugarcane production. These nevertheless, are the maps that were combined through the process of weighted sum overlay to come up with agro-climatic land suitability for sugarcane production in the study area.

Table 1: Conditions for Agro-Climatic Land Suitability Selection for Sugarcane Production in the Study Area

Serial Number	**Criterion**	**Ideal Condition for Sugarcane Cultivation**	**Source**
1	Mean Annual Rainfall	Between 750 to 1500 mm	Mondale (2017)
2	Mean Annual Temperature	Between 25 to 40°C	Directorate of Sugarcane Development (2013); Asiafarming.com (2018)
3	Relative Humidity	At least 70%	Srivastava and Rai (2012), Binbol *et al.*
4	Sunlight	18-36 MJ/m^2 Daily	NETAFIM (n.d)
5	Soil Types	Deep loamy soil, heavy clay soil, sandy loam soil	SC (2012), Letstalkagric (2017), Republic of South Africa (2014)
6	Relief	Highland and Medium highland	Sugarcane Production (2012)
7	Drainage	Well drained Land, Not waterlogged	Rhum Agricole (n.d), (Tarimo & Takamura (1998)

Table 2**:** Area Coverage for Reclassified Datasets

S/N	DATA	SUITABILITY			
		Suitable		**Not Suitable**	
		Km²	**%**	**Km²**	**%**
1	Rainfall	20,008.99	96	730.31	4
2	Temperature	20,739.30	100	0	0
3	Sunlight	20,739.30	100	0	0
4	RH	6,621.21	32	14,118.09	68
5	Soil	12,888.40	62	7,850.90	38
6	Relief	14,667.20	71	6,072.10	29
7	Drainage	19,867.40	96	871.90	4

2.6 Datasets Integration and Degree of Suitability

Following the integration of all the analysed dataset the result of the finding is shown in figure 16. On the map, values for degree of suitability for each site are shown. That is, 7, 6, 5, 4, and 3 depending on the number of conditions a given area meets for sugarcane production. This map is further analysed to come up with four degree of suitability that is Most suitable, Moderately suitable, Marginally suitable and Not suitable for sugarcane production.

All the analyzed datasets (maps) containing only **1**s and **0**s were combined (overlaid) identify degree of suitability of the lands in the study area. Therefore, on the overlaid map, some areas meet all the seven conditions used for this study and were assigned value 7, other areas meet six conditions assigned value 6, other five conditions assigned value 5, other four conditions assigned value 4 and still others meet three conditions and were assigned value 3. Need noting is that, from the outcome of the overlay process, no area meets less than three conditions, hence no value less than 3 is included (Figure 2).

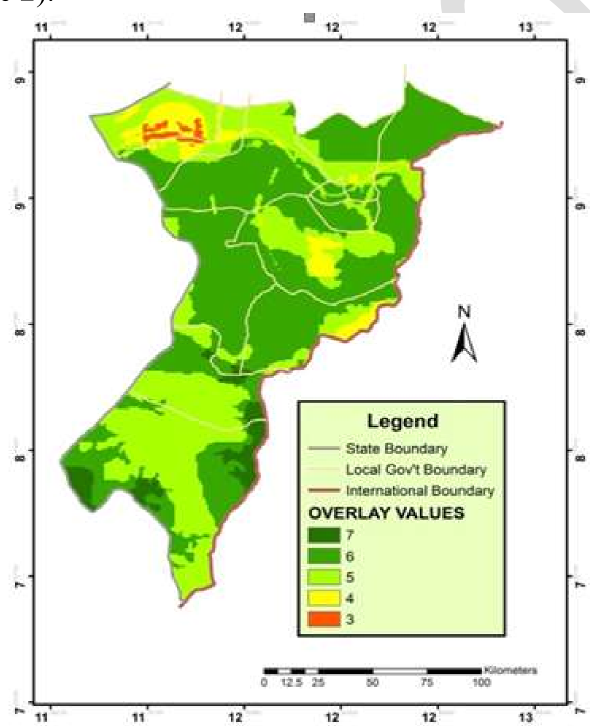

Figure 2: Integrated Datasets for Sites Suitability Selection.

In line with the FAO guidelines on land suitability analysis, areas that have value **7**, were assigned S1, areas with value **6** were assigned S2; while areas with **5** were assigned S3; and areas with values **4** and **3** were assigned N. Consequently, the final result generated from weighted sum overlay (integration of all the datasets used in this study) shows only four (4) degrees of site suitability for sugarcane production in the study area. These are:

1. Most suitable (areas with S1),
2. Moderately suitable (areas with S2),

3. Maginally suitable (areas with S3), and
4. Not suitable (areas with N) (See Figure 3)

As can be seen in Figure 17, the areas that are Most Suitable for sugarcane production are spread over places like Toungo and partly in Ganye, Jada and Mayo-Belwa Local Government Areas (LGAs). Moderately suitable areas cover the largest area, and these areas are spread across all the LGAs in the southern parts of Adamawa state, however, are more pronounced in the central part and towards the northern part of the study area. The Marginally suitable areas for sugarcane production in the study area are mostly located in Toungo, Ganye, Fufore, Numan, Demsa, Lamurde and Girei LGAs axis. Finally, areas that are Not suitable for sugarcane growth are dotted in Southern part of Fufore, Jada, Numan, Demsa and Lamurde LGAs. The area coverage of each degree of suitability is shown in Table 3.

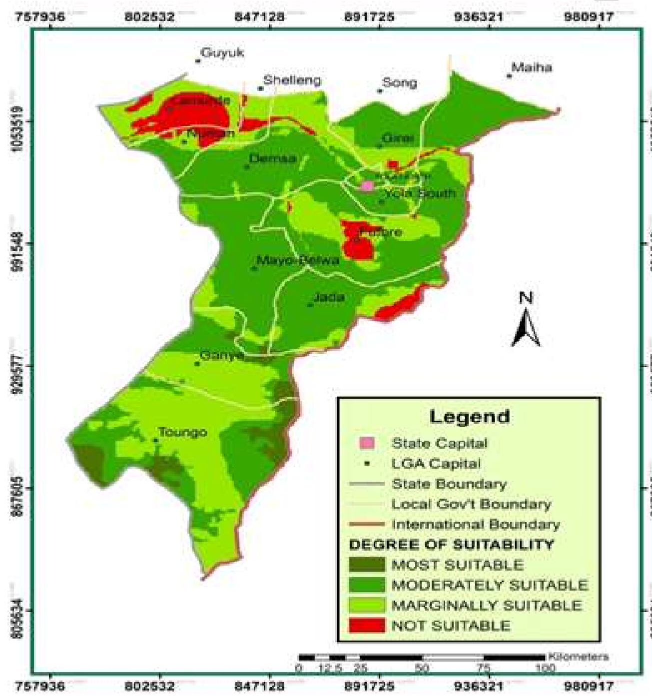

Figure 3: Degree of Suitability for Sugarcane Production in Parts of Adamawa state

Table 3 : Area Coverage for Each Degree of Suitability

Degree of Suitability	Weighted Sum Value	**FAO Classification**	Area Coverage (Km^2)	Percentage Coverage (%)
Most Suitable	7	S1	849.51	4.10
Moderately Suitable	6	S2	10,978.18	52.93
Marginally Suitable	5	S3	6,247.64	30.12
Not Suitable	4, 3	N	2,663.97	12.85

Total	20,739.3	100

3. Conclusion

This study leaned on the agro-climatic factors in selecting the site suitability for sugarcane production in the southern parts of Adamawa state of Nigeria, and result shows the spatial distribution of the degree of site suitability. These are Most suitable, Moderately suitable, Marginally suitable and Not suitable sites for sugarcane growth in the study area.

From the finding, the sites that are suitable for sugarcane production cover the greater part of the study area, that is about 12,689 Km2 (61%) see Table 3. These lands are underutilised for sugarcane cultivation in the state. The authors believe that, if this land could be put to use for sugarcane production, the state as well the country's economic base could be strengthened. Because it could result into chain-benefits, ranging from job creation, infrastructural development, and most importantly source of revenue for the state and all the stakeholders.

Therefore, this large area of land as suitable for sugarcane production shows that, the southern parts of Adamawa state, is one of the right places to invest in sugarcane business. Presently, the only company that produces sugar and its by-products is the Dangote Group of Company which bought the forma Savannah Sugar Company Limited, and it has not been able to utilise the whole area. This shows that, there is room for more investors.

The authors therefore, recommend that, the state government should spare headedly key in to this finding in this work. They should take it seriously, if they really strive to diversify the economy of the state, because depending on federal allocation is a risky idea. Even the federal government depends majorly on the oil, which price in the international market affects it. When the price of oil falls in the market, it usually affects our economy, thus there are urgent need to find other source of revenue.

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APPENDIX I

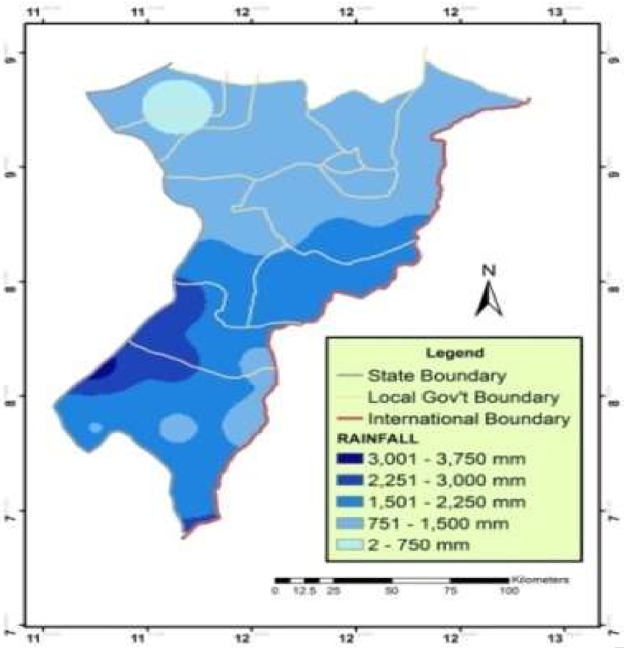

Figure 2 Mean Annual Rainfall

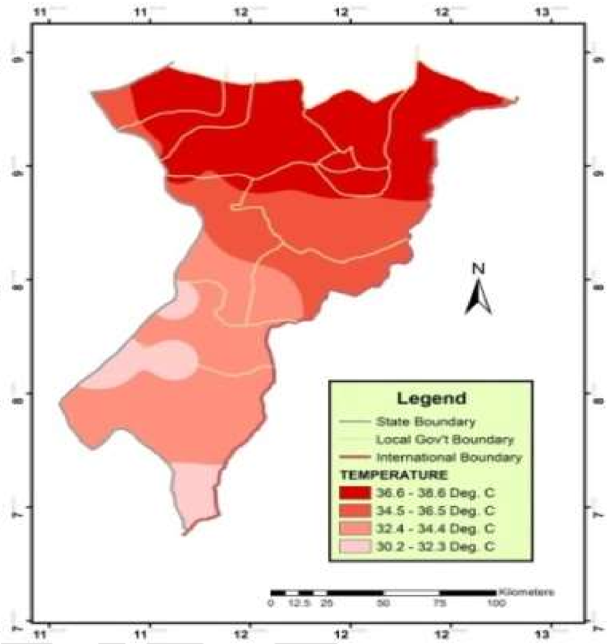

Figure 3 Mean Annual Temperature

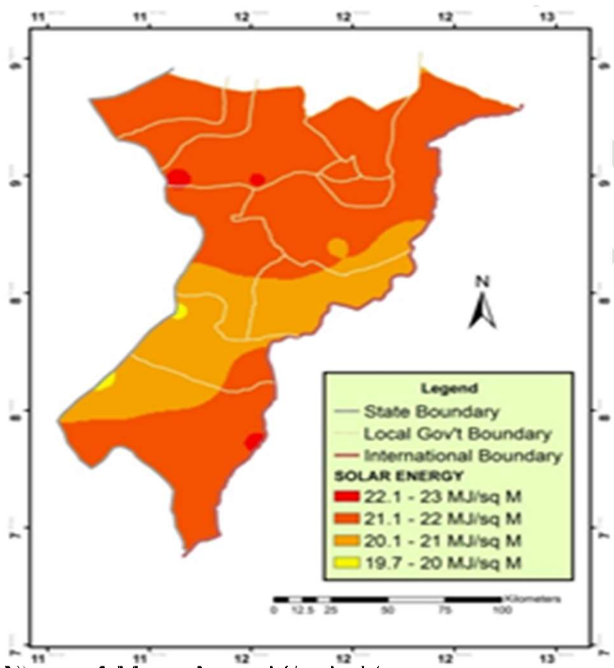

Figure 4 Mean Annual Sunlight

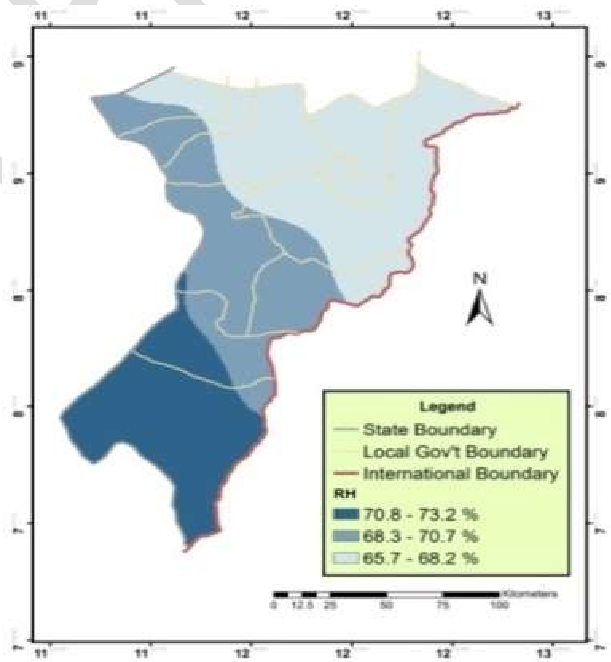

Figure 5 Mean Annual Relative Humidity

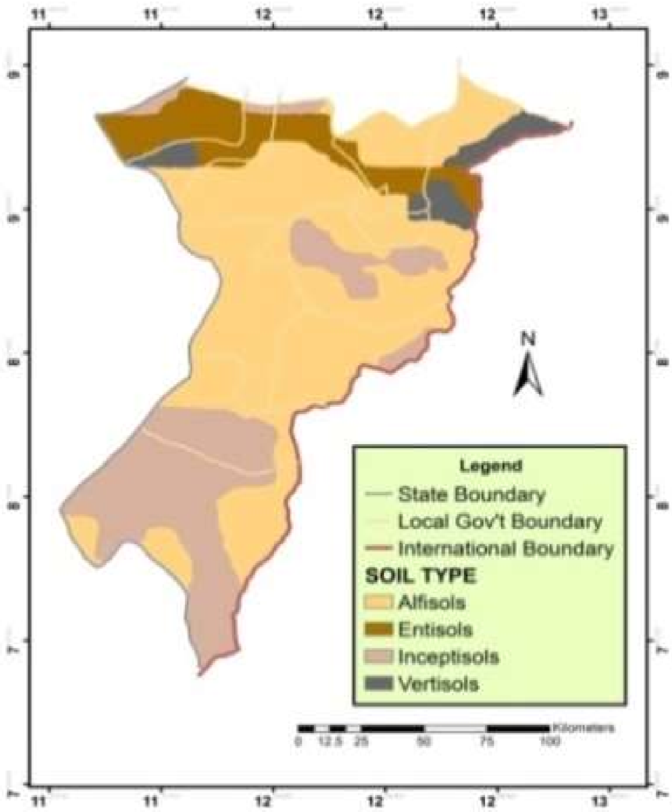

Figure 6 Soils Types

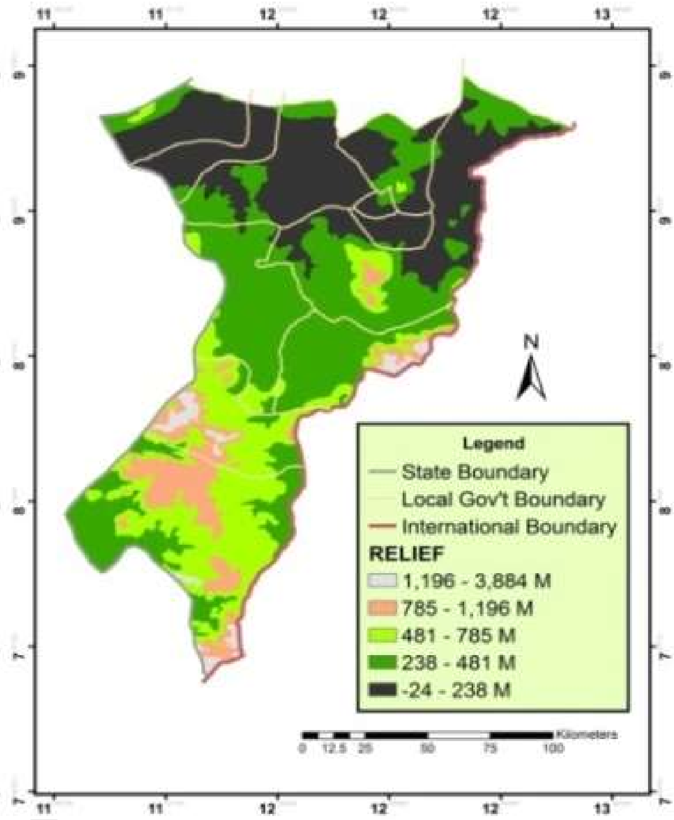

Figure 7 Relief

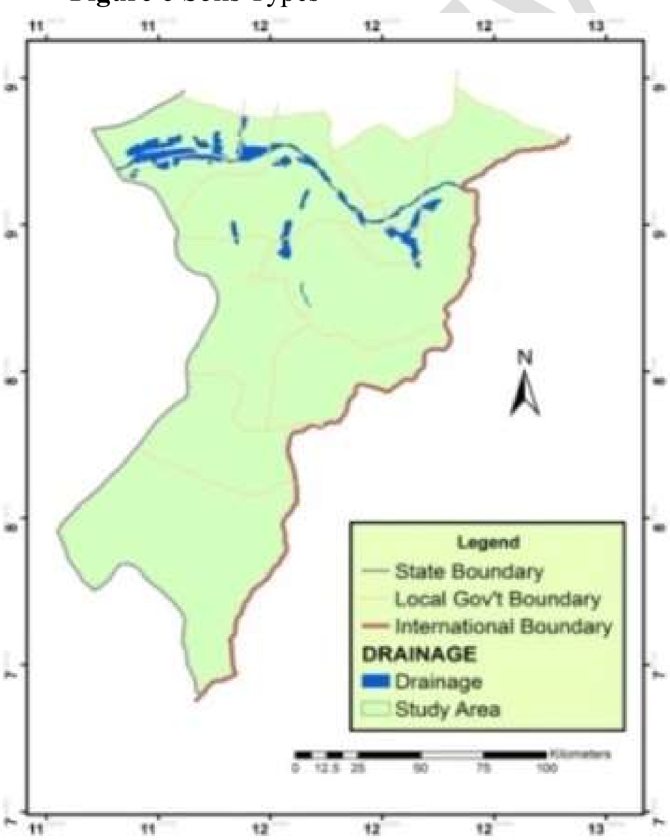

Figure 8 Major Drainage

APPENDIX II

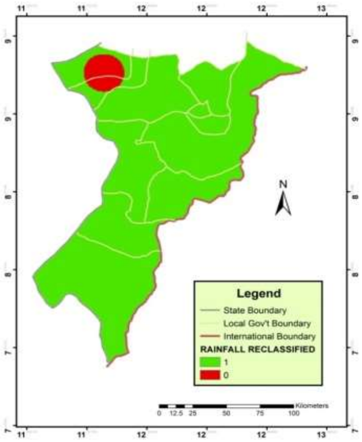

Figure 9 Reclassified Rainfall

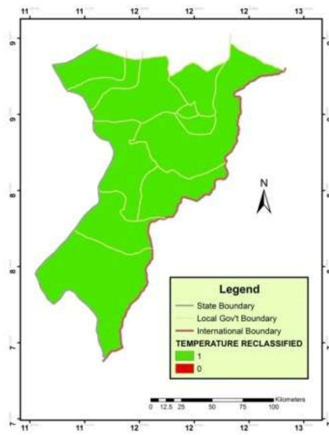

Figure 10 Reclassified Temperature

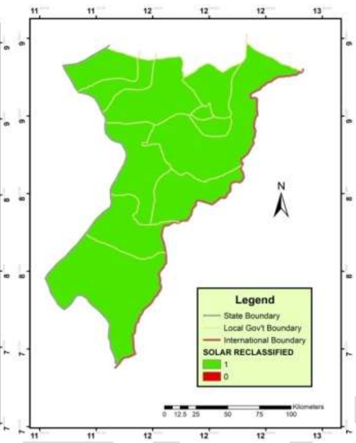

Figure 11 Reclassified Sunlight

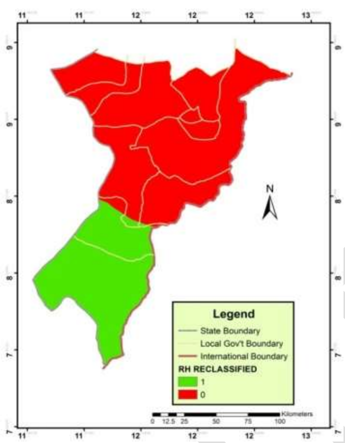

Figure 12 Reclassified Relative Humidity

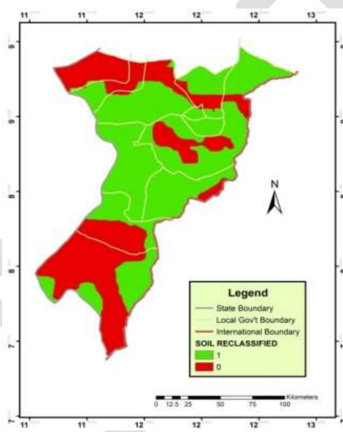

Figure 13 Reclassified Soil

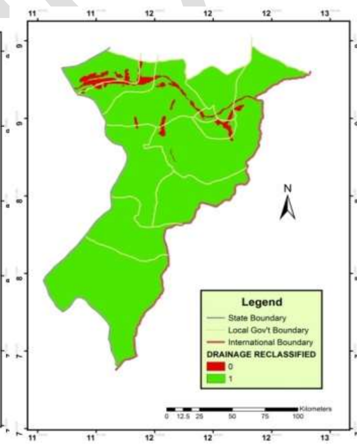

Figure 15 Reclassified Drainage

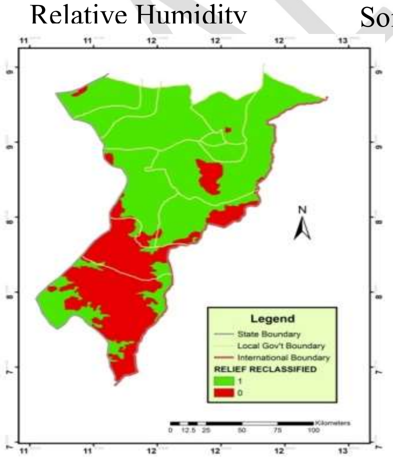

Figure 14 Reclassified Relief