Agro-Climatic Land Suitability Map for Sugarcane Production in Adamawa State, Nigeria

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Abstract
Agro-climatic conditions were used in mapping out suitable sites for sugarcane production in the southern parts of Adamawa state of Nigeria. The study covers eleven Local Government Areas with total area of about 20,739.30 Km². 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 results show that, most suitable areas cover a total area of about 849.51 Km² (4.10% of study area), moderately suitable areas cover about 10,978.18 Km² (52.93%), marginally suitable areas cover about 6,247.64 Km² (30.12%) and not suitable areas 2,663.97 Km² (12.85%). Both most suitable and moderately suitable areas for sugarcane cultivation cover a total area of about 11,827.69 Km². This is about 57% of the total area of study. 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
Introduction

For maximum crop production, especially commercially inclined ones, the knowledge of areas that will be good for the cultivation of the crop in questions is paramount. Sugarcane and any other crop, yield best on a certain climatic environment. Srivastava & Rai (2012) agrees with that, as noted in their words: climate plays an important role in all the phases of sugarcane crop (and of course any other crop). They stressed further that, sugarcane stands in the field for 12-24 months, therefore it passes through all possible limits of weather parameters such as rainfall, temperature, sunshine, and humidity. Consequently, all climatic parameters have significant role in the crop’s growth, yield, quality and of course juice content.

The major source of income in Adamawa state is the monthly federal allocation and that is not the best for the state’s economy. The state is blessed with vast arable lands that could be used for agriculture (Federal Republic of Nigeria, 2017). The federal allocation must not blind us from seeing some other potential source of revenue, such as agriculture. Therefore, Adamawa state needs to look into this sector with the aim at augmenting her economic base for the good of the citizens of the state and the country at large. Consequently, in this work, is an effort made in the area of agriculture, to encourage the government and the farmers in the state to invest in the cultivation of sugarcane so as to diversify the state’s source of income. The researchers are positive that, by studying the agro-climatic factors and to use them in selecting sites suitability for sugarcane growth in the study area, one of the most important steps would have been taken.

In this study, two objectives were pursued to come up with sites selection for sugarcane production in the southern parts of the Adamawa state. These are: to analysed the major agro-climatic parameters that

finding with the aim at promoting sugarcane production as one of the major source of income to the state.

Keywords: agro-climatic, site suitability, sugarcane, suitability analysis, spatial data
influence the optimum growth of the sugarcane crop and to come up with a comprehensive sites selection for sugarcane cultivation in the study area.

**Literature Review**
Srivastava & Rai (2012) stated that, sugarcane is a taxa represented by stout, jointed, fibrous stalk of 2-6 m with sugar is a tall perennial grass of the genus *Saccharum* of family Poaceae. Sugarcane is a perennial crop with determinate growth habit; its yield is located in the stem as sucrose and the yield formation period is about two-thirds to three quarters of its cultivated life span (Vooren, 2008). There are six species that are included in the classification of sugarcane. Among the species known are *officinarum*, *spontaneum*, *barberi*, *sinense*, *edule* and *robustum*. These species survive in both tropical and sub-tropical regions (Tarimo&Takamura, 1998). According to Letstalkagric (2017), sugarcane is used as a sweetener in beverages and various foods. It is also used in making confectionaries, example bread, cakes and biscuits. In the production of alcohol example ethanol, sugarcane is useful too. The by-productions of the processing are used in the following ways: cane residue (bagasse) can be used as fuel, manure or fodder.

The concept, “land (site) suitability” is a measure of how well the qualities of a land unit match the requirements of a particular form of land use (FAO, 1976). Land use evaluation is a procedure that involves a lot of information which is distinguished by its geographical and multivariate character (Daniel et al., 2013) Land use suitability assessment provides important reference for planning, planning management, planning implementation and planning evaluation (Lingjun & Yan, 2008).

**MATERIALS AND METHODS**

**Preamble**
Both climatic and physical parameters were integrated to achieve the aim of this study. The climatic parameters used were rainfall, temperature, sunlight and relative humidity. However, physical parameters include the soil types, relieve and drainage. These were used based on the fact that they are the major parameters that have great influence in the growth of the crop. These parameters were converted to spatial datasets in Geographic Information System (GIS) environment and were integrated to delineate lands that are suitable for the production of sugarcane in the study area. In the end,
quantitative agro-climatic map of the study area showing spatial distribution of the degrees of land suitability for sugarcane production were produced.

**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 latitudes 7°N and 11°N and longitudes 11°E and 14°E. 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 7°N and 10°N (Field work, 2019).

According to Adebayo & Tukur (1999), 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 Fufure 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.

![Figure 1. Location of the Study Area](Source: GAMERS, 2019)
The major vegetation formation of the state is divided into three zones: The Southern Guinea Savannah, the Northern Guinea Savannah and the Sudan Savannah. However, each formation is characterised by interspersion of thickets trees Savannah, open grass Savannah and fringing forest in the river valleys (Adebayo & Tukur, 1999).

**Data Source and Analysis**
The dataset used for the study are grouped in two; as pointed earlier: the climatic data and physical data. Climatic data used include: Rainfall, Temperature, Sunlight, and Relative Humidity (RH); while physical data are soil, Relief and Drainage. 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). For the Relief of the study area, [http://data.bioge.ucdavis.edu/data/diva/alt/NGA_Alt.zip](http://data.bioge.ucdavis.edu/data/diva/alt/NGA_Alt.zip) was the source used to obtain the related data. Drainage dataset was extracted from Google.com.ng/maps. These data were in JPEG formats and imagery and added (imported) in the Arc Map environment where they were geo-referenced and captured for used in the study.

**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 were used on each of the climatological dataset. Therefore, on each dataset, a map

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
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. In the end, seven (7) datasets were produced for this study (figures 2-8).

**Reclassification of Datasets**

The climatic datasets having been produced through the process of *interpolation* in Arc Map environment are automatically in form of raster map and can be used directly for further analysis. However, the physical data needed to be converted into raster maps by digitising them. Therefore, various units on the physical datasets (maps) were digitised as polygons. In the Arc Map10.2 environments, each unit digitised, a value is assigned on the *attribute table* for each dataset. 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. 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. The reclassification process was guided by the requirements in table 1. The datasets which were initially having various units shown by different colours (figures 2-8) now were 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 (figures 9-15). It was this analysed agro-climatic parameters (reclassified datasets), that were integrated to come up with the final result (figures 16 and 17).
Figure 9 Reclassified Rainfall
Figure 10 Reclassified Temperature
Figure 11 Reclassified Sunlight
Figure 12 Reclassified Relative Humidity
Figure 13 Reclassified Soil
Figure 14 Reclassified Relief
Figure 15 Reclassified Drainage
Table 1: Conditions for Agro-Climatic Land Suitability Selection for Sugarcane Production in the Study Area

<table>
<thead>
<tr>
<th>Serial Number</th>
<th>Criterion</th>
<th>Ideal Condition for Sugarcane Cultivation</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean Annual Rainfall</td>
<td>Between 750 to 1500 mm</td>
<td>Mondale (2017)</td>
</tr>
<tr>
<td>2</td>
<td>Mean Annual Temperature</td>
<td>Between 25 to 40°C</td>
<td>Directorate of Sugarcane Development (2013); Asiafarming.com (2018)</td>
</tr>
<tr>
<td>3</td>
<td>Relative Humidity</td>
<td>At least 70%</td>
<td>Srivastava and Rai (2012), Binbolet al.</td>
</tr>
<tr>
<td>4</td>
<td>Sunlight</td>
<td>18-36 MJ/m² Daily</td>
<td>NETAFIM (n.d)</td>
</tr>
<tr>
<td>6</td>
<td>Relief</td>
<td>Highland and Medium highland</td>
<td>Sugarcane Production (2012)</td>
</tr>
<tr>
<td>7</td>
<td>Drainage</td>
<td>Well drained Land, Not waterlogged</td>
<td>RhumAgricole (n.d), (Tarimo&amp;Takamura (1998)</td>
</tr>
</tbody>
</table>

Source: Field work, 2020

Weighted Sum Overlay

Weighted Sum is a data analysis process which works by multiplying the designated field values 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 (figures 9-15) were integrated through the process of Weighted Sum overlay explained in previous paragraph of this section. This process could be expressed mathematically as follows:

\[
\text{Weighted Sum output} = \text{weighted Sum (weighted Sum Table [Criteria 1, Value *weight Value], [Criteria 2, Value*weight value], [Criteria 3, Value*weight value],.....[Criteria N, Value*weight value])}(\text{Esri, 2016})
\]
Overlay in more clear terms means that units on the reclassified maps which have only values 0s and 1s were all combined so that, where for instance 1 and 1 meet the resultant value will be 2, and where 1, 1, and 1 meet the result is 3. Therefore, on the overlaid map, the maximum value on the weighted sum table (also on the map) is 7, meaning that; the area(s) in question meet(s) all the required seven agro-climatic conditions. Therefore, some places meet six, others, meet five, four, and three respectively as shown in figure 16.

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. Marginally suitable (areas with S3), and
4. Not suitable (areas with N) (figure 17)

RESULTS AND DISCUSSIONS

Results of the Analysed Datasets

The analysed datasets are shown in figures 9 to 15. These are the reclassified datasets as discussed in section 3.5 of this work. 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 as explained earlier. 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>
<thead>
<tr>
<th>S/N</th>
<th>DATA</th>
<th>SUITABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Suitable</td>
</tr>
</tbody>
</table>

Table 2 Area Coverage for Reclassified Datasets
Datasets Integration and Degree of Suitability
Following the integration of all the analysed dataset as explained in section 3.6 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 as discussed in 3.6 of this work, that is Most suitable, Moderately suitable, Marginally suitable and Not suitable for sugarcane production.

Figure 16 Integrated Datasets for Sites Suitability Selection

<table>
<thead>
<tr>
<th></th>
<th>Km²</th>
<th>%</th>
<th>Km²</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rainfall</td>
<td>20,008.99</td>
<td>96</td>
<td>730.31</td>
</tr>
<tr>
<td>2</td>
<td>Temperature</td>
<td>20,739.30</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>Sunlight</td>
<td>20,739.30</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>RH</td>
<td>6,621.21</td>
<td>32</td>
<td>14,118.09</td>
</tr>
<tr>
<td>5</td>
<td>Soil</td>
<td>12,888.40</td>
<td>62</td>
<td>7,850.90</td>
</tr>
<tr>
<td>6</td>
<td>Relief</td>
<td>14,667.20</td>
<td>71</td>
<td>6,072.10</td>
</tr>
<tr>
<td>7</td>
<td>Drainage</td>
<td>19,867.40</td>
<td>96</td>
<td>871.90</td>
</tr>
</tbody>
</table>

Source: Field work, 2019
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, Lamurde LGAs and along the major drainages in the study area. The area coverage of each degree of suitability is shown in table 3.

<table>
<thead>
<tr>
<th>Degree of Suitability</th>
<th>Weighted Sum Value</th>
<th>FAO Classification</th>
<th>Area Coverage (Km²)</th>
<th>Percentage Coverage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most Suitable</td>
<td>7</td>
<td>S1</td>
<td>849.51</td>
<td>4.10</td>
</tr>
<tr>
<td>Moderately Suitable</td>
<td>6</td>
<td>S2</td>
<td>10,978.18</td>
<td>52.93</td>
</tr>
<tr>
<td>Marginally Suitable</td>
<td>5</td>
<td>S3</td>
<td>6,247.64</td>
<td>30.12</td>
</tr>
<tr>
<td>Not Suitable</td>
<td>4, 3</td>
<td>N</td>
<td>2,663.97</td>
<td>12.85</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>20,739.3</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Author’s Analysed Datasets, 2020

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 12,689.01 Km² (61%) see table 3. These areas encompass the Most suitable and Moderately suitable degree of suitability in the study area. This size of land as suitable for sugarcane growth in more than 450 Km² (45,000 hectares) used by Zimbabwe to produce 600,000 tons of sugar annually before land seizure in 2002 (Tyler, 2008). 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 serious, 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.

REFERENCE