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# GIS- BASED SITE SUITABILITY STUDY OF RICE FARM LOCATION IN BENDE LOCAL GOVERNMENT AREA, ABIA STATE, NIGERIA

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## ABSTRACT

The aim of this study was to demonstrate the capacity of Geographic Information System (GIS) procedure in the analysis of suitable site for rice farming in Bende Local Government Area (LGA), Abia State. Rice is one of the most important staple foods consumed in every household in Nigeria. Therefore, studies of this nature are highly needed as rice production in Nigeria is still below the consumption rate. The result from the suitability mapping of suitable farm location for rice production using GIS therefore will aid in optimizing its production by revealing the varying degrees of suitable location for rice production. The GIS suitability map will enable farmers to be aware of the best location for rice production. Optimal location is important for every business venture to thrive. The GIS-based suitability map will contribute to the call for the mechanization of rice to encourage increase in production rate from 5.4 million to 7.2 million tons. To achieve this aim, individual maps which represent factors that determine rice production such as soil, slope, nearness to river, and accessibility were developed and applied in analysis. These maps were re-classified and assigned suitability weight based on their relative importance. The soil was assigned the highest weight while accessibility (road) was assigned the lowest weight. The essence of re-classifying the maps and assigning weights to the individual maps was to generate individual factor suitability maps. Thereafter, the new re-classified and individual suitability maps were overlaid on each other using ArcGIS 10.4 weight overlay tool to generate the rice suitability map. The final suitability map showed that 13.16 % of the area in Bende Local government Area is highly suitable for rice production, 34.67% is moderately suitable and 35.60% is marginally suitable. The other 15.94% is currently not suitable. This study recommended setting up field trials in the various suitability classes as identified in the study. This will allow for testing of the various management options for sustainable rice production in each of the suitability classes. The outcome of this study is important for policy makers and planners for efficient rice production.

**Key words**: GIS, Site-Suitability, Bende, rice production, Farm location

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## INTRODUCTION

Rice (*Oryza glaberrima*) is one of the most important cereal crops in the world. It plays a strategic role in food consumption of households located both in cities and villages [1]. Rice provides 20% of the world's dietary energy supply, compared with other important staples such as wheat (supplies 19%) and maize (supplies 5%) [2]. Rice is a grass plant (monocot) with round culms, flat leaves, and terminal panicles. The primary tillers grow from the lowermost nodes of the transplanted/germinated seedlings, further giving rise to secondary and tertiary tillers. The plant takes 70 to 160 days to mature, depending on the variety and growth conditions. In agriculture, location of farmland has significant influence on crop performance as each crop has unique characteristics and conditions which are required for the crop to thrive. Evaluating the appropriateness or ability of land for crop performance is referred to as crop suitability analysis. It is a prerequisite to achieving optimum utilization of the available land resources for sustainable agricultural production [3].

Determining land suitable for cultivation of different crops has transcended the initial manual method of trial and error to a more efficient technical method using Geographic Information System (GIS) technology. The Environmental Systems Research Institute (ESRI) [4] defines GIS as an organized collection of hardware, software, geographic data, and personnel designed to efficiently capture, store, update manipulate, analyze and display of all forms of geographically referenced information. Remote sensing and the GIS technology have been recognized and used as powerful and effective tools to monitor land use and surface changes. Geographic Information System (GIS) is now providing new tools for advanced ecosystem management. Identifying land areas for a specific purpose using GIS packages is known as Site Selection. Site selection involves the use of spatial data, which is also known as geospatial data or information that identifies the geographic location of physical features on the earth. Suitability is a function of crop requirements and land characteristics. Matching land characteristics with crop requirements gives its suitability.

Therefore, land suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land-use. For this study, the goal is to get site suitable for efficient rice production. Although different actors in the public and private sectors have revealed interest in rice production in Bende Local Government Area, the current pattern of land suitability assessment and ecological techniques are outdated. Land is gradually becoming scarce as there is an increase in the number of farmers due to population increase that places a lot of pressure on the available arable land. Since farming is their major source of livelihood, scarcity of land most times results to cultivation of farm plots that are not

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suitable for rice production. Furthermore, the rice crop is not limited to the various existing areas as there are various plots of land that can support rice production that farmers are not aware of. Therefore, there is an urgent need to develop more efficient and sustainable agricultural production systems by using GIS to match the available land resources with the current land-use for sustainable food production and food security for the society.

Several studies have been conducted on rice production globally and particularly in Nigeria. Raza, Mahmood, Khan and Liesenberg [5], while focusing on climatic and physical factors mapped out land suitable for rice cultivation in Punjab, Pakistan. Result of their study, indicated that 5.9% of rice cultivation was done in least suitable areas, 44% in highly suitable, 23.2% in moderately suitable and 16.8% was in unsuitable regions. Kuria, Ngari and Waithaka [6] used GIS in their study to determine land suitability for rice production in the Tana Delta. The result of their study produced a rice suitability map of the most suitable, suitable, less suitable and unstable arable land for rice production. GIS land suitability classification will help in the optimum use of the suitable areas of land thereby leaving the unsuitable areas for other crops that will survive in those areas. Ayehu and Besufekad [7] studied land suitability to identify permissible areas suitable for rice production in the West Central highlands of Amhara Region of Ethiopia which revealed that the study area has a huge potential for rice production. Kihoro, Bosco and Murage, [8] in their study in Kenya also showed that 95% of the allotted land for rice cultivation was highly underutilized for rice cultivation. They observed that only 12% of the said land was put into rice cultivation. This further explains the effectiveness of using GIS in identifying the potential areas suitable for increased rice production. Merem *et al*. [9] used GIS to determine rice production trend in Niger State and discovered fluctuations in cultivated land area. Most rice farms were located in places not suitable for rice farming. Therefore, climatic stressors including inadequate rainfall and at times flooding from erratic rainfall were found to be responsible for excessive losses in rice yield. Emenike *et. al,* [10] used GIS to assess land suitability for rice cultivation in the Opa River Basin, Osun State, Nigeria. Their study showed that areas not suitable for rice production were attributed to build up areas, bare soil surfaces from soil erosion and rock outcrop. Mba *et. al.,* [11] studied the patterns of rice production and yields in Southeastern Nigeria. Results of their studies showed that variations in the patterns of rice production had positive effects on the rice yields. Conclusions drawn from results of reviewed literature show that GIS is significant in the management of time and resources that would have been otherwise wasted in the wrong land-use [12, 13, 14].

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Bende LGA, a major rice producing area of Abia State, [15], is noted for upland and low land rice with varieties including R-box, Faro23, 24-27, B12, Faro 44-47 with majority farming the variety R-Box because of its resistance to pest and diseases [16]. Rice productions in Bende are mainly among rural dweller and are subsistence in nature [17]. Also, in the area, youth and women participation in rice production was found to be beneficial and profitable [18, 16]. Rice production in Bende is normally done by smallholder farmers [19] which might be part of the contributing factors to the moderate to low production of rice among rice producers in South Eastern Nigeria [11]. Rice production is found on smallholder level as a result there is limited farm size due to inadequate expanse of land for plantation farming of rice in the area. This shows that farm size is a major problem of rice production in the area. Offor, Amusa and Udochukwu, [19] found in their study in Bende LGA that majority of rice farmers in the area have mean farm size of 1.0 hectares. They established that the small size of farms will affect rice output. Their result further shows that there is a positive relationship between farm size and output of rice farmers. This implies that as the farm size increases, output of rice production increases. Productivity increases with farm size because they are more amenable to mechanization and application of superior technology leading to increased output per unit area [16]. Land tenancy is another big problem of rice production in Bende state leading to fragmented farm and low productivity. Iheke and Chikezie [15], studied the productivity of land owners and rented farmers in Bende LGA, and result shows that rice farmers that owned land profit more than those that rented land. Other problems associated with rice production in the area which is related to land issues are Provision of easy and accessible agricultural land, restricted access to land, limited capacity to expand [18, 16]. Therefore, to contribute to solve the problem of land availability for rice production in Bende Local Government Area, employing the uses of geospatial technology (GIS) in agricultural production has brought a lot of revolution towards better achievements. Prior to the period this technique was directed towards agricultural fields, farmers at all levels leveraged on certain unpredictable gambling while trying to decide on suitable areas for their crops. Losses have been witnessed because of failure to do prior analysis before commencement of farming activities. This had led to misuse of labor and farm inputs, not to mention waste of time, which could have been avoided through certain approaches. Land suitability evaluation therefore, determines the quality of a given area for optimum production of specific crops. The suitability classification results of the area for rice production will be beneficial to farmers and the community at large as it could guide their farming system and improve their production capacity [20]. Thus, land suitability studies of this nature, will lead to identification of more land which are suitable for rice cultivation but not on use presently. Hence, the outcome of the study will aid in enlarging the area of

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land used for rice production and help rice farmers to have access to more land for expansion and rise in productivity. Land sustainability therefore is aimed at reducing trial and error. This study demonstrated the capacity of Geographic information system procedures in the analysis of site selection for rice farming. Therefore, for efficient use of land, a GIS tool is very important in giving precise, adequate and efficient land utilization.

## METHODOLOGY

Bende Local Government Area (LGA) is one of the seventeen LGAs in Abia State with land area of 601km$^2$. The Bende LGA is made up of thirteen communities which include: Akoli, Alayi, Bende (administrative headquarter), Ezeukwu, Igbere, Item, Itumbuzo, Nkpa, Ntalakwu, Ozuitem, Ugwueke, Umuhu, and Uzuakoli. Bende LGA is located between latitude 5°25'N and 5°50 and longitude 7°30'E and 7°39E (Fig1).

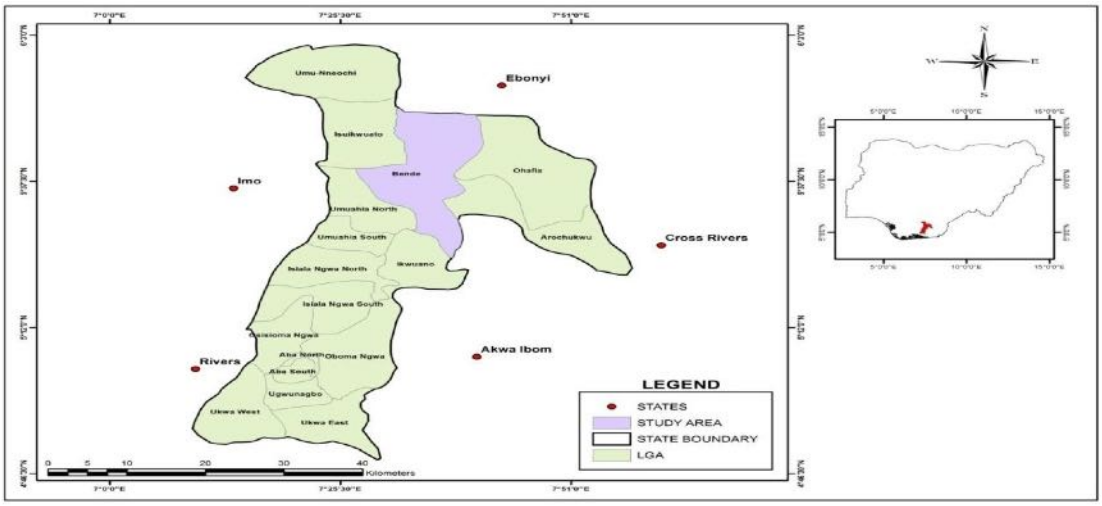


**Figure 1: Map of Abia State Showing Study Area**
*Source: Google Earth, 2019*

The study area is part of Abia North Senatorial District which shares its borders as follows. To the north is Afikpo, and to the east by Ohafia and Arochukwu LGAs. Futhermore, Bende LGA shares its western border with Umuahia North and Isiukwuato LGAs and in the south, shares border with by Ikwuano and Ini LGA in Akwalbom State. The study area lies in the sub equatorial zone of Nigeria, with high temperatures, with an average (diurnal of 24$^o$C), a bimodal high conventional rainfall in the range of (2200-2400mm), high humidity and high amount of cloud cover. The Bende LGA falls within the tropical high forest vegetation zone. Some of the forest trees in the area are bamboo (Bomusceae family), mango (*mangifera indica*), tamarind (*Tamarindus indica*) neem (*Azadiratcha indica*), cashew (*Anacardium occidentale*), oil palm (Elaeis guineensis) among other forest trees.

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The major rivers and streams in the study location area are Avu, IyiAkwa, Ogboko, Igwu and Aha. These rivers and streams are the major sources of water for domestic, agricultural, recreational uses. The Bende-Ameki group is the geological formation located in Bende. It is primarily made up of shale, sandstone, and siltstone. The Landscape of the area is characterized by physiographic variations to landform comprising of low plains, ridges as well residual and conical hills.

**Data collection and Analysis**

**Data sources**

The data used in this study was sourced from primary and secondary sources. Primary data was obtained through ground truthing exercise using a Global Positioning System (GPS) to obtain co-coordinates for geo-referencing of features of interest in the Bende LGA. Secondary data like soil map, slope map, climate was obtained from Harmonized World Soil Database, Shuttle Radar and Topography Mission respectively (Table 1).

**Explaining variables used for mapping land for the rice suitability**

**Slope**: - Slope was considered a variable used in mapping because it impacts soil erosion and contribute to loss of soil fertility to impact rice cultivation.

**Soil:** - we used soil as a variable in our mapping because soil is required by plants for anchorage and nutrients supply. Therefore, very important for rice production also, knowledge of the soil chemical and physical properties is essential for rice production. Soil properties are essential for crop land suitability analysis and mapping [21].

**Land-use:** - A land-use map shows the extent of use of a piece of land for different purposes. Therefore, for sustainable production to occur, knowledge of land from its land-use map is essential.

**Climate:** - The available datasets for rainfall and temperature for Bende LGA were not adequate as there is no weather station in the area. Elevation was therefore used as a proxy for climate (rainfall and temperature). This is because of the well-known principle that the micro-climate of an area can be related to elevation [22].

**Roads**: - Roads were considered a variable in this study because they influence the productive suitability of an area in terms of transporting inputs and access to markets. Therefore, roads were considered necessary for rice production.

**Rivers:** - Rice is usually cultivated along Flood plains and along river banks especially in developing countries like Nigeria where agriculture is rain fed. Thus, we considered map of rivers to mapping the suitability of land to support rice production. We selected and used these variables for mapping because Bolstad [22] backs the

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use of these variables (slope, roads, river, land use/land cover) in producing suitability map for rice production.

**Re-classification of data set**

The dataset for this study, which comprised of slope, soil, distance to road network, elevation, distance to rivers, and land-use and land-cover maps derived from input maps were re-classified into common number of classes. The Food and Agricultural Organization (FAO)'s standard scale of suitability classification was used for reclassification of the land suitability for rice production. The suitability values range from extremely high to least and not suitable areas. The re-classification values used in this suitability analysis ranges from 1 to 4, where 1 refers to most suitable site for rice cultivation, 2 is moderately suitable, 3 is marginally suitable and 4 is not suitable. These classes were represented as S1, S2, S3 and NS respectively. A uniform colour was assigned to each suitability class for easy interpretation.

**Weighting of the Dataset**

The datasets were thereafter ranked and assigned weights according to rice suitability. The weight of each processed datasets were calculated using the following equation;

$$Wi = (n - ri + 1)/\sum (n-rk+1) \quad 1$$

Where Wi is the weighting for criterion I, n is the number of criterion, ri is the rank for the ith criterion and k is a counter for summing across all criteria [24]. Table 2 shows the weights calculated for each criterion used in the study.

The higher the score, the more suitable will be the site for rice cultivation. The suitability weights assigned to each classified dataset was defined based on its relative importance to rice production. Criteria used in the study are land use land cover (LULC), accessibility (road), proximity to water body (river), topography (elevation and slope), and soil (soil texture and soil pH).

**Data analysis**

Data was loaded into the ArcGIS 10.4 software and analyzed by application of the weighted overlay tool. The ArcGIS 10.4 tool was applied in the overlay of shape files of the individual suitability index spatial data layer dataset map to get the final rice suitability map. This provided gainful trends and insights to enable the generation of the final rice sustainability map. This research adopted the following framework (Fig. 2).

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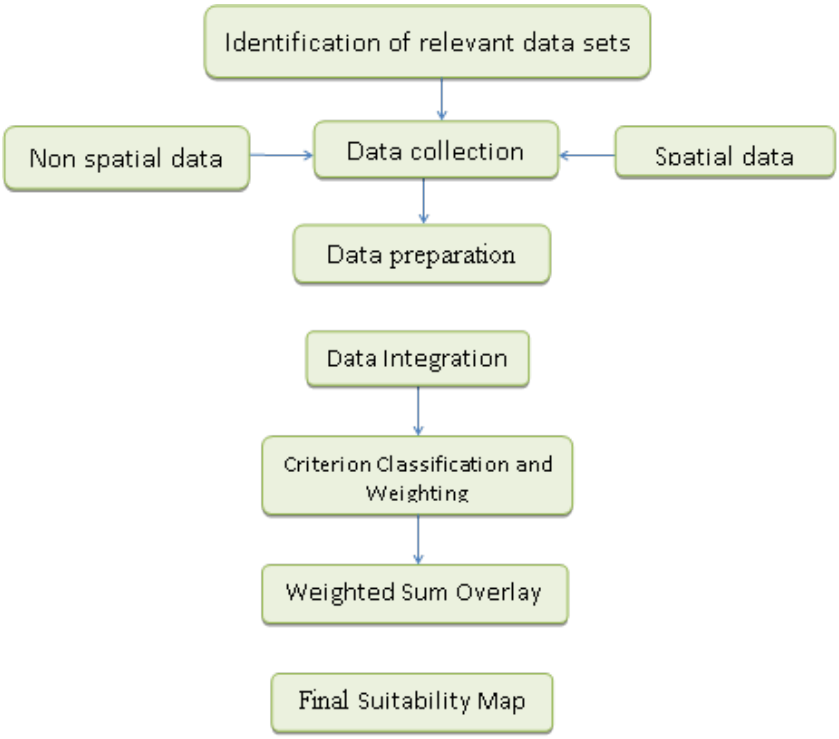


**Figure 2: Flow of Spatial Data Methodology**

## RESULTS AND DISCUSSION

### CRITERIA ANALYSIS

The result of the accessibility map shows that, land that lies at an altitude of 0-500km above sea level is the most suitable for rice production, while land areas at altitudes in the range of 3400 -5476km are the least suitable (see Fig 3a). Slope measures the topography of the land; flat and gentle slope are more suitable for rice farming compared to steeper areas. The thematic map of slope shows that areas exceeding 12 degrees in angle are usually not suitable for rice cultivation (Fig 3b). The Digital Elevation Model (DEM) analysis revealed that areas from angles 1-12 degrees are suitable for rice cultivation. Distance from rivers was generated using Euclidean distance spatial analysis tools. The result showed that areas within the range of 0 to 750km to rivers are the most suitable while areas farther within the range of 3,700-7179km were least suitable (Fig 3c). The land-use and land-cover exploration using land sat 8 satellite images generated the Land-use Land-cover (LULC) map. The LULC map show that areas that were classified as built-up area, and as a bare land will not be suitable for rice product. The elevation map of the area was used as a proxy for climate as elevation strongly governs the spatial distribution of the rainfall [22 25]. The analysis show that the maximum attitude of the town is 245m and it is not suitable when compared to the

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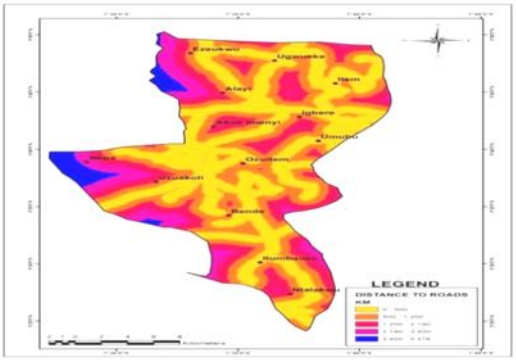
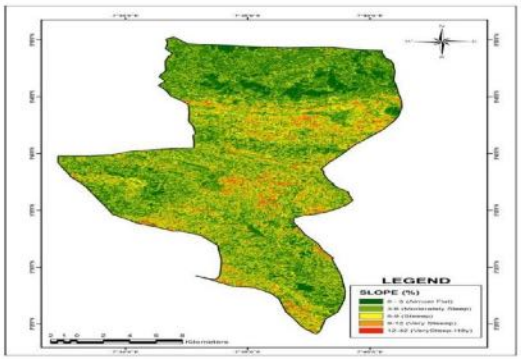
lowest altitude which is just 26 m (Fig 3e). Soil texture showed that areas high in clay soil are most suitable for rice cultivation (Fig 3f). The preliminary result of the rasterized and clipped data for soil pH shows that soil in the study area is relatively acidic in the range of 4.5 to a maximum value of 7.0 is relatively acidic in the range of 4.5 to a maximum value of 7.0.




3a

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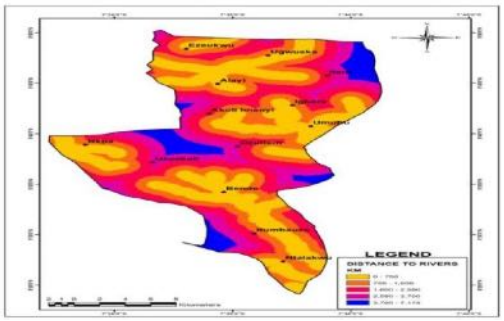


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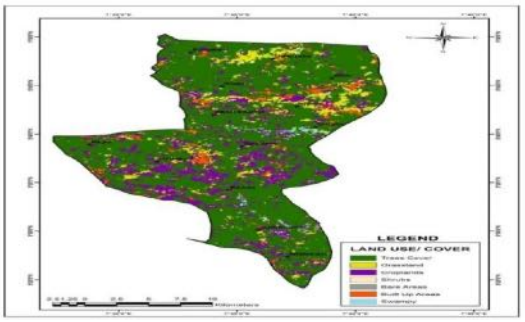


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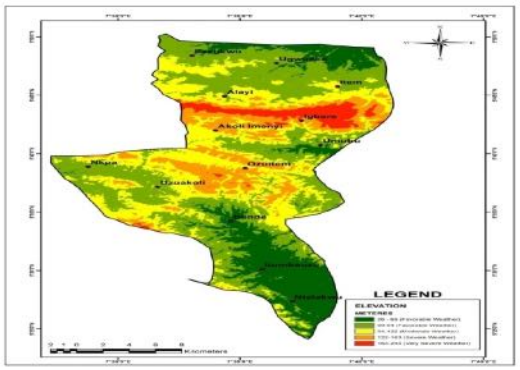
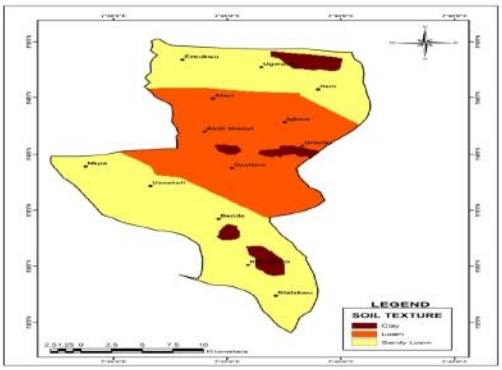



3e




3f

**Figure 3a-3f: Map of criteria analysis**

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**Criteria Suitability Result**

Result of the criteria suitability map of roads revealed that 47.46% of the area is most suitable while 5.88% of the area is not suitable for rice production in terms of accessibility in moving both inputs and outputs (Table 3 and, Figure 4).

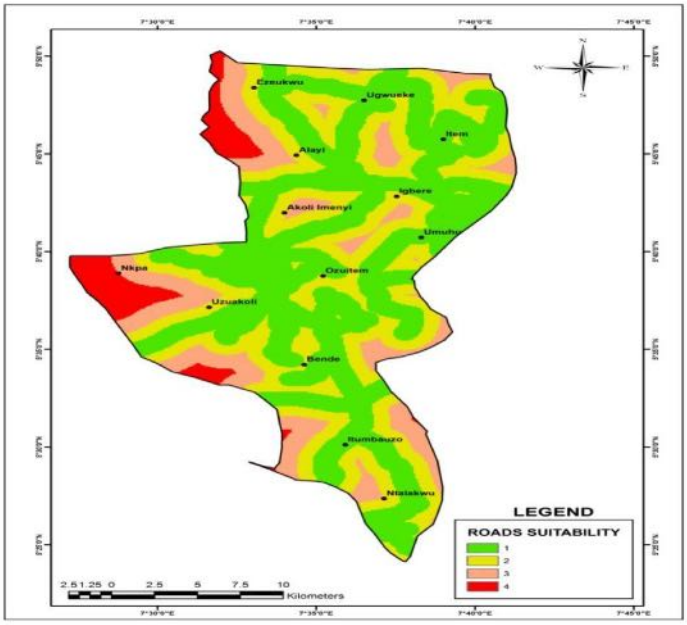


**Figure 4: Roads Suitability Map**

Source: Author, 2019

The result of the reclassified slope map shows that 41.07% of the land in the area is most suitable and 3.81% is not suitable. (Table 4 and Figure 5).

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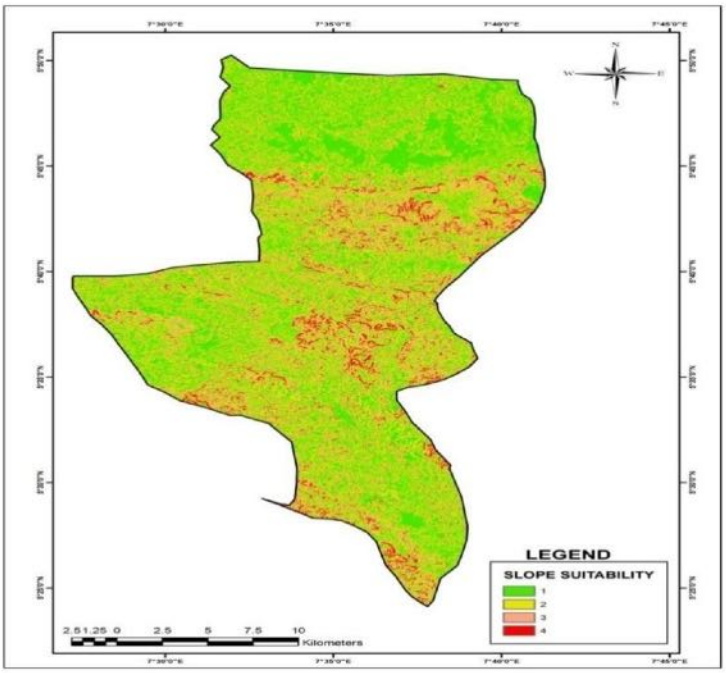


**Figure 5: Slope Suitability**
Source: Author, 2019

Table 5 and Figure 6, show that 18.31% of the land-use/ Land-cover of the area is swampy and are the most suitable for rice cultivation while bare land and built up areas which cover 17.5% of the area are not suitable for rice production.

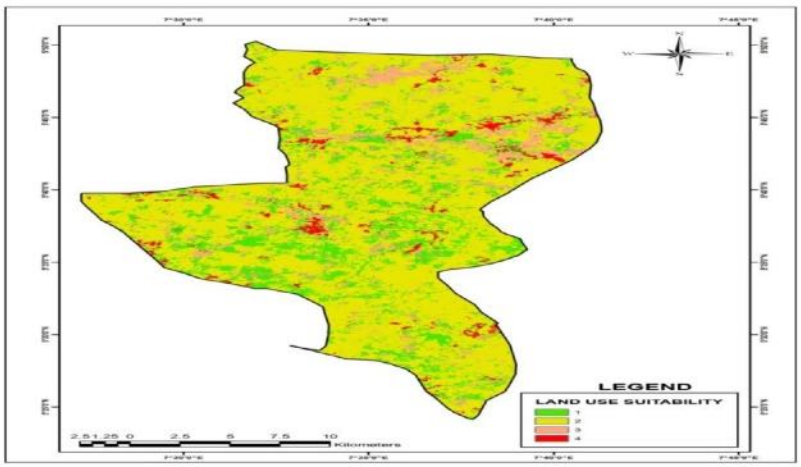


**Figure 6: Land-use/cover Suitability**
Source: Author, 2019

Table 6 revealed that 22.24% of the area was considered most suitable for rice cultivation with an elevation of 26-73m while 6.65% of the area was considered not suitable with an elevation of 148-245m. Additionally, the areas with low elevation

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had the most favourable weather condition while areas with high elevation have severe weather condition.

Rivers suitability analysis as shown in Table 7 and Figure 6 revealed that 38.96% of the study area is most suitable while 30.43% of the area is moderately suitable for rice production.

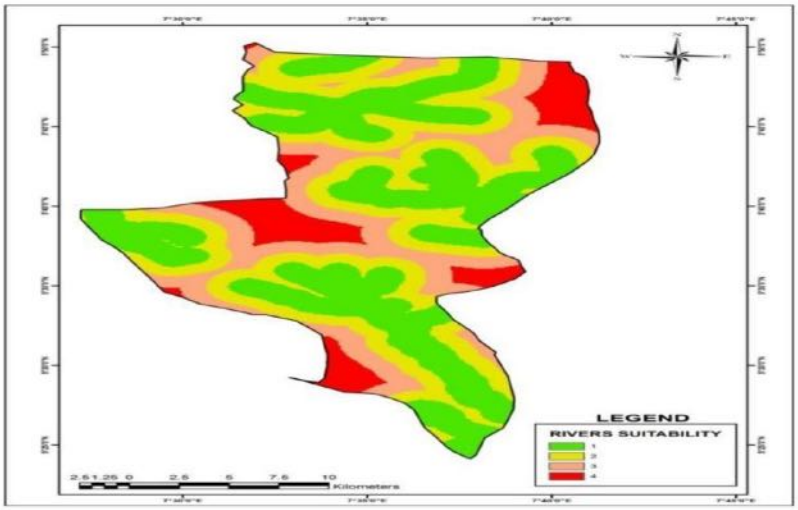


**Figure7: Rivers Suitability**
Source: Author, 2019

## FINAL SUITABILITY

The overlay of the individual reclassified maps was further overlaid on each other to get the final site suitability map for cultivation of rice in the Bende LGA, Abia State as shown in Table 8.

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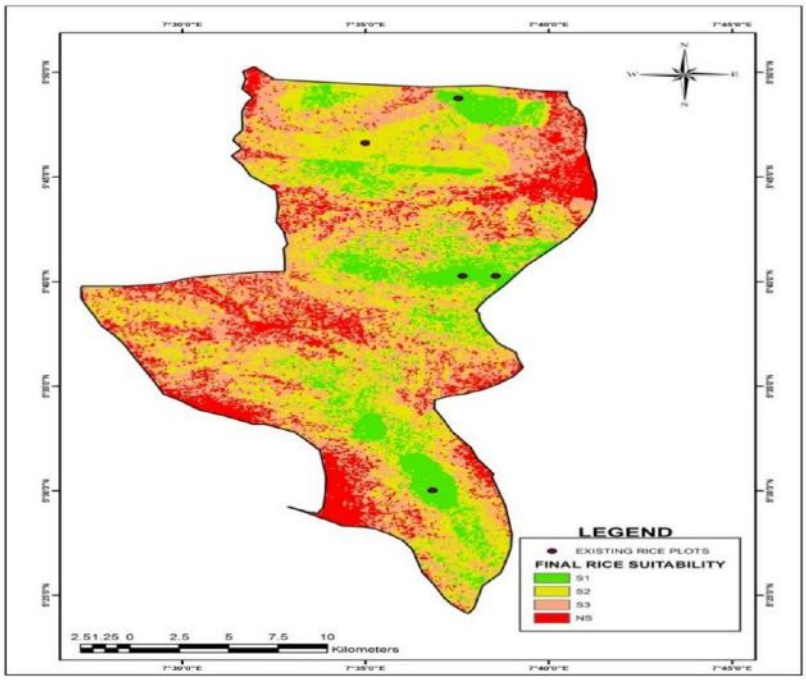


**Figure 8: Final Suitability Map**
Source: Author, 2019

Table 8 revealed that 83.43% (501.58km) of the land has the capacity to support rice cultivation while 15.94% (95.85km) is not suitable for rice cultivation. 83.43% of the land showed different degree of suitability with 13.16% being most suitable and therefore does not require much effort towards improving the land for rice cultivation. Table 8 further revealed that 34.67% of the area is moderately suitable while 35.60% of the area is marginally suitable. Table 8 revealed that 70.72% of the land area needed a small boost to make the land more suitable for rice production. The study shows that over 50% of the land is good for rice production. This is consistent with the findings of Islam, Ahamed and Noguchi [24] in Northern part of Bangladesh, which revealed that more than 50% of land in the area was suitable for rice cultivation. Lastly the unsuitability of some areas in the Bende LGA for rice production was the result of steep hilly topography, harsh climate, rock out crop, built up areas and this correspond positively with previous findings. Fanan, Tertsea and Moses [25] discovered in their study carried out in Benue state, Nigeria that land area not suitable for rice production was the result of limitations caused by built up areas and the presence of bare land.

## CONCLUSION, AND RECOMMENDATIONS FOR DEVELOPMENT

Rice is an important staple food eaten by every Nigerian family. Therefore, its maximum cultivation and production should be of utmost importance to stakeholders involved in its production. An increase in rice production is needed in

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Nigeria, especially given the ban on rice imports. Therefore, there is need to identify more areas and land that will yield maximum return on investment for rice production. The use of GIS revealed the potential of areas that are most suitable, moderately suitable and not suitable for rice production to guide farmers and land-use planners to use arable land sustainably for rice production in the Bende and Nigeria as a whole. The findings on the suitability index will be disseminated to farmers through organs like farmers' association, co-operatives, local smallholder farmer groups and local extension officers.

Based on the study findings, the authors recommend the following.

i. That, the methods used in this study be applied in future studies to map land suitability for the production of rice production and including other parameters such as socio-economic factors that were not included in this study.

ii. Agricultural extension activities should be given priority so that farmers in the grassroots can be enlightened on the rapid change in technology and introduction of GIS as a tool which can assist in land-use decision making.

iii. Field trials can be set up in the various suitability classes as identified in the study. This will allow for testing of the various management options for sustainable rice production in each of the suitability classes.

iv. Long term soil monitoring sites should be established using a localized soil map by the government and regular soil sampling and testing should be undertaken and stored in Database. With such data, temporal changes in soil fertility can be monitored.

v. Since land suitability analysis is necessary in agriculture, responsible government agencies should adopt this scientific approach to avoid loss-generating agricultural activities as farmers will avoid unnecessary losses by growing crop where they will increase productivity to maximize profit.

vi. The final suitability map of the area should be used by extension workers, planners, and policy makers to study for maximum rice production in the study area.

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**Table 1: Sources of study Data**

| DATA TYPE | DATA SOURCE |
|---|---|
| Soil Map | Harmonized World Soil Database (HWSD). |
| Slope Map | Shuttle Radar Topography Mission (SRTM) website |
| Climate (DEM) | Shuttle Radar Topography Mission (SRTM) website |
| Land Sat 8 | United States Geological Surveys (USGS) website |
| GPS coordinates (In UTM projection) | Field collection using a handheld GPS |
| Accessibility (Road) | Google Earth Pro |
| River | Google Earth Pro |
| Rice Cultivation Handbook. | International Institute of Tropical Agriculture (IITA) website |

**Table 2: Estimated percent weight for each study criterion**

| CRITERION | WEIGHT (%) | RANK | NUMERATOR (n-ri+1) | WEIGHT Ri+)/E(nrk+1) |
|---|---|---|---|---|
| Soil | 25 | 1 | 6-1+1=6 | 6/26=0.230 |
| River | 20 | 2 | 6-2+1=5 | 5/26=0.192 |
| Slope | 20 | 2 | 6-2+1=5 | 5/26=0.192 |
| Land-use | 15 | 3 | 6-3+1=4 | 4/26= 0.153 |
| Climate | 10 | 4 | 6-4+1=3 | 3/26 =0.115 |
| Road | 10 | 4 | 6-4+1=3 | 3/26= 0.115 |
| Total Weight | 100 | | 26 | 1 |

Source: [22]

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**Table 3: Distance to road suitability summary**

| Suitability rating | Distance to roads(km) | Description | Area (%) | Area(km$^2$) |
|---|---|---|---|---|
| S1 | 0-0.66 | Very close to road | 47.46 | 285.33 |
| S2 | 0.66-1.56 | Close to road | 31.66 | 190.33 |
| S3 | 1.56-2.90 | Moderately close | 15.0 | 90.12 |
| NS | 2.90-5.47 | Further from roads | 5.88 | 35.22 |
| Total | | | 100 | 601 |

**Table 4: Slope suitability**

| Suitability rating | Slope range (%) | Description | Area (%) | Area(km2) |
|---|---|---|---|---|
| S1 | 0-3 | Almost flat | 41.07 | 246.89 |
| S2 | 3-6 | Moderately steep | 37.32 | 224.38 |
| S3 | 6-12 | Steep | 17.78 | 106.91 |
| NS | 12-42 | Very Steep (Hilly) | 3.81 | 22.92 |
| Total | | | 100 | 601 |

**Table 5: Land-use suitability summary**

| Suitability rating | Land-use | Area (%) | Area(km2) |
|---|---|---|---|
| S1 | Swamp | 18.31 | 110.08 |
| S2 | Tree cover | 69.41 | 417.25 |
| S3 | Shrub, Grassland | 9.35 | 56.24 |
| NS | Bare land/Built up area | 2.91 | 17.53 |
| Total | | 100 | 601 |

**Table 6: Elevation suitability summary**

| Suitability rating | Elevation Range(m) | Description (weather condition) | Area (%) | Area(km2) |
|---|---|---|---|---|
| S1 | 26-73 | Favourable | 22.24 | 133.72 |
| S2 | 73-104 | Favourable | 45.63 | 274.34 |
| S3 | 104-148 | Moderate | 25.45 | 153.04 |
| NS | 148-245 | Severe | 6.65 | 40.03 |
| Total | | | 100 | 601 |

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**Table 7: Rivers suitability summary**

| Suitability rating | Dist. to Rivers(km) | Description | Area (%) | Area(km2) |
|---|---|---|---|---|
| S1 | 0-0.66 | Very close to road | 38.96 | 234.09 |
| S2 | 0.66-1.56 | Close to rivers | 30.43 | 182.86 |
| S3 | 1.56-2.90 | Moderately close | 20.37 | 122.40 |
| NS | 2.90-5.47 | Further away | 10.21 | 61.39 |
| Total | | | 100 | 601 |

**Table 8: Final suitability summary**

| Suitability rating | Area (Km2) | Area (%) |
|---|---|---|
| S1 | 79.13 | 13.16 |
| S2 | 208.41 | 34.67 |
| S3 | 214.04 | 35.60 |
| NS | 95.85 | 15.94 |
| Total | 601 | 100 |

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