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Determination of Soil-Crop Suitability for Enugu State using Geographic Information System (GIS) & Multi-Criteria Evaluation (MCE)

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***Abstract*:- The study was targeted at developing soil- crop suitability map for Enugu state through Geographic information system (GIS) and Multi-criteria evaluation (MCE).**

This suitability mapping carried out with the help of GIS was in reviewed side by side with the prevailing land use (LU) practice of the region. The research analyze prerequisite to achieving optimum utilization of the available land resources in Enugu State- Nigeria. Standard- relevant land characteristics (LCs), quality (Q), alongside that of climate, topography & soil – based on medium intensity survey techniques were collected, analyzed and the result was held after converting the data into a usable format for evaluation (E) process. Land mapping units (LMUs) were assigned to each location through an intensive querying analysis.

The current land use land map of the study location was produced and a clear inverse relationship between suitability map for selected crop types and current vegetation analyzed. The result shows that out of the 7,161km^2, about 28.06% was Highly suitable (S1), 22.66% Moderately suitable (S2), 14.51% Marginally(S3) suitable while 7.69% Not suitable (N) for rice production. Secondly, 25.93% was rated as highly suitable (S1), 17.47% moderately suitable (S2), 26.04% marginally suitable (S3) while 3.49% as Not suitable (N) for Maize crop. Thirdly, the result revealed that, 29.26% was highly suitable (S1), 18.88% moderately suitable (S2), 16.77% marginally suitable (S3) and 16.77% Not suitable (N) for Cassava production.

Overall, the results indicate that the study area has a varied-huge potential for rice, maize, cassava production. The results can serve as guide to investors in prioritizing investment towards large scale- commercial production of rice, maize, cassava etc. in Enugu state.

INTRODUCTION

Geographic information system (GIS) is a framework for gathering, managing, and analyzing spatial data which allows and enhances viewing, understanding, questioning, interpreting, and cross-analysis of data in many ways that previews patterns, inter-relationships, in the form of maps and charts etc. It answers questions and solves problems by looking at the data in a way that is quickly understood and easily shared. Basically, the input data for GIS are site-specific and are obtained through Remote Sensing (RS), the global positioning system (GPS) or Ground surveying.

Through the input of GIS, complicated analytical functions are simplified and the results presented visually as maps, tables or graphs, allowing decision- makers to virtually see the issues before them and then select the best course of action. GIS is playing an increasing role in agricultural production throughout the world by helping farmers increase production, reduce costs, and manage their land more efficiently. Striking a balance between the inputs and outputs on a farm forms the basis to its success and profitability. The proficiency and capability of GIS to analyze and visualize agricultural environments as well as that of workflows has proved beneficial to the farming industry.

GIS offers an agricultural system with the capacity to assemble, analyze, and apply relevant managerial variables such as metrological, soil, yield, moisture data etc which serves as a practical planning aid. A closer involvement and integration of which ensures precise "on the farm monitoring and control"; to assist resource allocation and boost better returns. Crop yields can be maximized through integrated soil-crop systematic planning which considers basic decisions like crop selection, planting, sowing and nutrient management etc.

1.2 STATEMENT OF PROBLEM

In many developing countries, there is a general paucity of land use information. There is little or no reliable soil/ crop data base to assist farmers towards optimal utilization of soil for agricultural production& systematic planning. The general knowledge of the in-depth richness of Nigerian agricultural soil alone has not helped to solve the escalating problem of food shortage.

To increase the production of rice, maize, cassava etc, environmental factors must be favorable. This requires the introduction and inclusion simple technological inputs.

The research is structured to shift away from the regular guess work in agricultural planning to a system of precise identification of "*the most favorable or viable agricultural land of the study region in respect to rice, maize and cassava production" and in addition, determine, the percentage of the land that is most suited and what level of yields the farmers should anticipate in the varied land suitability.*

1.3 STUDY OBJECTIVE

The aim of this research is to develop a soil- crop suitability of the study region through GIS and Multi-Criteria Evaluation (MCE). The study will further:

1. Determine the current land use profile of Enugu state;
2. Examine the level of suitability- variations of the cardinal locations within study area, based on FAO standard; and
3. Produce a schematic and comparative review of study area to assist managers/ farmers on key decisions- where future inputs etc should be required to improve crop production

MATERIALS AND METHOD

2.0 LOCATION

Enugu State has an estimated total area of 7,161km^2 and is situated in the eastern part of Nigeria (6°30′N7°30′E). The study location shares common boundary with Abia, Imo - toward the south, Ebonyi State – East ward, Benue State - northeast, Kogi State - northwest and Anambra State – West.

2.1CLIMATE

The soil status of the State is very good with compatible all year round climatic conditions. With an altitude of about 731.9 ft above sea level, the drainage system is fairly perfect during the rainy season. (www.nowchild.com.ng/enugu-state). The average temperature – is about 87.16 °F (30.64 °C) usually in the hottest period of February months each year. The lowest (15.86 °C) temperature occurs in the month of November. The highest rainfall which occurs in July, is about 35.7cubic centimeters- 2.18cu and its lowest is about 0.16 cubiccentimeters (0.0098 cu in) - which in most cases is observed within the month of February (www.nowchild.com.ng/enugu-state).

Study Area Location and Climatic Conditions

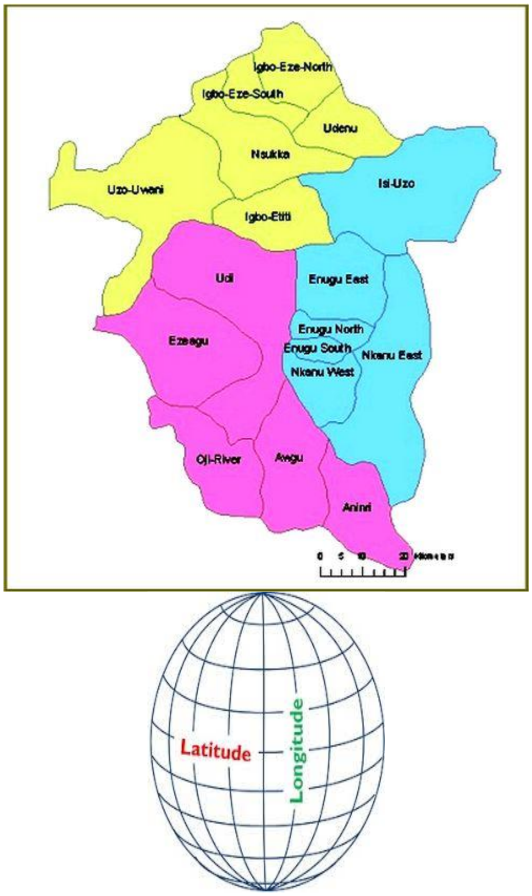

Fig.3.1 Map of Enugu State (Study location)

2. 2PARAMETERS FOR SUITABILITY ANALYSIS

Identification of the basic requirements for rice, maize and cassava growing areas were made possible through comparative review of various relevant literatures, FAO standards etc and desk search of available data. The identified factors included climate- humidity, temperature; topography (slope); Soil-soil texture, soil pH, soil drainage. The complete methodology includes identification and grouping of the spatial characteristics of Enugu state; conversion of same details into digital format, deduction of various suitability analysis within the GIS environment and further presentation of the outputs in a thematic map.

Relevant soil data (properties) was obtained from NASDRA, 2013. The detail here shows the soil properties- both physical, chemical details etc of the study location. Three soil parameters: drainage, texture and pH - obtained from an attribute table via Arc GIS 9.3 software. Subsequently, for each parameter, the thematic maps were developed. Accordingly, each map was geo-referenced to the Universal Transverse Mercator (UTM) coordinate system. Through the software package, necessary information for the slope was deduced from Digital Elevation Model (DEM). The overall work plan - methodology for the research is illustrated in Figure 3.2 below.

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2.3 RESEARCH METHODLOGY CHART

Below is the flow chart to achieve research objectives.

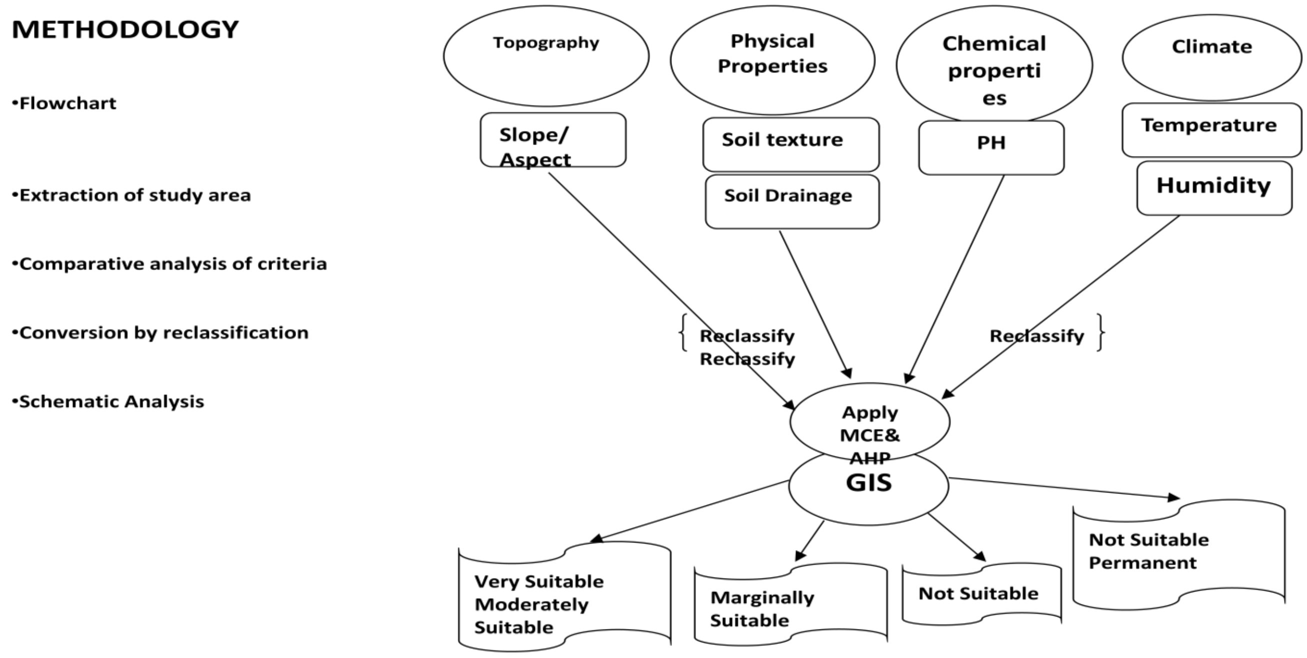

Fig. 1.0 Methodology: FLOWCHART

Basically, the climate, local topography, soil texture, and existing vegetation etc which are the main components of the environment, are key determinant assessment factors for Land Productivity. Analysis of suitability was carried out by cross examination of the prevailing land use pattern, potential feasibility and the economic viability.

Acquisition of spatial data and rendering of same into map or pictorial format were carried out to accomplish desired-relevant land resource management. Other inputs are here placed side by side as Land suitability cannot be solely based upon biophysical resource- information. Relevant information such as transportation and demographic features were put into consideration. The surface and overlay analysis were processed using GIS and the various vast amount of spatial information effectively captured.

3.4 DATA ASEMBLY

Data assembly and manipulations involves importation of Shape File of study region into the GIS environment. The assembled geographical data is processed after combination and transformation into relevant decision. This involves personal, expertise inputs or decision maker's preference as regards use of specified decision rules, manipulation of information etc. For the spatial multi-criteria decision-making process, the input data is geographical as captured in- Rice, maize and cassava suitability are deduced via the input of geographic data-physical and chemical properties of soil, topography, climate and land accessibility.

Table 2.5a Data Sources

S/N	Data type	Date of Acquisition	Resolution/Scale	Source
1	NIGERIA SAT 1 IMAGERY	2016	32m x 32m	NASRDA
2	Shape file of Enugu state	Sheet 266,1962	1: 50000	ESGOF/ MOE
3	SRTM (DEM)	2007	30m	Global Land facility
4	Climatic data – Temperature, Rainfall, Relative humidity	2009- 2012		NASA
5	Geology map of Nigeria	2006		NGSA
6	Soil Map of Nigeria	1997	1: 1,300000	WAGENINGEN The NETHERLAND

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Table 2.6a Data analysis

S/N	Data Name	Procedures	Analysis
i	NIGERIA SAT 1 IMAGERY	Radiometric correction& Geometric; clipping and classification	Extraction of Enugu -shape file (Imagery of Study area)
ii	Shape File of Enugu State	Importation into ArcGIS environment	Shape file creation
iii	STRM	Creation (Generation) of DEM, Imagery - study area	Extraction of shape & Reclassification
iv	Climatic data : Rainfall, Relative humidity & Temperature	Creation of shape files, clipping of study area	interpolation and Reclassification
V	Geology map of Enugu state	Importation into ArcGIS environment	Digitization-Reclassification and overlay
Vi	Soil map of Enugu	Importation into ArcGIS environment	Digitization, Reclassification and overlay

2.7 EXTRACTION OF THE STUDY AREA AND AGRICULTURAL LAND

The area of interest (AOI) -study area was extracted by means of an on screen digitization. This is accompanied by masking- out though subset module of ENVI software (ver.4.7). In order to identify the crop land with highest and lowest rank of vigor, the Normalized difference vegetation index (NDVI) which is an indicator assessment was adopted. Further, the detail is incorporated with decision tree classifier (DTC), and the agricultural land was successfully delineated from. This is consequently used for further analysis. The link roads, Rail ways etc were also put together in as shown in fig. 4.1

2.8 ASSIGNING WEIGHT OF FACTORS & MULTI-CRITERIAEVALUATION (MCE)

Factors established were the most relevant and weighting analysis are done to express the relative worth (importance) of each factor to the other with respect to the degree of effect or impacts on crop growth rates, performance and yield. Table 2.10 shows Suitability levels for each of the factors which as expressed, are used for the construction of criteria maps (one for each factor). Based on FAO suitability classification standard, the suitability levels for each factor were ranked. These included: “Highly (most preferably) suitable”-S1, Moderately (preferably) suitable-S2, Marginally (less preferably) suitable-S3, and “N” Not suitable etc.

Table 2.10: The Saaty Rating Scale

Intensity of importance	Definition	Remarks
1	1:1 (Equal importance)	Two factors contribute equally to the objective (equal weight).
3	Somewhat more important, greater	Experience and judgment slightly favour one over the other.
5	Much more important	Experience and judgment strongly favour one over the other.
7	Very much more important	Experience and judgment very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed

AGGREGATE OF THE CRITERIA

Weighted Linear Combination is the most commonly used decision rule.

Formula: $S = \sum w_i x_i \times \prod c_j$ ……………………………………… *i*

Where: S – is the composite suitability score

x_i – factor scores (cells)

w_i – weights assigned to each factor

c_j – constraints (or Boolean factors)

$\sum$ -- sum of weighted factors

$\prod$ -- product of constraints (1-suitable, 0-unsuitable)

Table 2.11: Random Consistency Index

n	1	2	3		4	5	6	7	9	10
RCI	0	0	0.58		0.90	1.12	1.24	1.32	1.45	1.49

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Fig. 3.8: **Soil map of Enugu State**

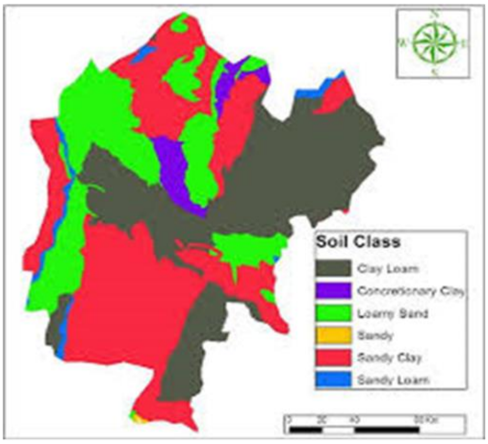

Fig. 3.9: **Topography of Enugu State**

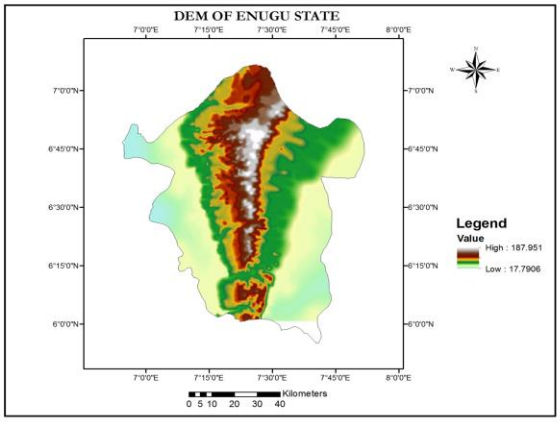

Table 3.15: **Spatial variation of slope**

Suitability class	Slope (%)	Area (Ha)	Area (%)
S1	≤ 6	861,250	37.09
S2	6-13	452,352	19.48
S3	13-25	354,201	15.25
N	> 25	654,112	28.17

Table 2.14: Pair wise comparison matrix of sub-criteria with respect to soil

	Soil PH	Soil texture	Soil depth	Soil drainage	n^{th} root of product of values	Eigenvector
Soil PH	1	1/3	1/3	1/3	0.439	0.093
Soil texture	3	1	3	3	2.280	0.480
Soil depth	3	1/3	1	1/2	0.841	0.177
Soil drainage	3	1/3	2	1	1.189	0.250
Sum					4.749	1
λ_{max}=4.214	CI =0.071	CR =0.08				

Table 2.15: Spatial variation of slope

Suitability class	Slope (%)	Area (Ha)	Area (%)
S1	≤ 6	861,250	37.09
S2	6-13	452,352	19.48
S3	13-25	354,201	15.25
N	> 25	654,112	28.17

RESULTS AND DISCUSSION

Figure(s) 6, 7 & 8shows the thematic map of the crop (rice, maize& cassava) / soil suitability rating for the study region. The tables- 4.1, 4.2 & 4.3 further present the varied suitability capabilities of the examined areas. Also, fig. 4a, 4b & 4c shows the pie chat of the result of the suitability dimensions for rice, maize and cassava respectively.

The agricultural land has been ranked as highly (most) suitable, moderately (appreciably) suitable, marginally (relatively less) suitable or not suitable, after cross examination and analysis. Highly suitable area (with respect to rice) is characterized by well/moderately poorly drained soil, very deep/deep soil and loamy texture, while marginally suitable area is characterized by shallow soil and very clayey texture.

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ISSN: 2278-0181
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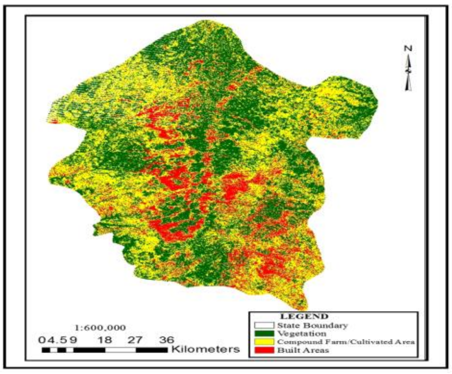
(Fig. 4.0) Land use Land cover of Enugu State

4.1 MAJOR ROAD NETWORK WITHIN STUDY AREA

4.0 LAND USE & LAND COVER OF ENUGU STATE.



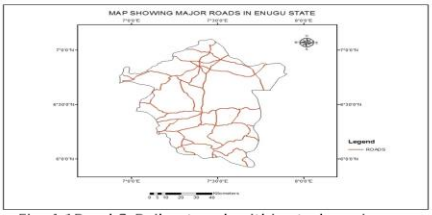


Fig. 4.1Road & Rail network within study region

4.2 RICE SUITABILITY

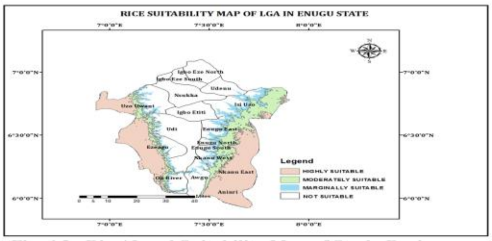


Fig. 4.2a Rice/ Land Suitability Map of Study Region

(Fig. 4.0) Land use Land cover of Enugu State

On the order hand, the characteristics crop- requirements for maize and cassava are presented in Table 10& 11 respectively. Cross matching of the each crop alongside the land units were done to arrive at the suitability classes. Through the principle of limiting conditions, the land was rated as marginally suited –S3for maize and cassava respectively. This is partly attributed to the high nutrients requirement of maize and other critical factors that affects maize production especially that of Moisture and drainage. Next in the ranking is the less suitable (moderately) suited (S2). The rating or grouping of the land was grossly affected by the nutrients requirements of each crop. The other portions were rated as highly (most) suited (S1) and not suitable (N) using the analytical approach respectively.

Table 4.2b Rice/ Land suitability area

Suitability class	Area (km²)	%
Highly suitable	2,768	38.65
Moderately suitable	865	12.08
Marginally suitable	1,265	17.67
Unsuitable	2,263	31.60
Total	7,161	100

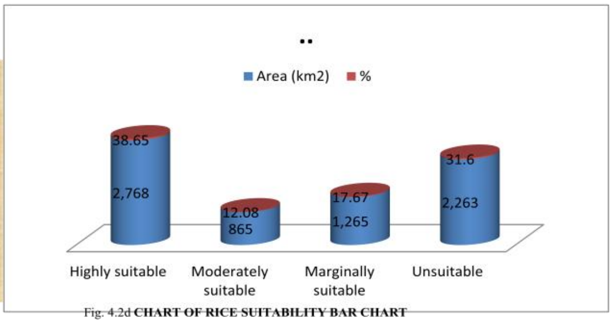


Fig. 4.2d **CHART OF RICE SUITABILITY BAR CHART**

4.3 **MAIZE SUITABILITY**

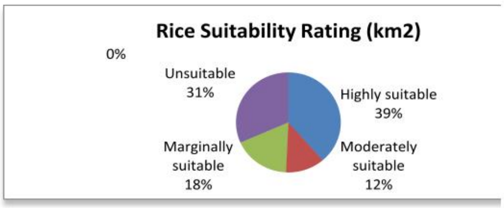


Fig. 4.2c **RICE SUITABILITY PIE CHART**

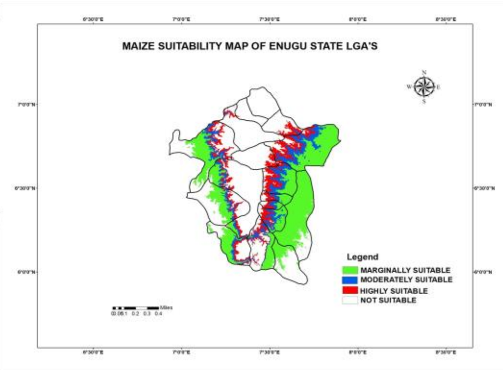


Fig. 4.3a **Maize/ soil suitability map**

Table 4.3b **Maize/ Land suitability area**

Suitability class	Area (km²)	%
Highly suitable (S1)	1,857	25.93
Moderately suitable (S2)	1,251	17.47
Marginally suitable (S3)	1,865	26.04
Unsuitable (N)	250	3.49
No data	1,938	27.06
Total	7,161	100

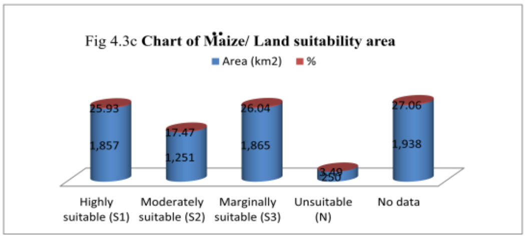


Fig 4.3c **Maize/ Land suitability area**

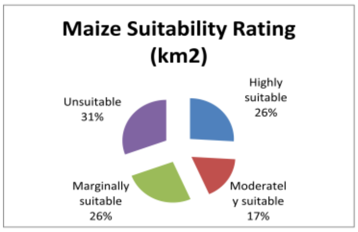


Table 4.4 **Cassava/ Land suitability area**

Suitability class	Area (km²)	%
Highly suitable	2,121	29.62
Moderately suitable	1,352	18.88
Marginally suitable	1,201	16.77
Unsuitable	521	7.28
No Data (Other LGA)	1,966	27.45
Total	7,161	100

4.5 PEDALOGIC INDEX FOR EACH CROP WITHIN STUDY AREA

Crop	Site				
	S1	S2	S3	N	No. Data
Rice	28.06%	22.66%	14.51%	7.69%	27.06%
Maize	25.93%	17.47%	26.04%	3.49%	27.06%
Cassava	29.62%	18.88%	16.77%	16.77%	27.45%

Table 4.5 SOILS/ CROP SUITABILITY RATINGS FOR ENUGU STATE

The suitability ratings reveal that the zones which are highly suitable and moderately suitable for Rice farming fall into the key LGA(s): Uzouwani, Ezeagu, Oji river, Aninri, Nkanu East and Isi uzo which are the principal areas of agricultural produce in the state. The outstanding performances of FADAMA Projects within the State also attest to the potential status of the regions viability. Based on the varied soil and environmental status, the suitability classifications for maize and cassava as indicated on the table above.

4.6 LIMITATIONS

The use of GIS is based on facts and figures- Geographic information. Availability of the needed data and the cost of acquisition remains one of the salient challenges. Footing the bill to collect new data and to convert paper maps and data into digital format continues to be a problem. In many cases digital data do exist, but there are issues of confidentiality, national security, etc.

There is no clearly- defined community and LGA boundary delineation for the study area. Most of the boundary reference points are either linked to a river course, hills or other demographic features. These made it difficult to ascertain the precise size of key and notable zones and areas of interest.

CONCLUSION

GIS analysis and spatial modeling offers one of the best planning aids for precision farming. As seen from the results, it makes it reliably efficient to analyze land capability or potential with higher accuracy. The result shows, at a glance, what to expect from where and how by ensuring judicious use and allocation of resources for optimum yield.

This work shows that the inclusion of GIS in pre-farming activities is an effective tool for cost effective projection when it comes to feasibility and productivity analysis. It helps to preview the results of the integral combinations of key factors of crop production to highlight most suited zone (areas) for commercial output of various crops. The results of this work should serve as guides to investors in prioritizing investment towards large scale- commercial production of rice, maize, cassava etc. in Enugu state.

CONTIBUTION TO KNOWLEDGE

Apart from boosting the confidence of agricultural investors, GIS simplifies farm – input- return analysis and guaranties justifiable allocation of resources. This research work directs focus on the indispensable need for inclusion of technological aids in today's agricultural practice which has not been given due attention. In summary, this work has simplified the answer to where is most suitable or less suitable for crop production across the study region.

RECOMMEDATIONS

While the result of this research reflects the real status of the varied crop production capability of Enugu State, I recommend it as guides in agricultural planning and investments. Secondly, further work should be done on accurate boundary delineation to reflect the sizes of each community and LGA across the Sates in Nigeria. Finally, the government should give attention to creation of agricultural data base and encourage the use and inclusion of GIS in the industry.

ACKNOWLEDGEMENT

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REFERENCE

[1] United Nations Environment Programme (UNEP), Promoting Sustainable Agriculture and Rural Development, 2015 [cited 2015 November 10]; Available from:pp://www.unep.org/Documents.multilingual/Default.asp?DocumentID=52&ArticleID=62.

[2] Food and Agriculture Organization (FAO), A framework for land evaluation, Soils Bulletin 1976; 32

[3] Klingebiel, A.A. and P.H. Montgomery, Land capability classification, Agriculture Handbook, 210. Soil Conservation Service, U.S. Department of Agriculture. Washington, DC, p. 1-3.

[4] Ahamed TR, GopalRao K, Murthy JSR (2000) GIS-based fuzzy membership model for crop-land suitability analysis. AgrSyst 63(2):75–95.

[5] Al-Mashreki, M.H., et al. (2011). GIS-based sensitivity analysis of multi-criteria weights for land suitability evaluation of sorghum crop in the Ibb Governorate Republic of Yemen. Journal of basic and applied scientific research, 1 (9), 1102–1111.

[6] Chow, T.F. and Sadler, R. (2010). The consensus of local stakeholders and outside experts in suitability modelling for future camp development. Landscape and urban planning, 94, 9–19.

[7] Coltelli, M., Fornaro, G., Franceschetti, G., Lanari, R., Migiaccio, M., Moreira, J. R., Papathanassaou, K. P., Puglisi, G., Riccio, D., and Schwabisch, M. (1996) *"SIR-C/X-SAR multifrequencymultipass interferometry: A new tool for geological interpretation"*, Journal of Geophysical Research, 101.

[8] Drobne and Lisec. (2009). Multi-attribute Decision Analysis in GIS: Weighted Linear Combination and Ordered Weighted Averaging. University of Ljubljana, Faculty of Civil and Geodetic Engineering, Jamova 2, SI-Ljubljana, Slovenia Informatica 33 (2009) 459–474.

[9] FAO. (2004). *Production Yearbook*. Vol.50. Rome. NRRDSE-rice report of Ethiopia.