MPRI-JSD | INTERNATIONAL JOURNAL OF AFRICAN SUSTAINABLE DEVELOPMENT
VOL. 10 NO.2 DEC-2019 ISSN: 2760-4106

EFFECT OF AGRO-CLIMATIC PARAMETERS ON SPATIAL DISTRIBUTION OF SUITABLE SITES FOR SUGARCANE CULTIVATION IN SOUTHERN PARTS OF ADAMAWA STATE, NIGERIA

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Abstract

Agro-climatic parameters were analysed to see how they dictate the spatial distribution of areas that are suitable for sugarcane cultivation in the southern parts of Adamawa state, Nigeria. The study encompasses eleven Local Government Areas laying on about 20,739.30 Km² of landmass. Climatic data on rainfall, temperature, relative humidity and sunlight along with physical data on soil, relief and drainage were analysed and integrated by adopting the Weighted Sum overlay in ArcGIS 10.2 platform. The process was guided by the FAO guidelines on suitability analysis. The study yielded four degrees of site suitability for sugarcane cultivation, these are: Most suitable, Suitable, Fairly suitable and Unsuitable sites for sugarcane cultivation. From this study, it was discovered that Most suitable sites cover about 849.51 Km² (that is about 4.10% of the study area), Suitable sites cover about 10,978.18 Km² (52.93%), Fairly suitable sites cover about 6,247.64 Km² (30.12%) and about 2,663.97 Km² (12.85%) is Unsuitable for sugarcane cultivation. Therefore, the total area considered to be suitable for sugarcane cultivation in Southern parts of Adamawa state, Nigeria is about 11,827.69 Km² (Most suitable and Suitable sites combined), that is about 57% of the total area of study. This is a huge size of land which could be utilised by the state for additional source of revenue for the state and also provide job opportunity to the teeming youths.

KEYWORDS:
cultivation, overlay, site suitability, spatial data, spatial distribution, sugarcane

Introduction

Farmers, both subsistent and commercial ones go into crop cultivation with the aim at harvesting an optimal yield after their effort. Therefore any method or information that can result to that would always be appreciated

by the farmer. This study therefore, would be a good source of information when it comes to identifying areas in the southern parts of Adamawa state, Nigeria that are suitable for the crop growth and yield. Sugarcane is sensitive to all the agro-climatic conditions analysed in this work (Srivastava & Rai, 2012). That the crop is a perennial one and stays in the field for 12-24 months, exposing it to all possible limits of weather parameters such as rainfall, temperature, sunshine, and humidity. This informs the fact that sugarcane growth and yield are affected by all the agro-climatic parameters.

Srivastava & Rai (2012) stated that, sugarcane is a taxa represented by stout, jointed, fibrous stalk of 2-6 m. It produces sugar and can be described as 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 food items. It is also used in making confectionaries, such as bread, cakes and biscuits. In the production of alcohol and ethanol, sugarcane is useful too. The by-products from processing are used in the following ways: cane residue (bagasse) can be used as fuel, manure or fodder.

Site suitability is a concept which means the process of measuring how well the attributes of a portion of land match the requirements of a particular form of land use (FAO, 1976). It involves land use evaluation, which means a procedure that involves a lot of information which is distinguished by its geographical and multivariate character (Daniel *et al.*, n.d.). To have a good planning, planning management, planning implementation and planning evaluation the starting point however is land use suitability assessment (Lingjun & Yan, 2008).

Adamawa state like many other states in the country has always depended on the monthly federal allocation to finance her budget at the expense of other potential source of revenue such as agriculture. The state is blessed with vast arable lands that could be used for agriculture (Federal Republic of Nigeria, 2017). Therefore, it is advisable that the state should utilise the potentials in the agricultural sector. This could help augment her economic base for the betterment of the citizens of the state and the country at large.

Therefore, in this work, an effort has been made in the area of agriculture—for instance cultivation of sugarcane—to encourage stakeholders in the business of sugarcane production in the state to invest more in the cultivation of the crop so as to diversify the state's source of income. The researchers believe that, by studying the effect of agro-climatic parameters and how they determine the

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spread of sites suitability for sugarcane cultivation in the study area, significant information might have been provided.

To achieve the aim of this study, two relevant objectives were pursued to come up with a comprehensive site suitability map of the study area, clearly delineating the various degree of suitability for sugarcane cultivation as dictated by the agro-climatic parameters of the Southern parts of Adamawa state, Nigeria.

Study Area

Adamawa state with its capital Yola is situated in the north-eastern part of Nigeria. As one of the largest states in the country it occupies about 36,917Km^2 of land and lies between latitudes 7°N and 11°N and longitudes 11°E and 14°E. It shares boundaries with Taraba state in the south-west, Gombe state in the north-west and in the north with Borno state. Nevertheless, it has an international boundary with the Republic of Cameroon (Adebayo & Tukur, 1999). However, the area covered by this study, that is the southern parts of the Adamawa state consists of only eleven (11) Local Government Areaslies between latitude 7°N and 10°N (Field work, 2019). Adebayo & Tukur (1999), reported that, Adamawa state is characterised with varied rainfall ranging from 700mm in the north-western part to 1600mm in the southern part. In general the mean annual rainfall in the central part is less than 1000mm. This region covers 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. The altitude of the state was observed to be the major cause of this variation of the annual rainfall amount.

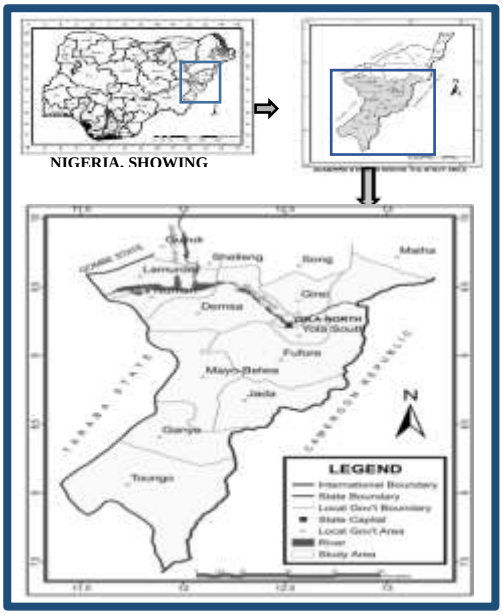

Figure 1. Location of the Study Area

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).

MATERIALS AND METHODS

Preamble

The authors integrated the agro-climatic and physical parameters in this study to arrive at the aim of this study. All the parameters which serve as the conditions used in testing the suitability of the study area include: rainfall, temperature, sunlight, relative humidity soil, relief and drainage. These are the main conditions

that affect the life cycle of sugarcane in the field before harvesting. These seven (7) conditions were first transformed into spatial datasets (maps showing various units on them) in Geographic Information System (GIS) platform and were then integrated. Following the integration process through the Weighted Sum of Overlay in ArcMap 10.2, site suitability map for the production of sugarcane in the study area were produced. In the end, quantitative agro-climatic the study area showing spatial distribution of the degrees of land suitability for sugarcane production were produced.

Data Source

As stated earlier, climatic data used include: Rainfall, Temperature, Sunlight, and Relative Humidity (RH) and the physical data are soil, Relief and Drainage. The climatic data were obtained from Nigerian Meteorological Agency (NiMet), Global Weather Data for SWAT (GWDS) and NASA Prediction of Worldwide Energy Resources (POWER). The data cover the period of 35 years—that is from 1982 to 2017. The soil map of the study area was obtained from Global Soil Survey and NRCS (Natural Resources Conservation Service) map of 2005 from United State Department of Agriculture (USDA). Relief of the study area was downloaded from http://data.biogeo.ucdavis.edu/data/diva/ alt/NGA_Alt.zip, while drainage was extracted from Google.com.ng/maps. The data on climate were in numerical form while other physical datasets were in JPEG formats and imagery. Following their *geo-referencing,* and digitizing the physical data were then *added* in ArcMap platform for anaysis. However, the climatic data, which are in numeric form, were *interpolated* and converted into maps for use in the study.

Preparation and Production of Parameter Maps

The climatic data used, were computed in the Microsoft Excel to come up with means and total amount in tabular form. This was later added in the ArcMap (ArcGIS 10.2). It is pertinent to note that, these data (the four climatic data) were extracted for about 42 points (coordinate) so that means values for 35 years were computed for each point in the study area. On adding the table of these values in ArcMap, about 42 sets of values with their coordinated were spread on the map of the study area through the use of *Display XY Data* command in ArcMap. To produce map out of these points for each dataset, *interpolated* command were applied. This command joined all the points of equal or almost equal value depending on the range given to the values, to produce maps showing various units. These maps were ready for integration with other physical data. The remaining three physical data (soil, relief and drainage) were already in form of thematic maps. Therefore, they were geo-referenced making them compatible with the other maps earlier prepared. In all, seven (7) datasets were prepared and ready for the subsequence analysis (figures 2-8).

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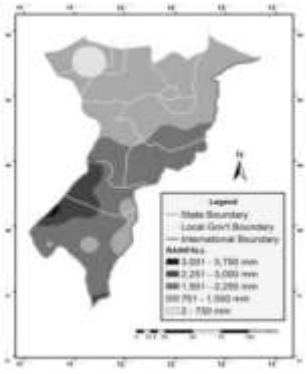

Figure 2 Rainfall

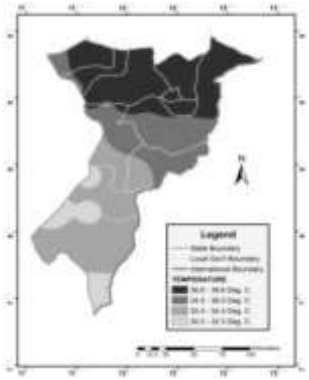

Figure 3 Temperature

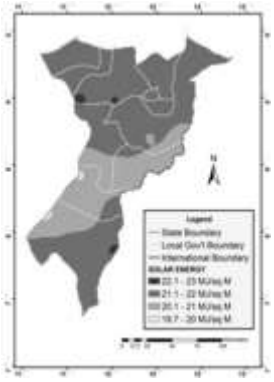

Figure 4 Sunlight

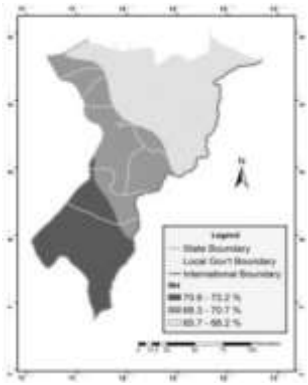

Figure 5 Relative Humidity

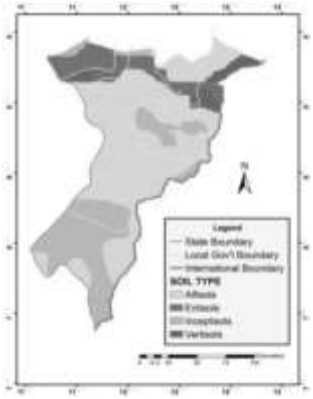

Figure 6 Soils

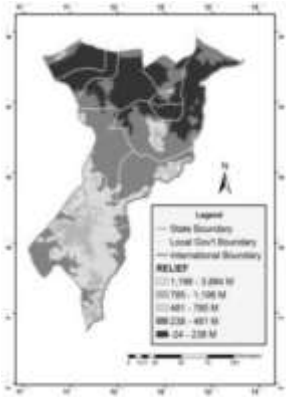

Figure 7 Relief

Figure 8 Drainage

Analysis of Parameters

The *interpolate* procedure carried out on the climatic datasets automatically produced raster form of maps which could be used directly for integration process (overlay). Physical data unlike the climatic data, had to be converted into raster maps by capturing them in ArcMap (capturing here means digitising). Therefore, various units on the physical datasets (maps) were digitised as polygons. Each unit

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digitised, an *attribute* table were generated for it and value assigned in related to it.

The next process before the *Weighted Sum Overlay* was the *reclassification* of all the seven datasets. On each dataset's attribute table explained earlier, two values were used to group the various units on the maps. These values are **1**, for areas that meet the condition for sugarcane cultivation and **0** for areas that do not meet the ideal conditions. The ideal conditions for sugarcane cultivation are shown in table 1. The datasets were now showing only two units: that is areas that are suitable and areas that are not suitable for sugarcane cultivation in the study area (figure 9-16).

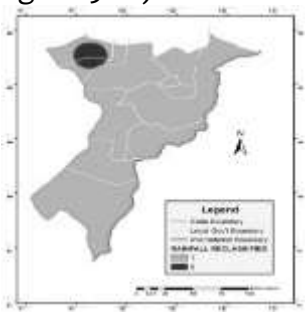

Figure 9 Reclassified Rainfall

Figure 10 Reclassified

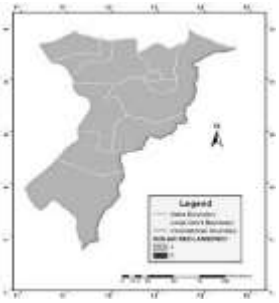

Figure 11 Reclassified Sunlight

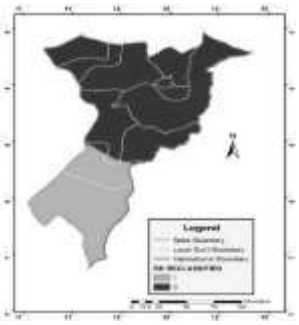

Figure 12 Reclassified Relative Humidity

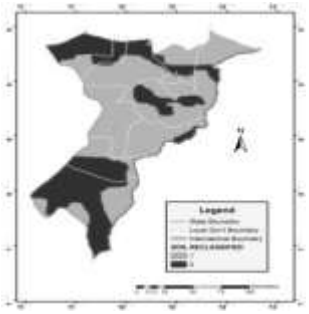

Figure 13 Reclassified Soils

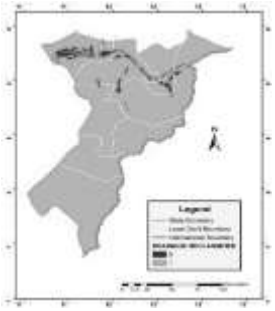

Figure 15 Reclassified Drainage

Figure 16 Reclassified Relief

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Table 1: Ideal Agro-Climatic Parameters for Sugarcane Cultivation

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)

Integration of Parameters

For this study, *Weighted Sum Overlay* procedure in ArcGIS 10.2 was employed in integrating the parameters. In ArcMap, weighted Sum overlay is a process of combining various datasets (maps) to come up with one map showing various units based on the criteria used. The process 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). The maps otherwise called criteria used for the study have various levels of significance or effect to the cultivation of sugarcane, this level is term *weight.* It refers to the importance attached to a criterion, which could be in percentage or ratio. Therefore, before integrating the seven conditions, weights were assigned to each. However, for this study, all the conditions were considered as equal, therefore, the value of **1** was given to each of the reclassified datasets. At the end, the seven reclassified criteria (figures 9-16) were integrated (combined) through

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the process of *Weighted Sum* overlay explained in previous paragraph of this study.

In other words overlay refers to the process in which all the units on the reclassified maps (unit with values **0**s and **1**s) combined to produce one map in which for instance, where 1 and 1 meet the value yield will be 2, and if 1, 1, and 1 meet they yield value 3. Thus, since seven parameters were used for the study, the highest value on the resultant map is 7. This implies that the sites on the map that meet all the conditions required for sugarcane cultivation carries the value 7. Still some sites meet six, others meet five, four, and three in that order (figure 17).

Applying the FAO guidelines on site suitability analysis, S1 was assigned to sites that have value **7**, S2 was assigned to sites with value **6**; while S3 was assigned to sites with **5**; and sites with values **4** and **3** were assigned N. This give only four degree of site suitability on the final weighted sum overlay result, which include are:

1. Most suitable (S1),
2. Suitable (S2),
3. Fairly suitable (S3), and
4. Unsuitable (N)

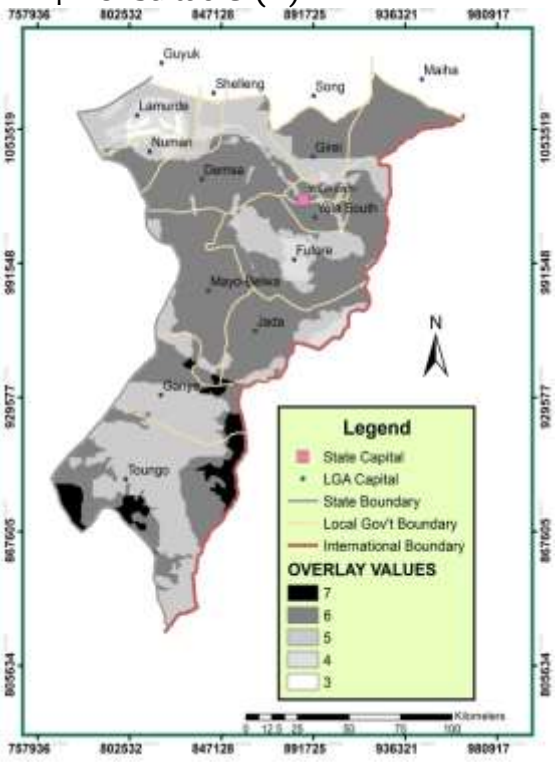

Figure 17 Integrated Parameters

This can be seen in figure 17.

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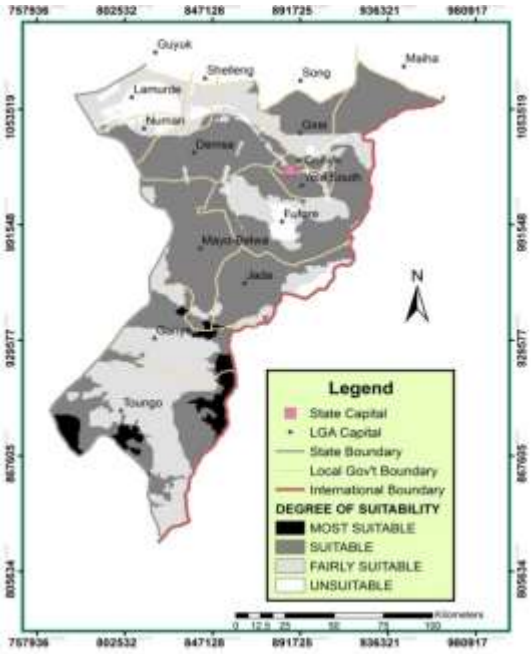

Figure 18 Spatial Distribution of Site Suitability for Sugarcane Cultivation in Southern Parts of Adamawa state, Nigeria

RESULTS AND DISCUSSIONS

Analysed Parameters

This refers to the reclassified parameter maps (conditions) discussed earlier (figures 9-16). The result shows only sites in the study area that meet the condition for sugarcane cultivation and sites that do not meet. That is suitable and not suitable sites for sugarcane cultivation.

The Measure tool in ArcMap was used to calculate the area coverage for each site on the map (table 2).

Table 2 Reclassified Parameter's Area Coverage

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

Integration of Parameters

The result of the combination or weighted sum overlay is shown in figure 17. This map displays all the number of conditions a given portion of the study area meets. As explained in one of the sections in this study, these values (that is 7, 6, 5, 4 and

3) on the map, denote the number of conditions met by the related sites. However, this map, that is integrated parameter map, was further reclassified to produce the final map showing only four (4) degrees of suitability (figure 18).

From figure 18, the sites that are Most Suitable for sugarcane cultivation are obtained in Toungo and partly in Ganye, Jada and Mayo-Belwa Local Government Areas (LGAs). While, sites that are Suitable and cover the largest landmass, are identified in all the LGAs in the study area, however, these sites are widely spread in the central part moving towards the northern part. The Fairly suitable sites for sugarcane cultivation are mainly located in Toungo, Ganye, Fufore, Numan, Demsa, Lamurde and Girei LGAs axis. Finally, sites that are Unsuitable can be seen dotted in Southern part of Fufore, Jada, Numan, Demsa, Lamurde LGAs and along the major drainages in Southern parts of Adamawa state. Table 3 shows the total area coverage for the four degrees of suitability.

Table 3 Area Coverage for the Degrees of Suitability

Degree of Suitability	Weighted Sum Value	FAO Classification	Area Coverage (Km^2)	Percentage Coverage (%)
Most Suitable	7	S1	849.51	4.10
Suitable	6	S2	10,978.18	52.93
Fairly Suitable	5	S3	6,247.64	30.12
Unsuitable	4, 3	N	2,663.97	12.85
Total			**20,739.3**	**100**

CONCLUSION

Agro-climatic parameters were analysed in this study to examine how they affect spatial distribution of the site suitability for sugarcane cultivation in the southern parts of Adamawa state, Nigeria. The result of the study succinctly shows the spatial distribution of the degrees of suitability for sugarcane cultivation. These were identified as Most suitable, Suitable, Fairly suitable and Unsuitable sites for sugarcane Cultivation.

Sites considered most suitable for sugarcane cultivation, in other words meet all the seven conditions used in this study, covers a total area of about 849.51 Km^2 (that is about 4.10% of the study area). Suitable sites for sugarcane cultivation cover a total of about 10,978.18 Km^2 (that is about 52.93% of the study area). Therefore, both sites that are most suitable and suitable for sugarcane cultivation cover a total of about 11,827.69 Km^2, this is about 57.03% of the total area coverage

of the study area. This size of land as suitable for sugarcane cultivation is comparatively larger than the 450 Km^2 (45, 000 hectares) used by Zimbabwe to produce 600,000 tonnes of sugar annually before land seizure in 2002 (Tyler, 2008).

Unfortunately, not all these lands are under cultivation for sugarcane production in the state. This land if properly utilised to cultivate sugarcane, the state would hardly have economic crisis as it would boost her source of revenue and create jobs for the teeming youths in the state and environs. Therefore, this information (result of this finding), should be made available to the prospective investors in the business of sugarcane production. They should be encouraged and if possible, supported by the ministry of Agriculture to invest in the crop.

REFERENCES

Adebayo A. A. & Tukur A. L. (1999). *Adamawa state in maps*. First edition. Yola. Paraclete Publishers.

Akobundu, I.O. (1987). *Sugarcane*. In Weed Science in the Tropics I.O. Akobundu, (ed). John Wiley and Sons New York. 414 – 446.

Daniel, J. D., Adebayo, E. F., Shehu, J. F., & Tashikalma, A. K. (2013). Technical efficiency of resource-use among sugarcane farmers in the Northeast of Adamawa state, Nigeria. *International Journal of Management and Social Sciences Research (IJMSSR)*, 2 (6), 13—18, ISSN: 2319-4421

Daniel, P. D. L., Carlos, B. & Tatiana, D. (n.d.). Land suitability evaluation using combination of exploratory data analysis with a geographical information system on sugarcane areas. Scientific registration no: 2148.

Esri (2016). How weighted sum overlay works. Retrieved from http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-fuzzy-overlay-works.htm.

FAO. (1976). A framework for land evaluation: *Soils Bulletin*: 32, Food and Agriculture Organization of the United Nations, Rome.

Federal Republic of Nigeria. (2017). Adamawa state. Retrieved from Nigeria.gov.ng/index.php/2016-04-06-08-39-54/north-east/adamawa-state.

Letstalkagric (2017). Sugarcane farming guide. Retrieved from http://www.letstalkagric.com/crops/sugarcane-farming-information-guide.

Lingjun, L. & Yan, H. (2008). Study on land use suitability assessment of urban-rural planning based on remote sensing—a case study of Liangping in Chongqing.

The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. 37 (8), 123-130.

Srivatava A. K. & Rai M. K., (2012). Sugarcane production: impact of climate change and its mitigation. *Bio Diversit AS*. 12 (4) 214-227 doi: 10.13057/biodiv/d130408.

Tarimo, A. J. P. & Takamura, Y. T. (1998). Sugarcane production, processing and marketing in Tanzania. *African Study Monographs,* 19(1): 1-11.

Tyler, G. (2008). Background Paper for the Competitive Commercial Agriculture in Sub-Sahara Africa (CCAA) Study. The African Sugar Industry – A Frustrated Success Story. Retrieved from http://www.siteresouce.worldbank.org/in.Tafrica/resource/257994T 12154571 7825 67/ch6sugar PDF. Retrieved 15/11/08.

Vooren, P. Z. J. (2008). *Sugarcane ethanol contributions to climate change mitigation and the environment*. (ed). The Netherlands. Wageningen Academic Publishers. ISBN: 978-90-8686-090-6, e-ISBN: 978-90-8686-652-6. doi: 10.3920/978-90-8686-652-6