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Rice Farming Suitability Assessment in Anambra State Using Multi-Criteria Decision-Making Process

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ABSTRACT
Rice is very essential food crop of global significance, serving as a primary source of nutrition for over half of the world's population. Anambra State's agriculture embodies a mosaic of landforms, soil types, and climate patterns. These geographical variations offer distinct opportunities and challenges for rice cultivation. These challenges require a systematic and comprehensive assessment to inform evidence-based decision-making and mitigate potential adverse impacts on food security and livelihoods. Therefore, the primary aim of this project is to evaluate the suitability of rice farming in Anambra State, Nigeria, using a multi-criteria decision process (MCDP). This research utilized a GIS-based multi-criteria decision-making process for rice farming suitability assessment in Anambra State, Nigeria by analyzing some suitability factors such as the topographic factors (slope and drainage pattern), soil factors (soil textures), climate factors (temperature and rainfall), and Land use/land cover of the study area. The instruments used include the following hardware: HP Laptop PC and HP Deskjet printer (for plotting of the map on paper). More so, the following software were used; MS Office Word, ArcGIS version 10.8, Global Mapper 18.1 and MS Office Excel. The data sources include existing datasets and published literature accessed online/GIS Lab, Unizik. Geographic Information Systems (GIS) data, including soil maps, land use patterns, and climate data which were obtained from relevant government agencies and research institutions. The data utilized in this research were Sentinel-2 imagery, Tropical Rainfall Measuring Mission (TRMM), Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM), and soil type map covering the study area. The thematic layers for the aforementioned suitability factors of the study area were created in order to assess their individual impact on the suitability of land for rice cultivation. The land suitability map for rice farming in Anambra State was produced using the weighted overlay toolset in GIS, based on the combined analysis of the thematic layers. The research resulted to a comprehensive land suitability map. The findings reveal that a significant portion (49.13%) of the study area is moderately suitable for rice cultivation, with potential for increased output through interventions like irrigation systems and sustainable fertilizer application. Additionally, a substantial percentage (31.32%) of the land is highly suitable, warranting prioritized attention from both public and private investors. The research concludes with a set of comprehensive recommendations based on the result, making it a valuable resource for policymakers, investors, future researchers, etc. to enhance sustainable rice cultivation practices and address food insecurity challenges in Anambra State.

Keywords: Rice Farming, Land Suitability Assessment, GIS, Multi-Criteria Decision Making

1. INTRODUCTION

Rice (Oryza sativa) is a staple food crop of global significance, serving as a primary source of nutrition for over half of the world's population [1]. In Nigeria, rice holds a critical place in the daily diet, making it one of the most important crops for food security and economic livelihoods [2]. Anambra State, situated in the southeastern region of Nigeria, is renowned for its diverse agroecological zones, which present a unique opportunity for rice cultivation. Rice production in Anambra State not only sustains the local population but also contributes significantly to Nigeria's overall rice output.

Anambra State's diverse agroecological zones, including the lowlands and uplands, provide a range of conditions suitable for rice farming [3]. Additionally, the state's network of rivers and streams, including the famous Anambra River, provides water resources essential for rice irrigation.

The importance of rice in Anambra State's agriculture is evident in its contribution to both food security and the state's economy. Rice farming not only provides sustenance for the local population but also offers income-generating opportunities for thousands of farmers in the state [2]. The value chain associated with rice production encompasses various activities, including cultivation, processing, marketing, and distribution, creating employment opportunities and income streams along the way.

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The study aimed at assessing rice farming suitability in Anambra State, Nigeria, using a multi-criteria decision-making process (MCDP).

Rice farming suitability in this context refers to the degree to which a specific area of land in the study area meets the requirements for successful rice cultivation. It encompasses factors such as soil quality, climate conditions, land topography, land availability, and socioeconomic considerations [4].

GIS-based multi-criteria decision-making process was employed to assess the suitability of rice cultivation in the study area. Multi-criteria decision process (MCDP) is a decision support tool that facilitates the simultaneous consideration of multiple criteria and their relative importance in land suitability assessments. It allows for the integration of diverse factors such as named above to determine the suitability of land for a specific purpose [5]. Geographic information systems (GIS) technology aids in the collection, analysis, and visualization of spatial information, enabling the creation of the suitability map [6].

This suitability assessment provides valuable insights into where rice can be grown most effectively, considering a range of factors as earlier mentioned above [6]. By identifying areas with the highest potential for rice cultivation, stakeholders can make informed decisions about resource allocation and land use planning.

By employing a multi-criteria decision process (MCDP), this research endeavors to provide a comprehensive understanding of land suitability and offer practical recommendations for sustainable rice cultivation practices, ultimately contributing to food security, economic growth, and environmental resilience in the state.

The study encompasses Anambra State's geographical boundaries, historical, contemporary, and future temporal considerations, a focus on rice cultivation, and the incorporation of multiple criteria.

The research resulted to a comprehensive land suitability map. The findings reveal that about 49.13% of the study area is moderately suitable for rice farming while 31.32% of the land is highly suitable and 19.55% of the land is marginally suitable. The research concludes with a set of comprehensive recommendations based on the result, making it a valuable resource for policymakers, investors, future researchers, etc to enhance sustainable rice cultivation practices and address food insecurity challenges in Anambra State.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study area, Anambra State, is located in the southeastern region of Nigeria. Anambra State is situated approximately between latitude 5°45'N and 6°45'N and longitude 6°40'E and 7°20'E. It covers an approximate land area of 4,416 square kilometers spreading across 21 Local Government Areas (LGAs) namely: Aguata, Anambra East, Anambra West, Anaocha, Awka North, Awka South, Ayamelum, Dunukofia, Ekwusigo, Idemili North, Idemili South, Ihiala, Njikoka, Nnewi North, Nnewi South, Ogbaru, Onitsha North, Onitsha South, Orumba North, Orumba South, and Oyi. Anambra State is one of the smaller states in Nigeria. It shares borders with several other Nigerian states, including Delta to the west, Enugu to the east, Kogi to the north, and Imo to the south. Anambra State's geographic location places it within the Niger River basin, which has a significant influence on its climate and agricultural potential. The Niger River runs along the western border of the state, providing opportunities for irrigation and access to water resources that are crucial for agriculture in the region. More so, the state is characterized by a mix of rainforest vegetation and savannah. The vegetation cover plays a crucial role in agricultural practices and land suitability. Anambra State has a network of roads, markets, and other infrastructure that influences the accessibility and development of different areas within the state. The economic activities in Anambra State range from agriculture, trade, and commerce to manufacturing. The state is known for its agricultural produce, and rice

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cultivation is of particular interest in this study. Anambra State is home to a diverse population. The demographic composition includes various ethnic groups, and the population density varies across different areas. This location in the southeastern part of Nigeria, with its varied landscape and climate, makes it a suitable and significant study area for assessing land suitability for rice cultivation, particularly considering the state's importance in rice production and its unique agro-ecological characteristics.

The map of the study area is as shown in Fig 2.2 below.

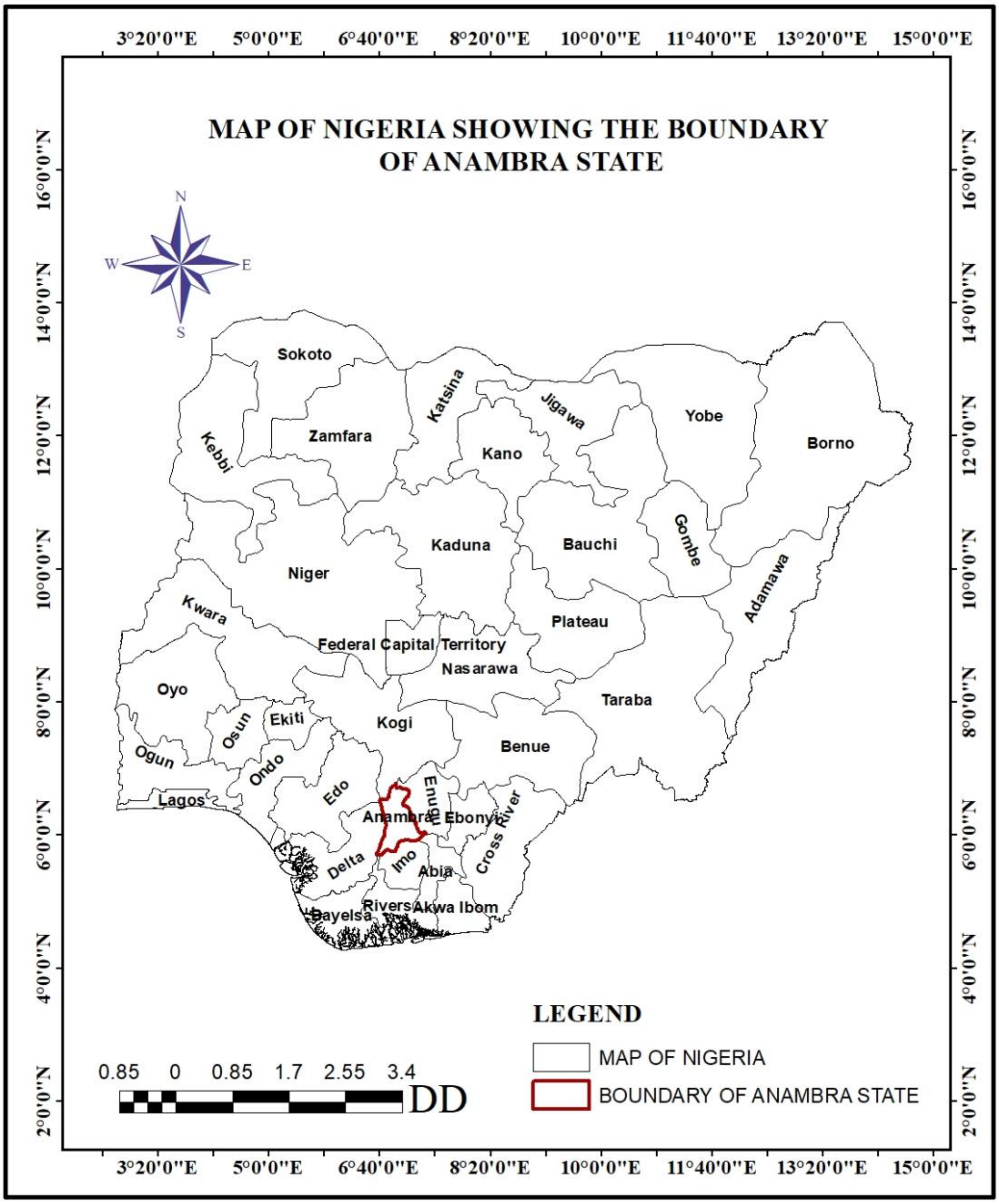

Fig 2.1: Map of Nigeria showing the study area (Anambra State)
Source: *Modified from Administrative Map of Nigeria*

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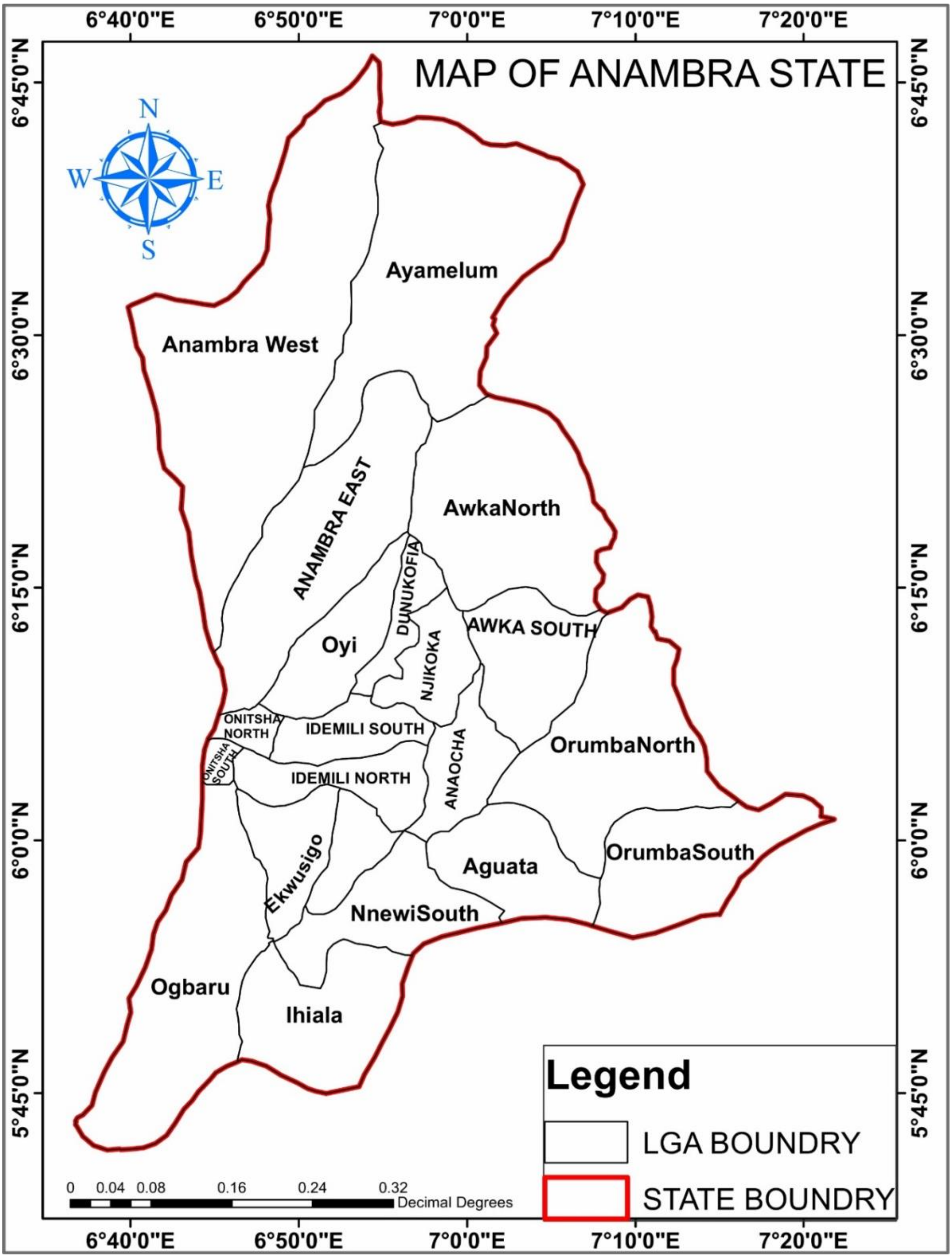

Fig 2.2: Map showing the local gov't areas of the study area (Anambra State)
Source: *Modified from Administrative Map of Nigeria.*

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2.2 Methodology workflow

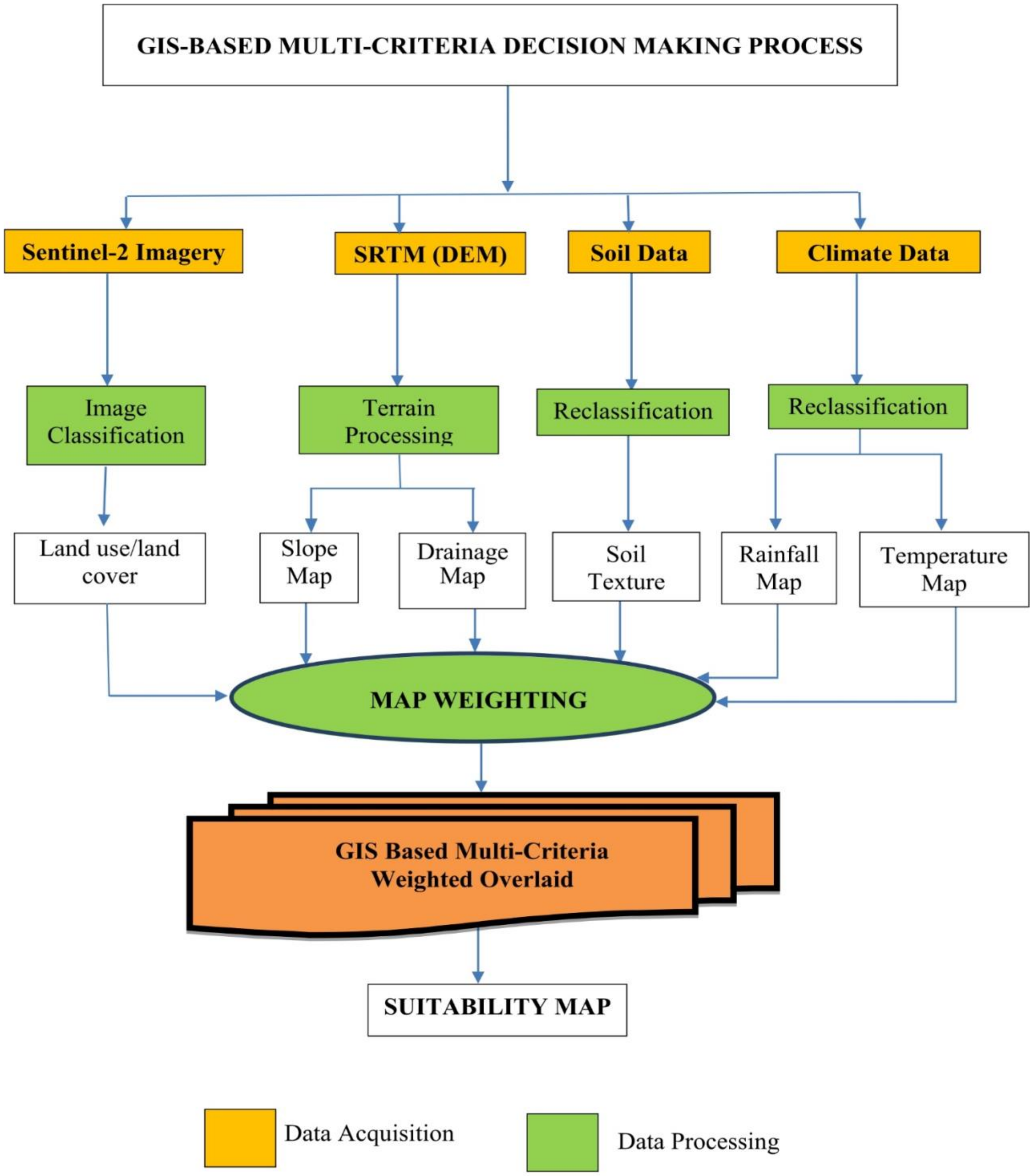

Fig 2.3: Methodology Flowchart
Source: *Author*

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2.3 Materials/equipment used

2.3.1 Hardware

The hardware used in this study includes the following

i. HP Laptop PC: System Properties Processor: Intel(R) Core(TM) i7-3740QM CPU @ 2.70GHz 2.70GHz Installed Memory (RAM):16.0GB System type: 64-bit Operating System, x64-based processor Pen and touch: Touch support with 2 touch points
ii. HP Deskjet printer (for plotting of the map on paper.)

2.3.2 Software

The following software were used to achieve the goal of this project

i. MS Office Word: This software was used for word processing, editing and formatting.
ii. ArcGIS version 10.8: This software was used for the data analysis, processing, data classification and manipulation to produce the suitability map.
iii. Global Mapper 18.1
iv. MS Office Excel: This software was used for statistical analysis.

2.4 Data Collection and Sources

The data sources include existing datasets and published literature online and offline. Geographic Information Systems (GIS) data, including soil maps, land use patterns, and climate data, were obtained from relevant government agencies and research institutions. Existing studies on rice suitability assessments in Nigeria and similar regions provided valuable insights and served as references for the research [4].

The data utilized in this research were Sentinel-2 imagery, Tropical Rainfall Measuring Mission (TRMM), Shuttle Radar Topography Mission(SRTM) Digital Elevation Model (DEM), and soil type map covering the study area.

List of Data	Format	Source
Sentinel-2	Raster	www.earthexplorer.usgs.gov
DEM (SRTM)	Raster	www.earthexplorer.usgs.gov
Nigeria Shapefile	Shapefile	GIS Lab, Department of Surveying and Geoinformatics, NAU
TRMM	Raster	www.earthexplorer.usgs.gov
Soil type map	Raster	https://websoilsurvey.sc.egov.usda.gov/

Table 2.1: Data Types and Sources

2.5 Data Processing and Analysis

GIS technology was employed to integrate and analyze the acquired spatial data. GIS software was used to create suitability maps, overlaying soil quality, climate data, land topography, and land availability information. These maps identified areas suitable and unsuitable for rice cultivation in the study area.

2.5.1 Land use/Land cover

According to the United States Geological Survey (USGS), land use/land cover is defined as "the biophysical pattern of natural and

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human-made features on the Earth's surface." This includes categories such as forests, grasslands, wetlands, urban areas, and agricultural land. Land use/land cover data is used for various purposes, including urban planning, natural resource management, and environmental monitoring.

Sentinel-2 classified image as shown in Fig 2.5 below which was sourced from GIS Lab, Department of Surveying and Geoinformatics, UNIZIK (originally sourced from www.earthexplorer.usgs.gov) was used to produce the Land use and land cover map of the study area.

Sentinel-2 (S2) systematically acquires optical imagery and provides global monitoring data with high spatial resolution (10–60 m) images. Sentinel-2 data as used for this project is more recommended than Landsat images because it provides a slightly higher spatial resolution, allowing for more detailed and accurate analysis of land cover and land use. Additionally, Sentinel-2 has a higher revisit frequency, which means that it can capture more frequent and up-to-date images of the Earth's surface. [7].

To produce the land use/land cover map from the sentinel-2 already classified image, it was reclassified as stated in the procedure below.

Classification procedure

Though this stage was by-passed because the acquired data had already been classified, the following are the standard procedures commonly used in the field of remote sensing and GIS.

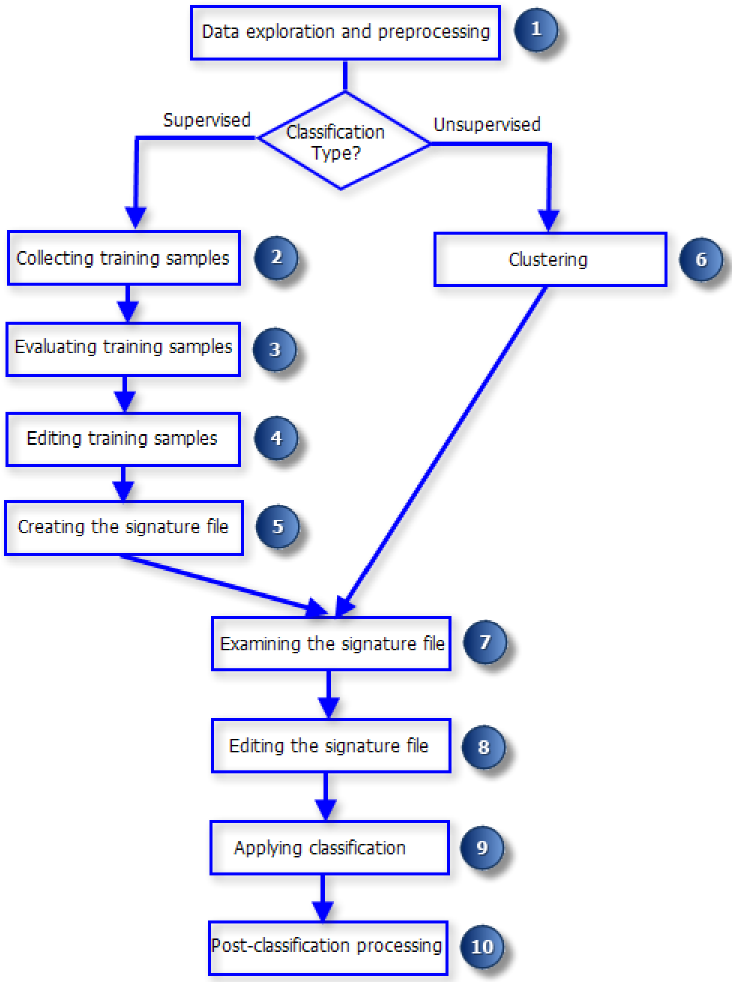

Fig 2.4: Image classification procedure in ArcGIS

Source: *ArcGIS Desktop/ArcMap 10.8 Help archive; https://desktop.arcgis.com/en/arcmap/latest/extensions/spatial-analyst/image-classification/image classification-using-spatial-analyst.htm*

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1. Import the Sentinel-2 image into ArcMap.
2. Image enhancement (Preprocess the image): Before classification, it is important to preprocess the Sentinel-2 image. This may include steps such as atmospheric correction, radiometric calibration, and image enhancement to improve the quality of the image for classification.
3. Choose a classification method: Select a classification method based on the specific objectives of your project. Common methods include supervised classification (e.g., maximum likelihood, random forest) and unsupervised classification (e.g., K-means clustering).
4. Collect training samples: For supervised classification, collect representative training samples for each class of interest within the Sentinel-2 image. These training samples will be used to train the classification algorithm to recognize different land cover or land use classes.
5. Perform the classification: Use the chosen classification method to classify the Sentinel-2 image into different land cover or land use classes based on the training samples and spectral characteristics of the image.
6. Evaluate the classification results: Assess the accuracy of the classification by comparing the classified image to ground truth data or validation samples. This step helps to validate the reliability of the classification results.
7. Refine and finalize the classification: Based on the evaluation, refine the classification if necessary and finalize the classified image for further analysis and visualization in your project.

Reclassification procedure

Reclassifying the Sentinel-2 Image in ArcMap 10.8, the steps employed are as followed:

1. Add Data: Import the Sentinel-2 image into ArcMap by clicking the "Add data  " icon on the menu bar. The added data is as shown in fig 2.5 below.
2. Open the Reclassify tool: Navigate to the Spatial Analyst Tools in the ArcToolbox, and open the Reclassify tool.
3. Select the input raster: Choose the Sentinel-2 image as the input raster for the Reclassify tool.
4. Define the reclassification scheme: In the Reclassify tool, define the reclassification scheme by specifying

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the input ranges and the corresponding output values for each class. Use the standard class names for reclassification (e.g., water, forest, urban, etc.). To replicate the colors and class names, the class definition is given hereafter

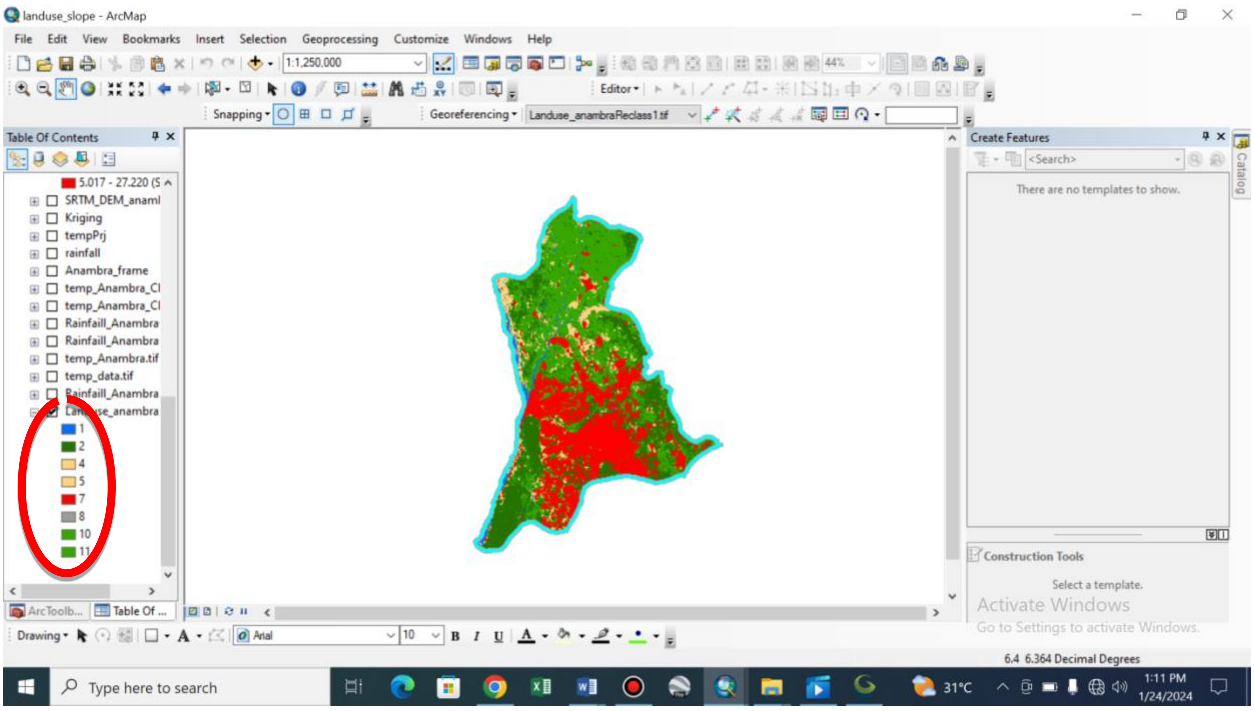

Fig 2.5: Classified sentinel-2 image
Source: *GIS Lab, Department of Surveying and Geoinformatics, UNIZIK*

Class definitions
The numbering corresponds with the class values encircled in fig 3.4 above. [8].

- 1 = Water

  Areas where water was predominantly present throughout the year; may not cover areas with sporadic or ephemeral water; contains little to no sparse vegetation, no rock outcrop nor built up features like docks; examples: rivers, ponds, lakes, oceans, flooded salt plains.

- 2 = Trees

  Any significant clustering of tall (~15-m or higher) dense vegetation, typically with a closed or dense canopy; examples: wooded vegetation, clusters of dense tall vegetation within savannas, plantations, swamp or mangroves (dense/tall vegetation with

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ephemeral water or canopy too thick to detect water underneath).

- 4 = Flooded vegetation

  Areas of any type of vegetation with obvious intermixing of water throughout a majority of the year; seasonally flooded area that is a mix of grass, shrub, trees and bare ground; examples: flooded mangroves, emergent vegetation, rice paddies and other heavily irrigated and inundated agriculture.

- 5 = Crops

  Human planted/plotted cereals, grasses, and crops not at tree height; examples: corn, wheat, soy, fallow plots of structured land.

- 6 = Built Area

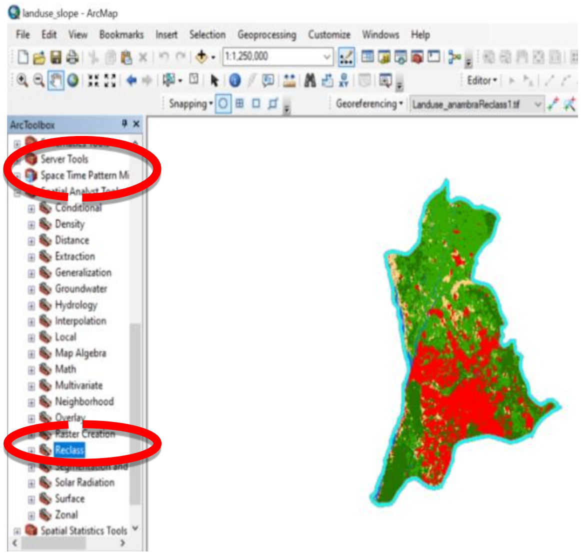
  Human made structures; major road and rail networks; large homogenous impervious surfaces including parking structures, office buildings and residential housing; examples: houses, dense villages / towns / cities, paved roads, asphalt.

- 7 = Bare ground

  Areas of rock or soil with very sparse to no vegetation for the entire year; large areas of sand and deserts with no to little vegetation; examples: exposed rock or soil, desert and sand dunes, dry salt flats/pans, dried lake beds, mines.

- 8 = Snow/Ice

  Large homogenous areas of permanent snow or ice, typically only in mountain areas or highest latitudes; examples:



  glaciers, permanent snowpack, snow fields.

- 9 = Clouds

  No land cover information due to persistent cloud cover.

- 10 = Rangeland

  Open areas covered in homogenous grasses with little to no taller vegetation; wild cereals and grasses with no obvious human plotting (i.e., not a plotted field); examples: natural meadows and fields with sparse to no tree cover, open savanna with few to no trees, parks/golf courses/lawns, pastures. Mix of small clusters of plants or single plants dispersed on a landscape that shows exposed soil or rock; scrub-filled clearings within dense

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forests that are clearly not taller than trees; examples: moderate to sparse cover of bushes, shrubs and tufts of grass, savannas with very sparse grasses, trees or other plants.

5. Output the reclassified raster: Run the Reclassify tool to create the reclassified raster based on the defined reclassification scheme.

Fig 2.6: reclassifying process into 4 classes

6. Symbolize the reclassified raster: Symbolize the reclassified raster using the standard class names to visually represent the different land cover or land use classes.

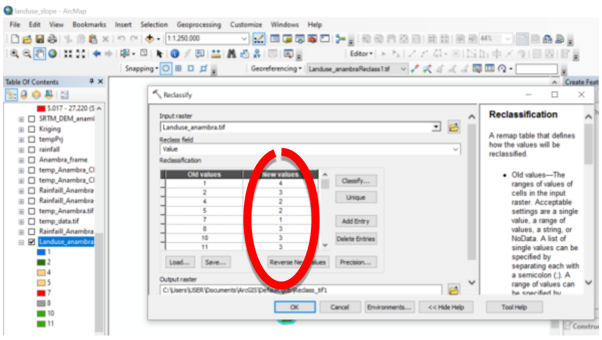

Fig 2.7: Reclassify dialog box showing the new class values

7. Save the reclassified raster: Save the reclassified raster to a location of your choice for further analysis and visualization in your project.

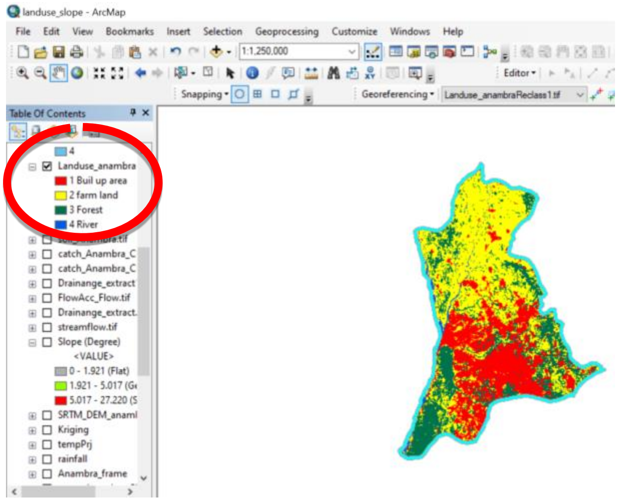

Fig 2.8: Reclassified land use/land cover map of the study area

2.5.2 Slope operation

The Slope tool in Arcmap identifies the steepness at each cell of a raster surface. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain.

Steps employed to produce the slope of the study are stated below:

1. Obtain SRTM data from a reliable source such as the USGS Earth Explorer or NASA Earthdata.
2. Import the SRTM data into ArcMap using the "Add Data" button and selecting the downloaded SRTM file as shown in fig 2.9.
3. Preprocess the SRTM data by filling any voids or holes using the "Fill" tool in the Spatial Analyst toolbox.
4. Use the "Slope" tool in the Spatial Analyst toolbox to calculate the slope

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from the SRTM elevation data as shown in fig 2.10.

5. Customize the slope map by adjusting the symbology and reclassify into 3 ranks of degree as shown in. fig 2.12.
6. Save the slope map as a new layer or export it as an image for further use. See fig 2.13.

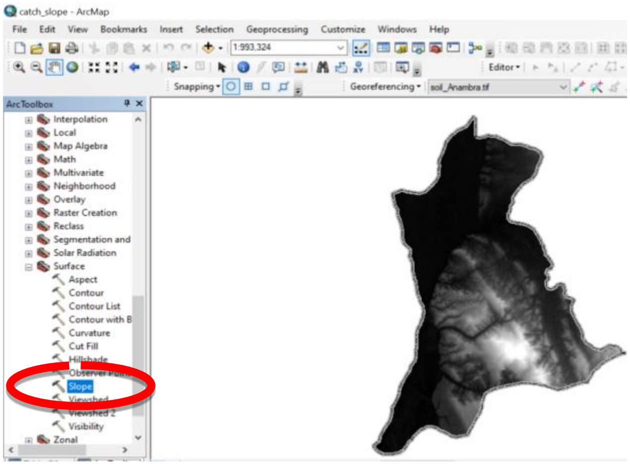

Fig 2.9: SRTM data of the study area
Data Source: [*https://ers.cr.usgs.gov/login?RET_ADDR=https%3A%2F%2Fearthexplorer.usgs.gov%2Forder%2F*](https://ers.cr.usgs.gov/login?RET_ADDR=https%3A%2F%2Fearthexplorer.usgs.gov%2Forder%2F)

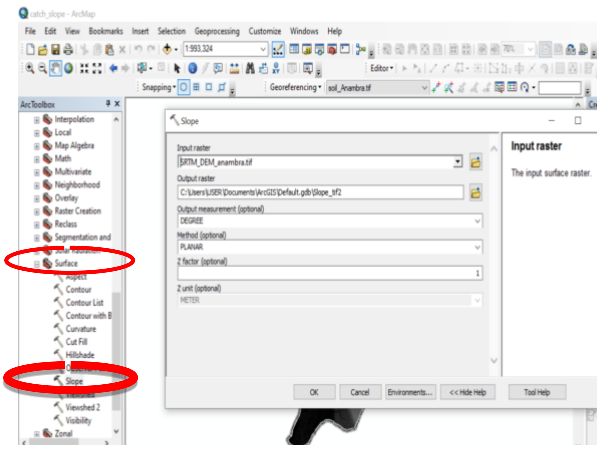

Fig 2.10: Slope calculation in Arcmap 10.8

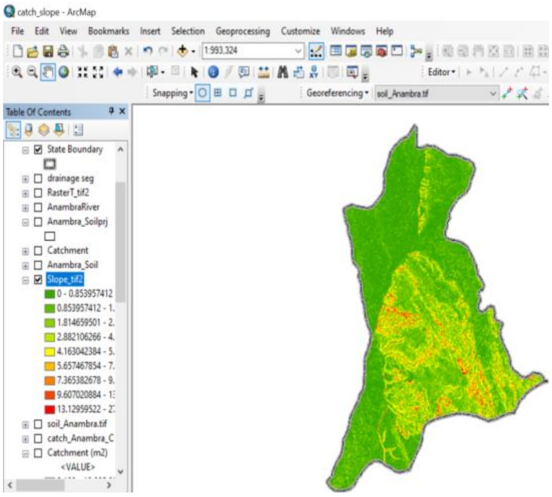

Fig 2.11: Distribution of range of slopes in degrees

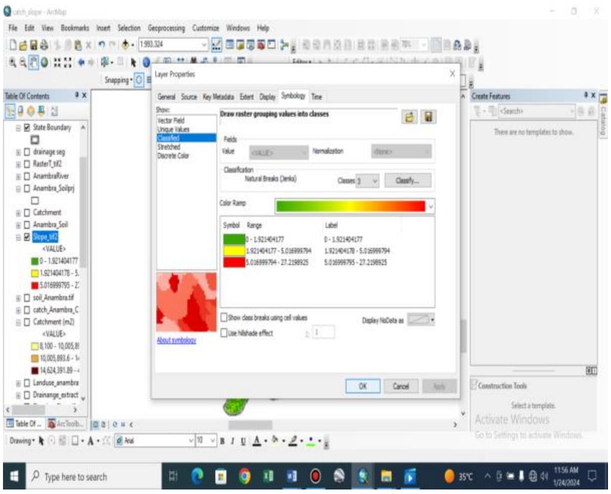

Fig 2.12: Reclassified slope into 3 ranks of degree

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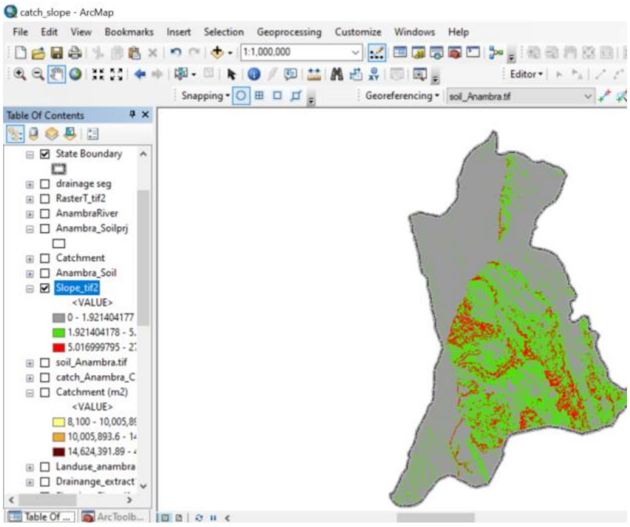

Fig 2.13: Slope map result of the study area

2.5.3 Catchment/Drainage operation (done in global mapper) procedure

A catchment, or drainage basin, is defined as an area that collects precipitation and drains it into a network of water channels. This network often drains into a larger outlet, such as a river, reservoir, or body of water. Catchments are usually open systems and precipitation and other materials flow freely into and out of the system. The surface topography of an area determines the size of a catchment area. A catchment area is bound by raised natural features, such as hills or mountains, off which precipitation flows into a drainage network in an area of depression. Large catchments can be composed of smaller sub-catchments. Sub-catchments feed tributaries, which are small streams that feed larger streams or rivers. *(https://energyeducation.ca/encyclopedia/Catchment).*

Global Mapper was used instead of ArcMap for the catchment mapping due to its user-friendly interface, cost-effectiveness, built-in tools for watershed analysis among other reasons.

To produce the catchment map using SRTM data in Global Mapper, the following steps were taken:

1. Download SRTM data for the area of interest from a reliable source such as USGS Earth Explorer.
2. Open Global Mapper and load the SRTM data.
3. Use the "Create Watershed" tool under the Analysis menu to delineate the catchment area based on the SRTM data.
4. Adjust the parameters for the watershed delineation, such as the flow accumulation threshold and the minimum area for a catchment.
5. Once the watershed delineation is complete, further analyze and visualize the catchment area using the various tools and options available in Global Mapper.

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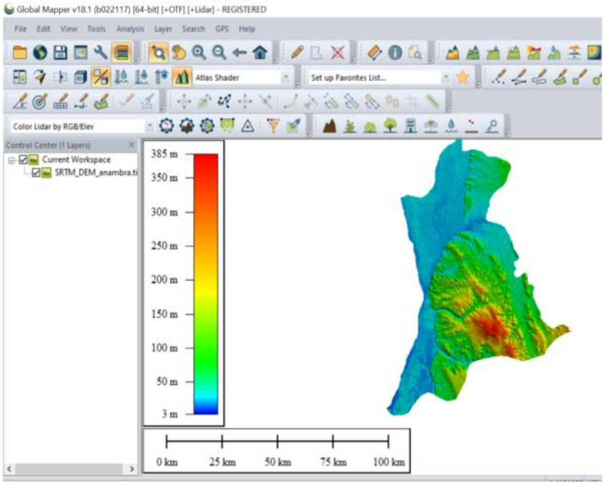

Fig 2.14: SRTM data of the study area

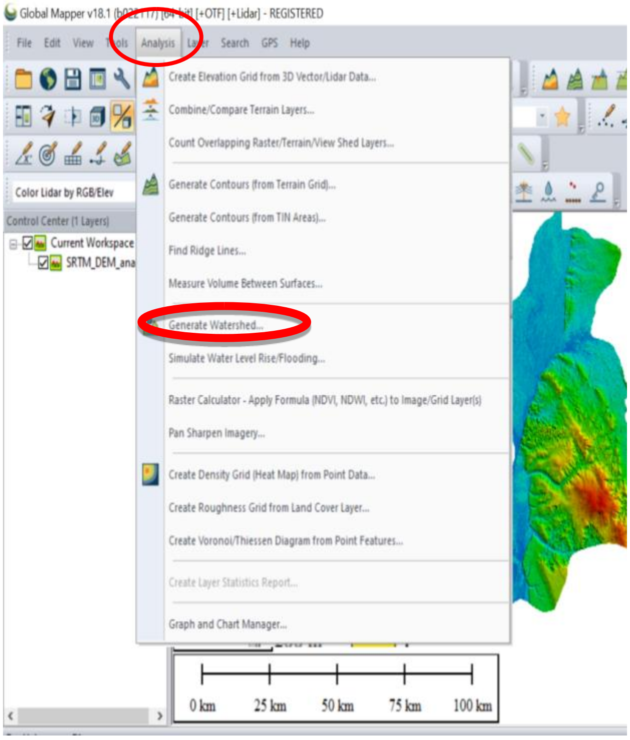

Fig 2.15: Watershed calculation in Global Mapper

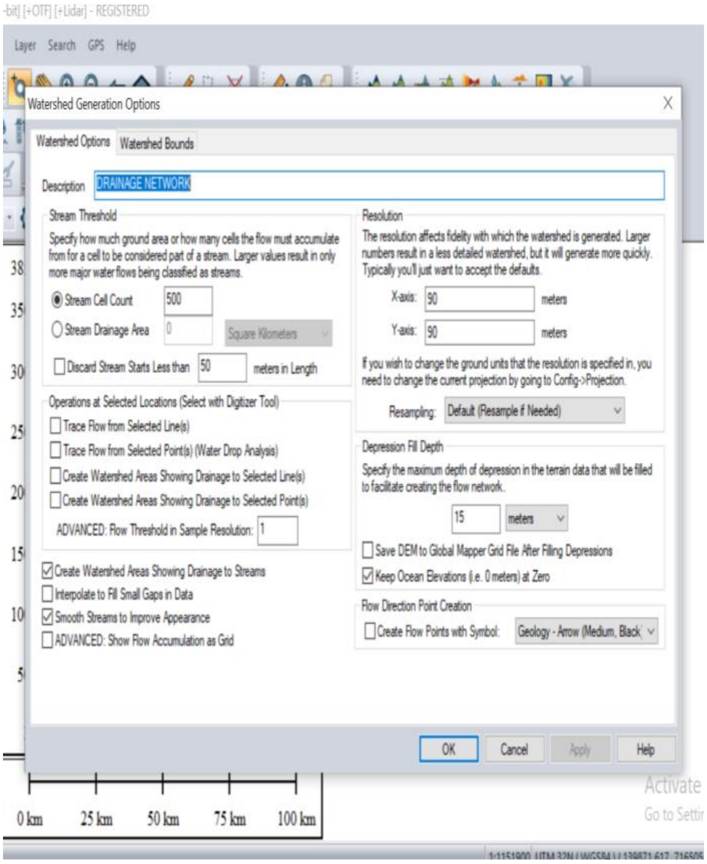

Fig 2.16: Watershed options' dialog box

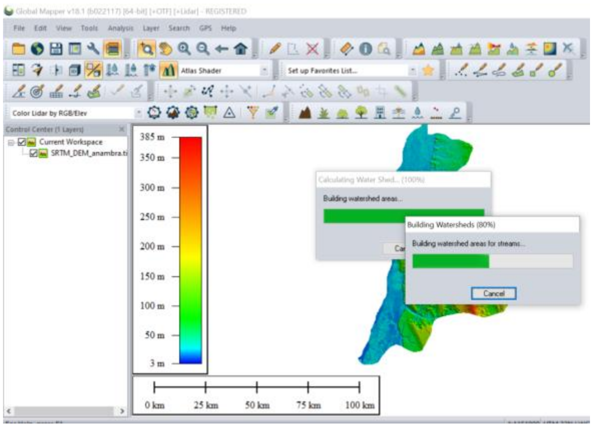

Fig 2.17: Calculating water sheds and building watersheds

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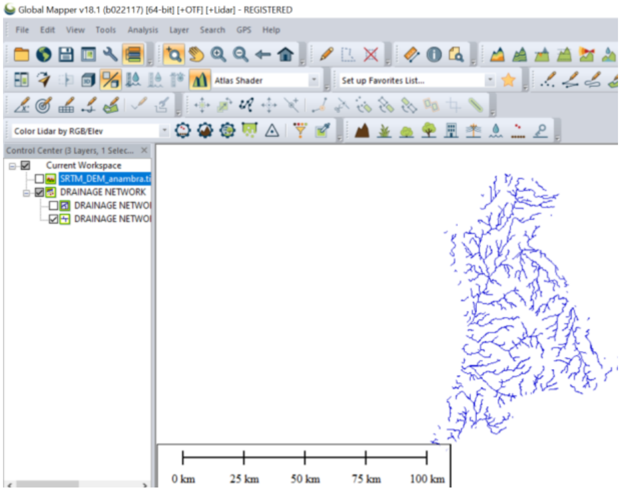

Fig 2.18: Drainage

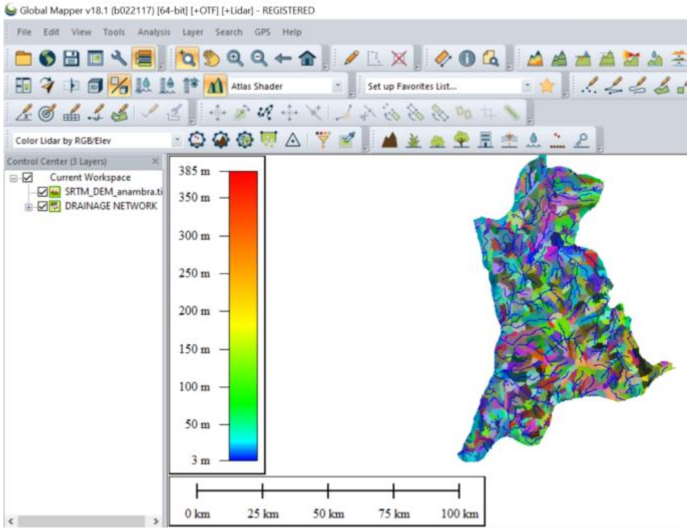

Fig 2.20:Overlay of the watershed

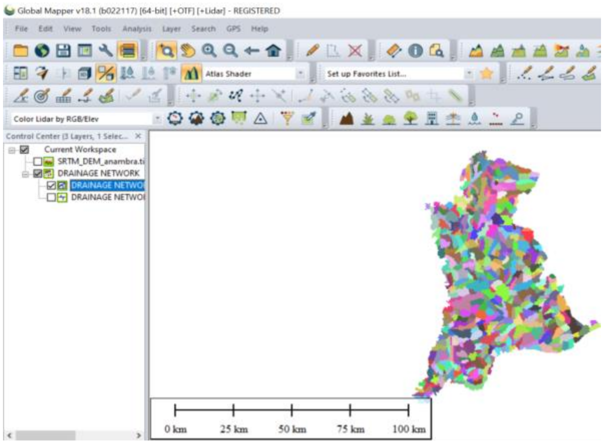

Fig 2.19: Watershed calculation in Global Mapper

2.5.4 Suitability Map Creation

Map weighting/Weighted overlay

The Weighted Overlay tool applies one of the most used approaches for overlay analysis to solve multi-criteria problems such as site selection and suitability models. In a weighted overlay analysis, each of the general overlay analysis steps is followed. *(https://desktop.arcgis.com/en/arcmap/latest/tools/spatial-analyst-toolbox/how-weighted-overlay-works.htm)*

For the map weighting, each value class in each input raster (catchment, LULC, Rainfall, Slope and Temperature data) is assigned a new, reclassified value on an evaluation scale of 1 to 3, where 1 represents the lowest suitability and 3 the highest.

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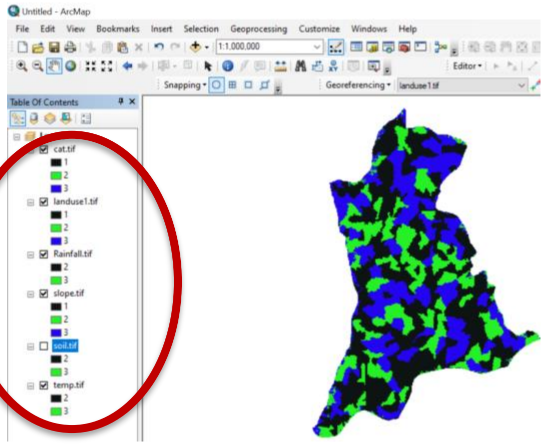

Fig 2.21: Overlay of all the themes

Steps:

Weighted overlay is one method of modeling suitability. ArcGIS uses the following process for this analysis. *(https://www.esri.com/about/-newsroom/arcuser/understanding-weighted-overlay/)*

1. Each raster layer is assigned a weight in the suitability analysis.
2. Values in the rasters are reclassified to a common suitability scale.
3. Raster layers are overlayed, multiplying each raster cell's suitability value by its layer weight and totaling the values to derive a suitability value as shown in fig 20 above.
4. These values are written to new cells in an output layer.
5. The symbology in the output layer is based on these values.

Assigning a weight to each raster in the overlay process helped in controlling the influence of different criteria in the suitability model.

Pictorially, the steps taken to produce the final suitability map as follows:

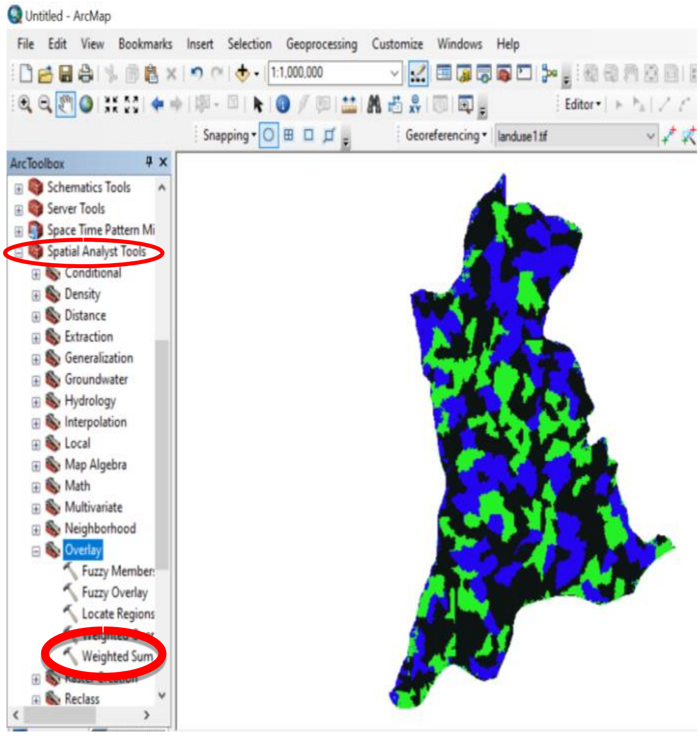

Fig 2.22: Weighted sum

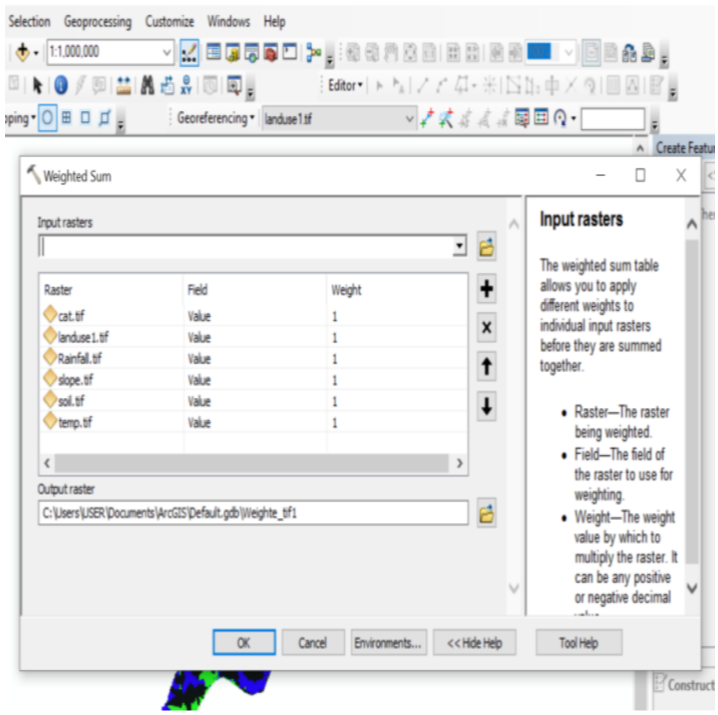

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Fig 2.23: Suitability map calculation

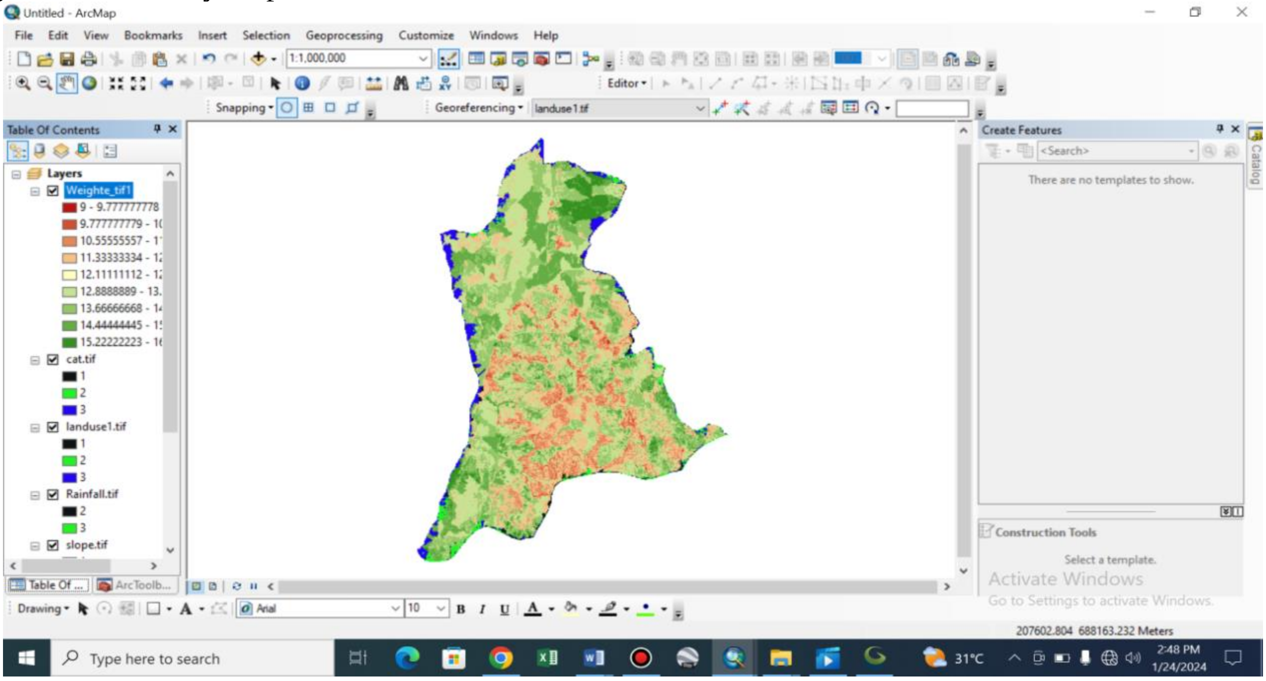

Fig 2.24: Overlay of suitability map on the themes.

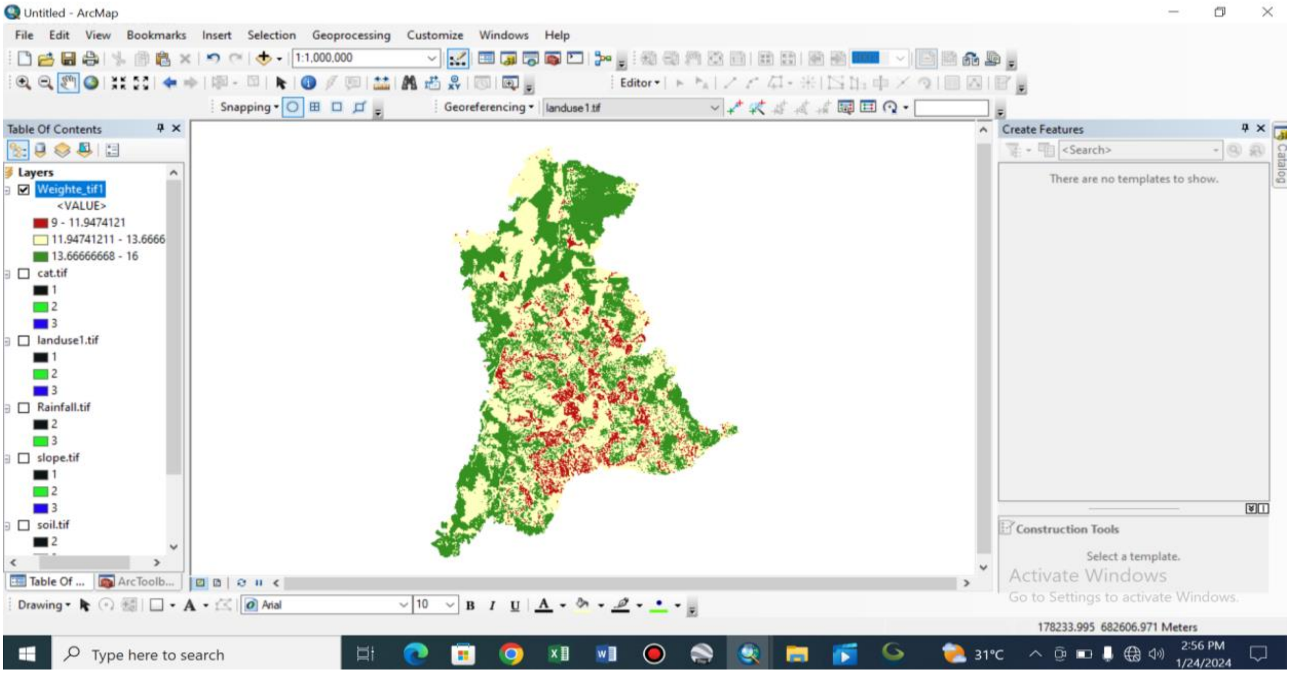

Fig 2.25: Suitability map result

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3.0 RESULTS

3.1 Suitability factors

S/N	Suitability Parameters	1 Low suitability	2 Medium suitability	3 High suitability
1	Land use/land cover	1284166600m2 Built up Area	1156884800m2 Forest	96907600m2 River 2054582100m2 Farmland
2	Catchment	8,000-10,000m2	10,000-14,000m2	14,000-40,000m2
3	Slope	5-27° (Steep)	1.9-5° (Gentle)	0-1.9°(Flat)
4	Rainfall	1400mm_1500mm	1500mm_1700mm	1700mm_1900mm
5	Temperature	13-13.6◦C(Warm)	12-13◦C (Cool)	11.5-12◦C (Coolest)
6	Soil Texture	NIL	Sandy Loam, Sandy Clay	Silty Loam

Table 3.1: Suitability Factors

3.1.1 Landuse/ landcover

According to Natural Resource Canada, although the terms land cover and use are often used interchangeably, their actual meaning is quite distinct. Land cover refers to the surface on the ground, while land use refers to the purpose which the land serves. The Land use/land cover of the map of the area was derived from layer stack of band 5, 4, and 3 in ArcGIS 10.8 composite banding toolset in Data Management tool, which was reclassified using maximum Likelihood Classification Method in the same software.

Land use/land cover statistical analysis:

- Land use/land cover percentage of the study area

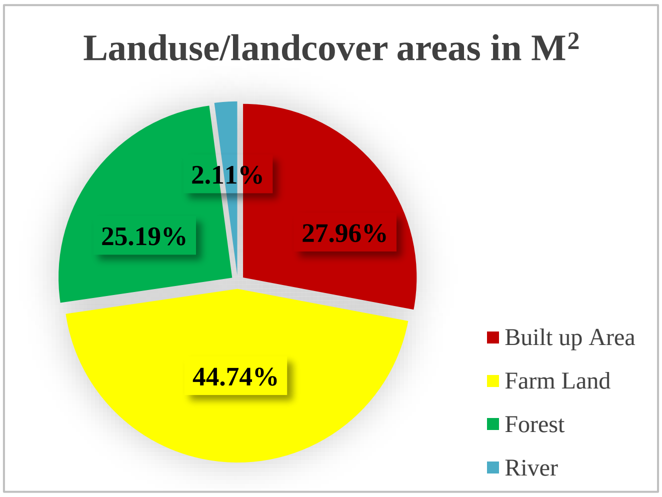

Fig 3.1a: A pie chart showing Land use/land cover percentage of Anambra State

- Land use/land cover Areas of the study area.

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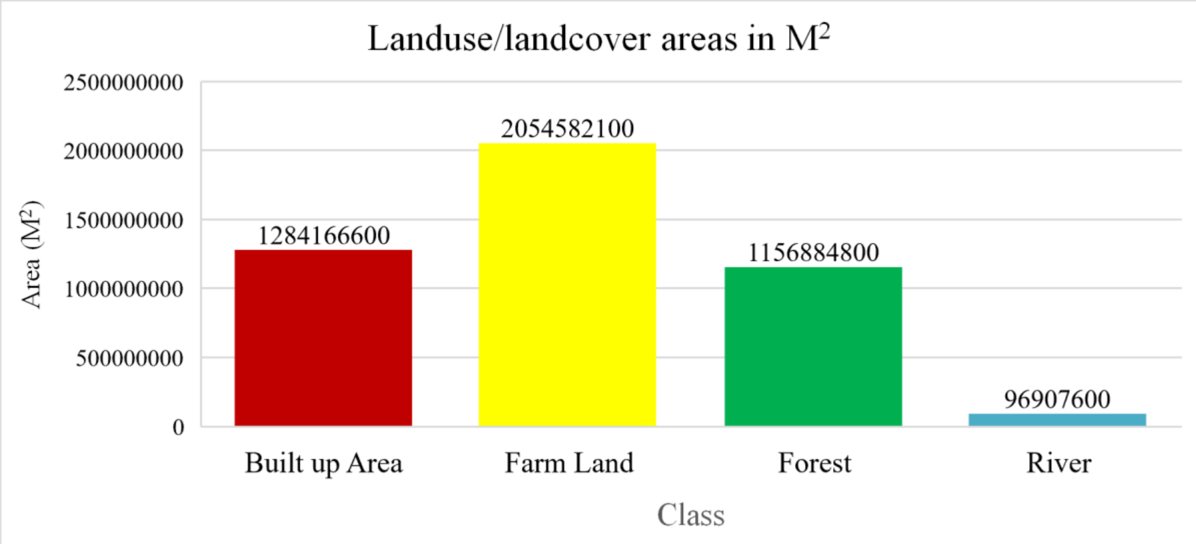

Fig 3.1b: A bar chart showing Land use/land cover Areas of Anambra State

The result shows that the low suitability part of the research area is made up of the built up area of the state with an area of 1284166600m2 which is 27.96% of the total area. While the medium suitability and high suitability parts are made up of the forest and river/farm land with the areas of 1156884800m2 and 96907600m2/2054582100m2 respectively.

In nutshell, it was discovered that aside the built up area, rice farming can thrive in about 72.04% of the research area which consist of the medium suitability and high suitability areas in every local government within Anambra State. The total area of the state that is highly suitable for rice farming according to this suitability factor (2151489700m2) is 46.85%of the whole research area while the medium suitability area (1156884800m2) is made up of 25.19% of the research and may be enhanced for better yield of crops such as rice.

The thematic map of the land use/land cover map of the research area is presented in Figure 3.2 below.

3.1.2 Catchment/Drainage

Drainage density is the total length of all the streams and rivers in a drainage basin divided by the total area of the drainage basin. It is a measure of how well or how poorly a watershed is drained by stream channels. The Drainage density map of the area is as shown in Figure 3.4 below.

It was discovered in the cause of this research that the study area has a catchment area of 10,000-14,000m2 and 14,000-40,000m2 which happened to be the medium suitability and high suitability parts respectively. The low suitability area has a catchment of 8,000-10,000m2. The result shows that Anambra State has a high catchment ability which makes

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Vol. 11 Issue 03
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it suitable for agricultural crops cultivation such as rice farming.

3.1.3 Slope

The **s**lope or gradient of a line is a number that describes both the direction and the steepness of the line. The slope of the area was generated using the Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model, it was reclassified, and the result is as shown in Figure 2.12.

The low suitability area has a Steep slope of 5-27° while the medium suitability and high suitability areas have gentle slope of 1.9-5°and flat slope of 0-1.9°respectively. This shows that Anambra State do not have much steep slope; hill, mountain, etc. It also points out that rice farming is best practiced where the land is flat because it ensures even water distribution (high catchment).

3.1.4 Climate factors: rainfall &temperature

Climate has a significant influence growth of crops, developments and yields of agricultural crops including rice, favorably or unfavorably. Temperature and rainfall are the two most important climatic elements considered in this study. Rice is a tropical and sub-tropical crop which is normally grown at a fairly high temperature – high rainfall regime, ranging from20 to 40°C and 1250mm to 2000mm of annual rainfall . The results shows that the Temperature and Rainfall of the area are favorable.

The thematic maps of these factors (Rainfall and Temperature) are all presented below as in fig 3.7a and fig 3.7b respectively.

3.1.5 Soil texture

Figure 4.4 shows the result of the study area soil texture. Soil Texture is the level of coarseness of the soil, and rice being a Tropical crop, requires a soil texture that can retain water for a longer period, according to the classification of soil suitability for rice by [9]. The Study area has 3 soil classification which is Sandy Loamy, Sandy Clay and Silty Loam. These soil textures are better for rice cultivation.

3.2 Thematic Layers Created In Order To Assess Their Individual Impact On The Suitability Of Land For Rice Cultivation

The following are thematic layers for Land use/land cover, slope, drainage density, soil texture, and climate factors were created in order to assess their individual impact on the suitability of land in Anambra State for rice cultivation as earlier discussed above:

3.2.1 Land use/ land cover

The thematic map of the study area is as shown bellowed.

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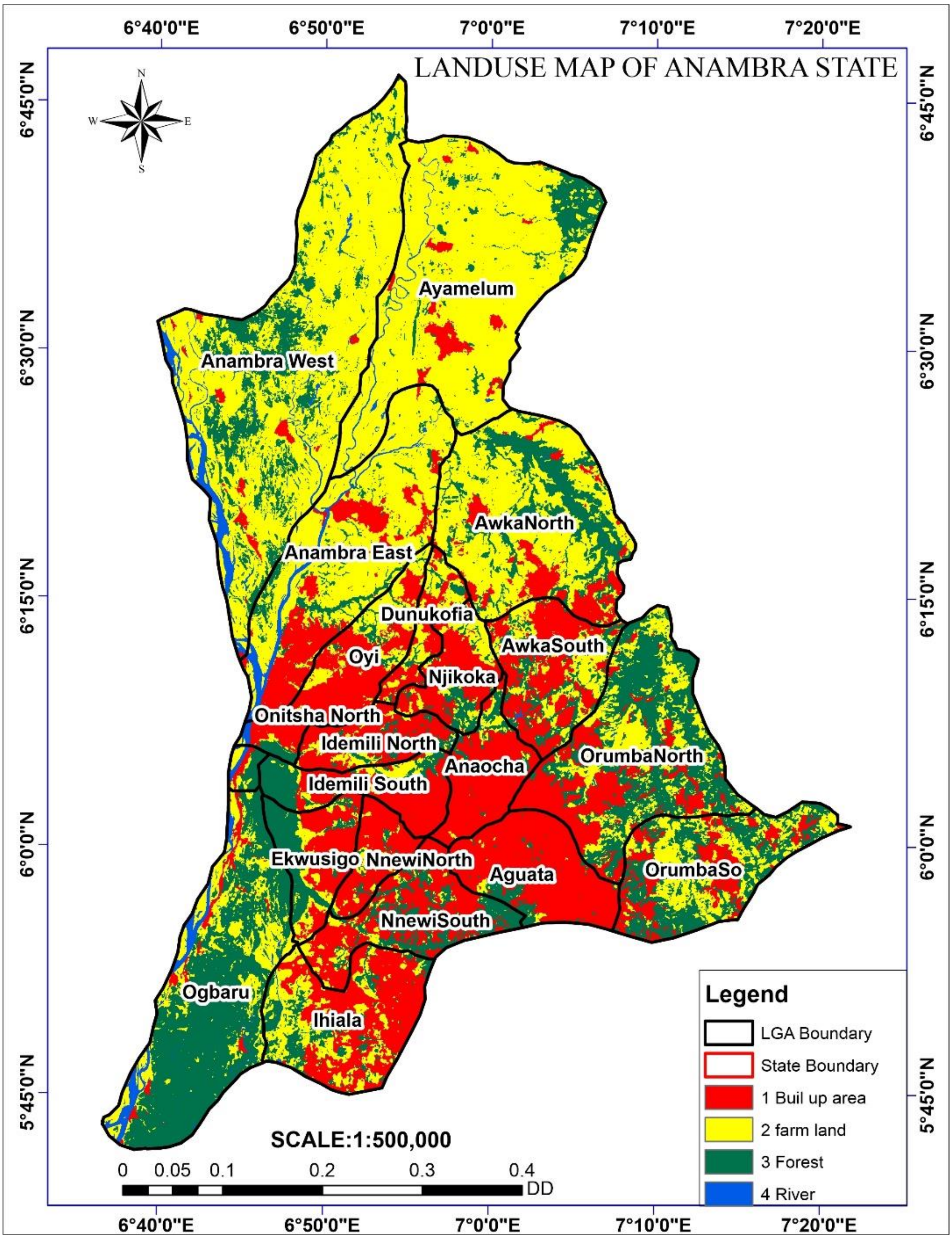

Fig 3.2: Land use/land cover Map of Anambra State

3.2.2 Slope

The slope map of the research area obtained is presented as follow.

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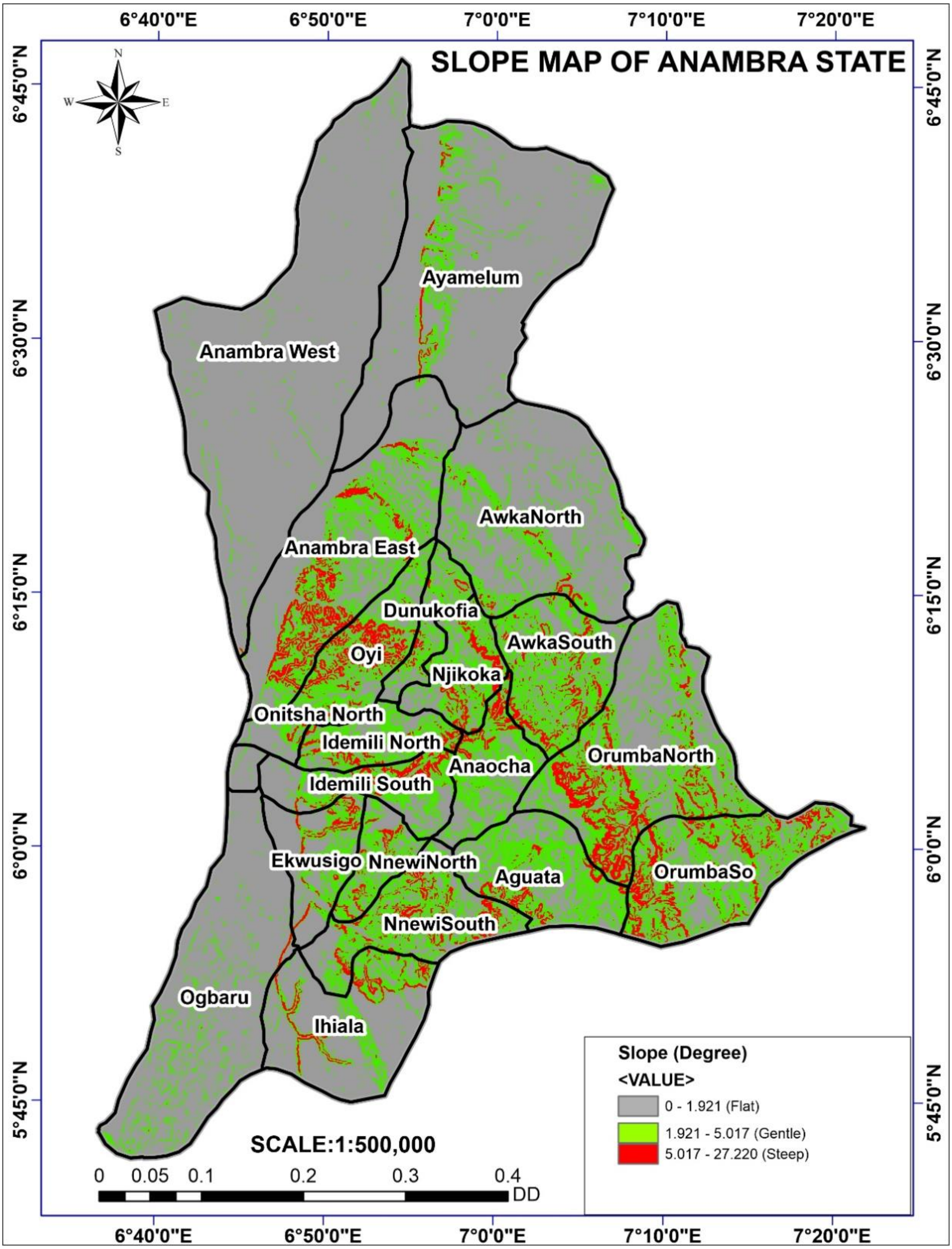

Fig 3.3: Slope Map of the Study Area

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Vol. 11 Issue 03
March 2024

3.2.3 Drainage density/catchment

The drainage density and catchment maps of the research are as shown below

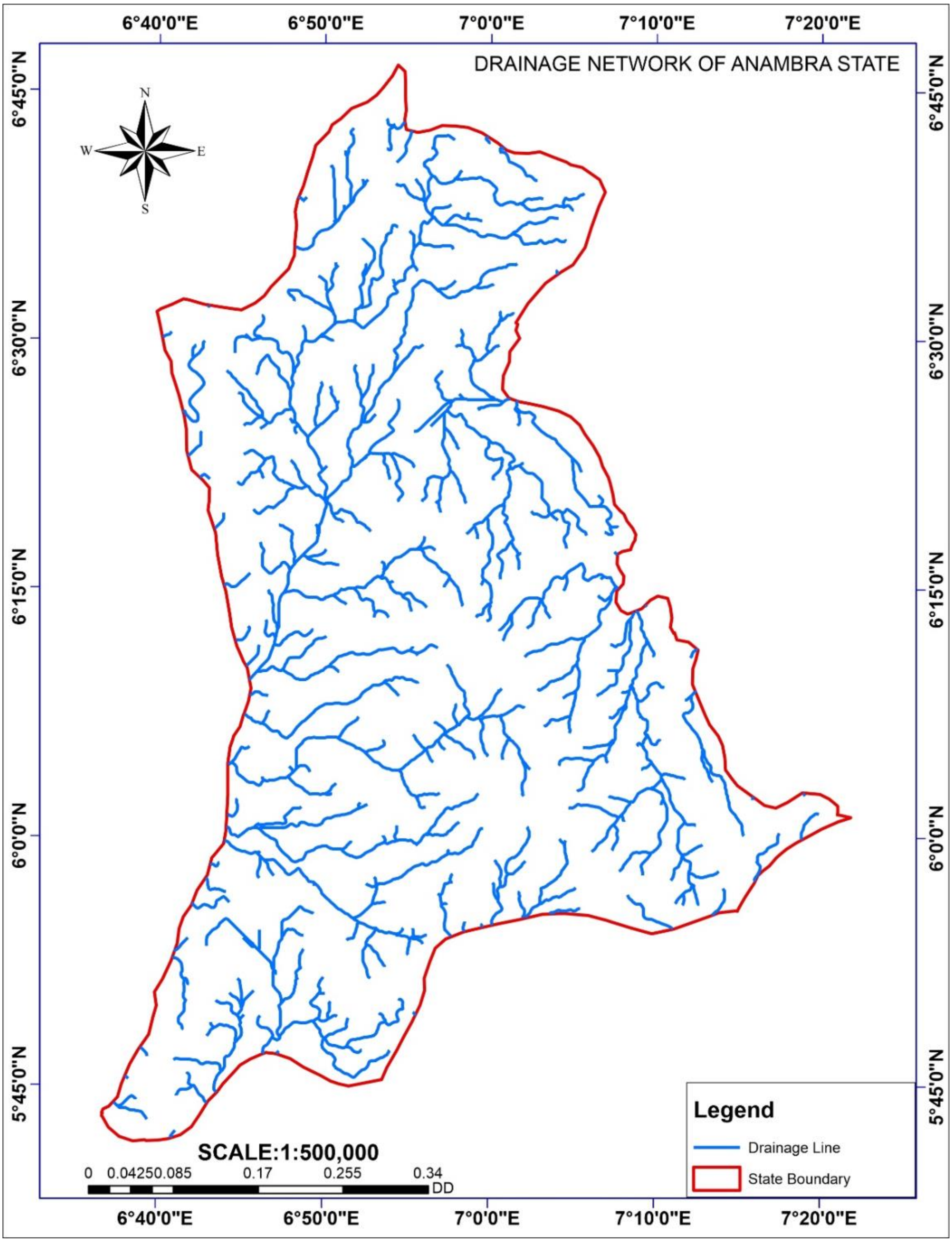

Fig 3.4: Drainage Density Map of the Study Area

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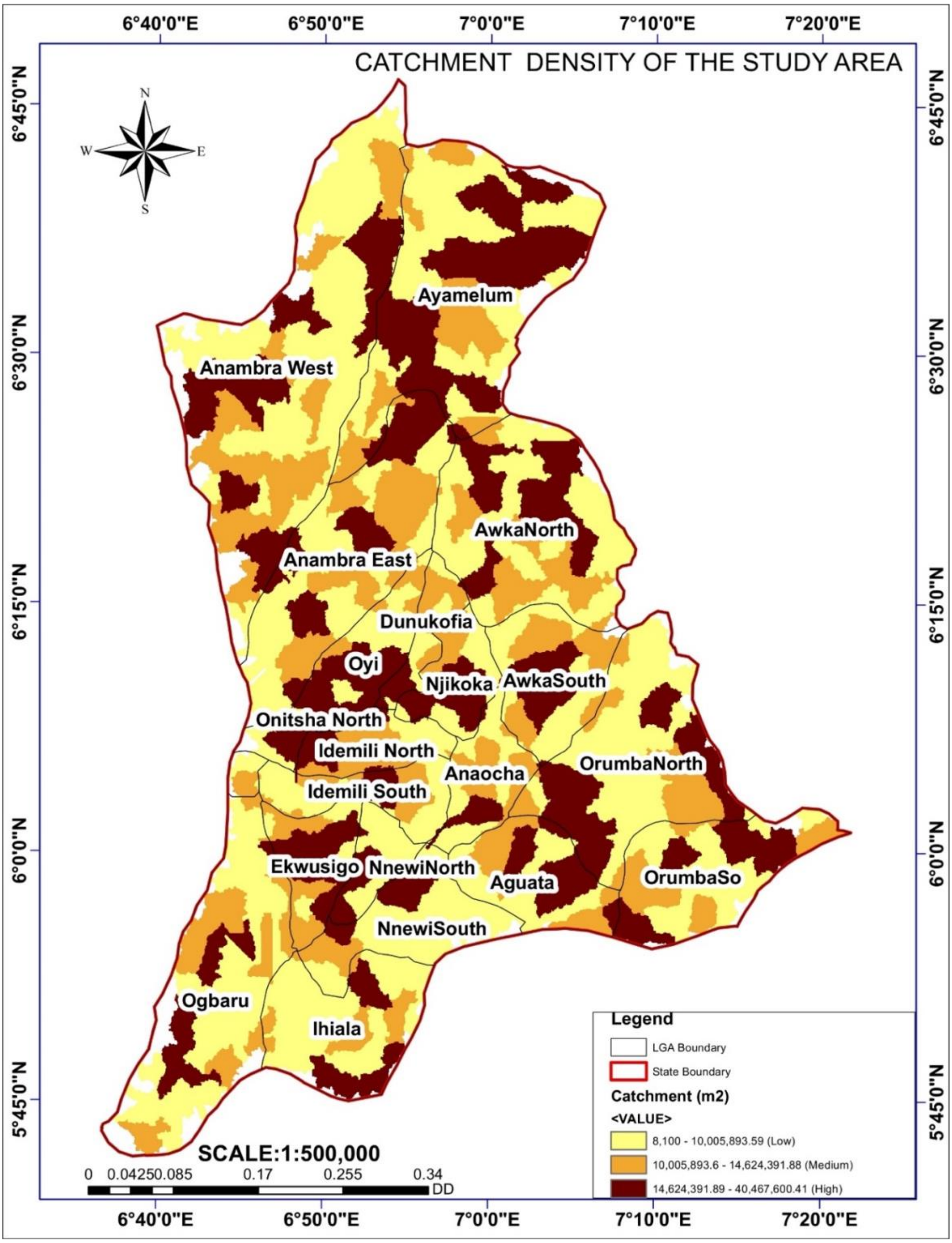

Fig 2.5: Catchment Map of the Study Area

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Vol. 11 Issue 03
March 2024

3.2.4 Soil Texture

The map below shows the soil texture of the study area.

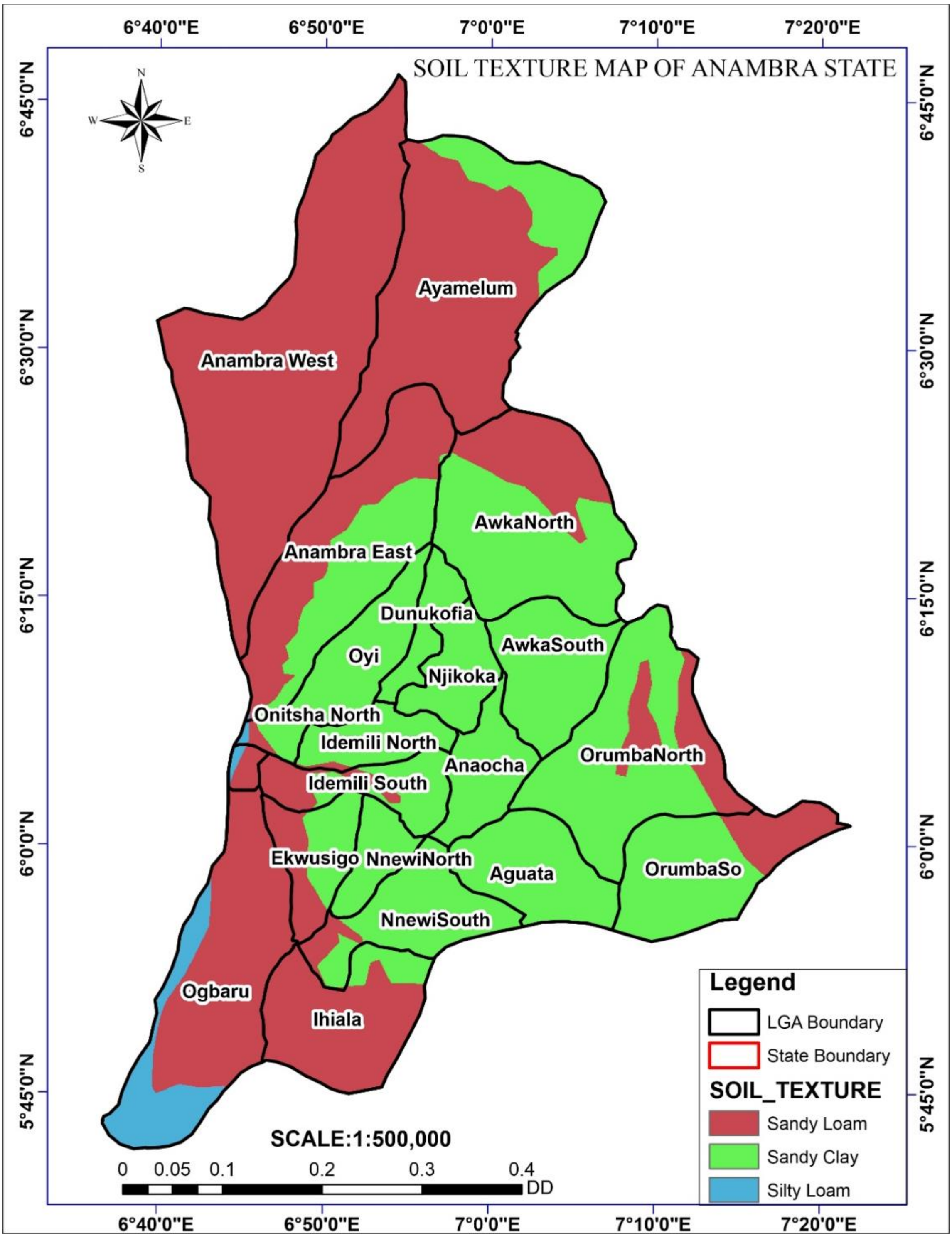

Fig 3.6: Soil Texture Map of the Study Area.

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Vol. 11 Issue 03
March 2024

3.2.5 Climate Factor

The maps of the two climatic factors (Rainfall and Temperature) considered in this research are presented below.

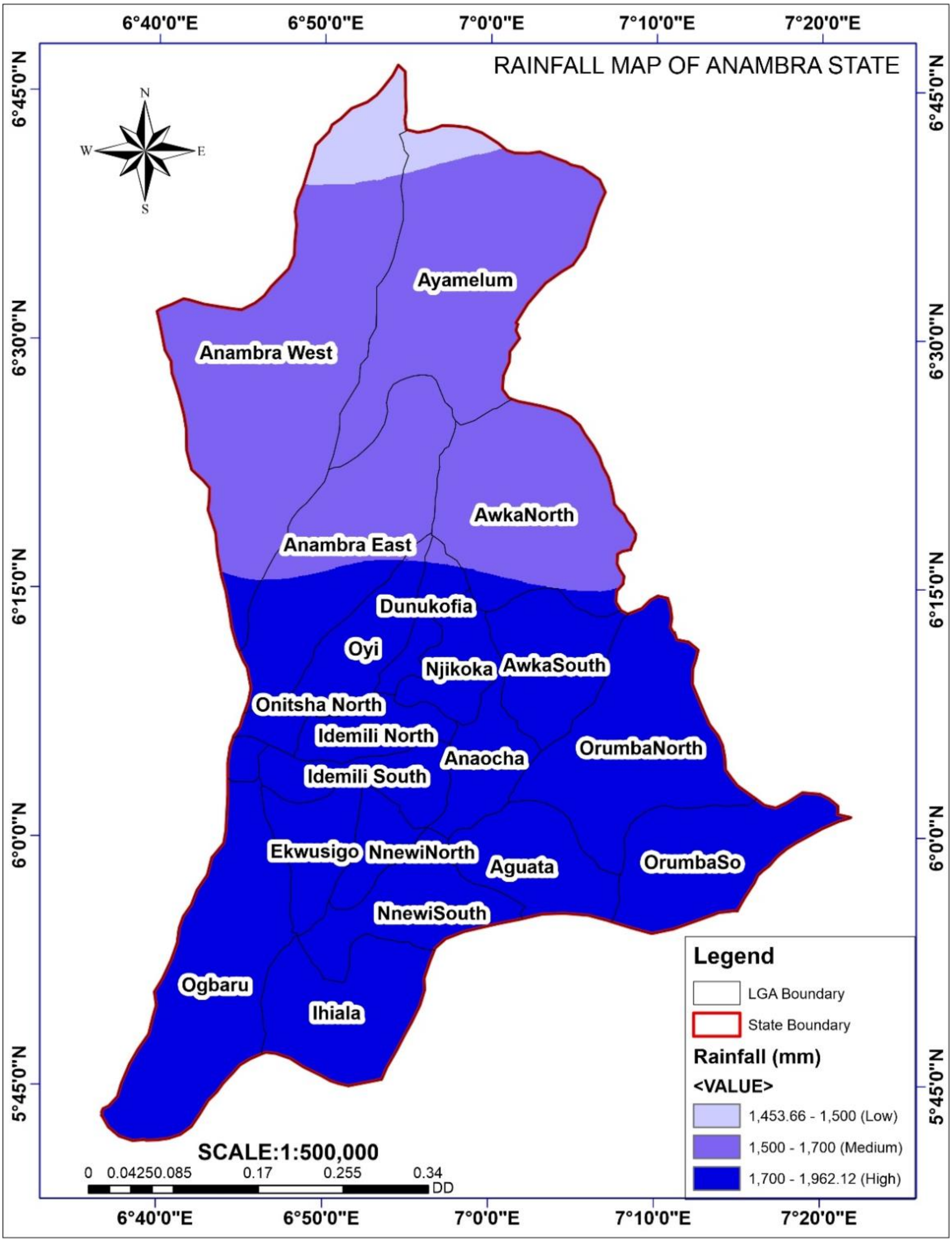

Fig 3.7a: Rainfall Map of the Study Area

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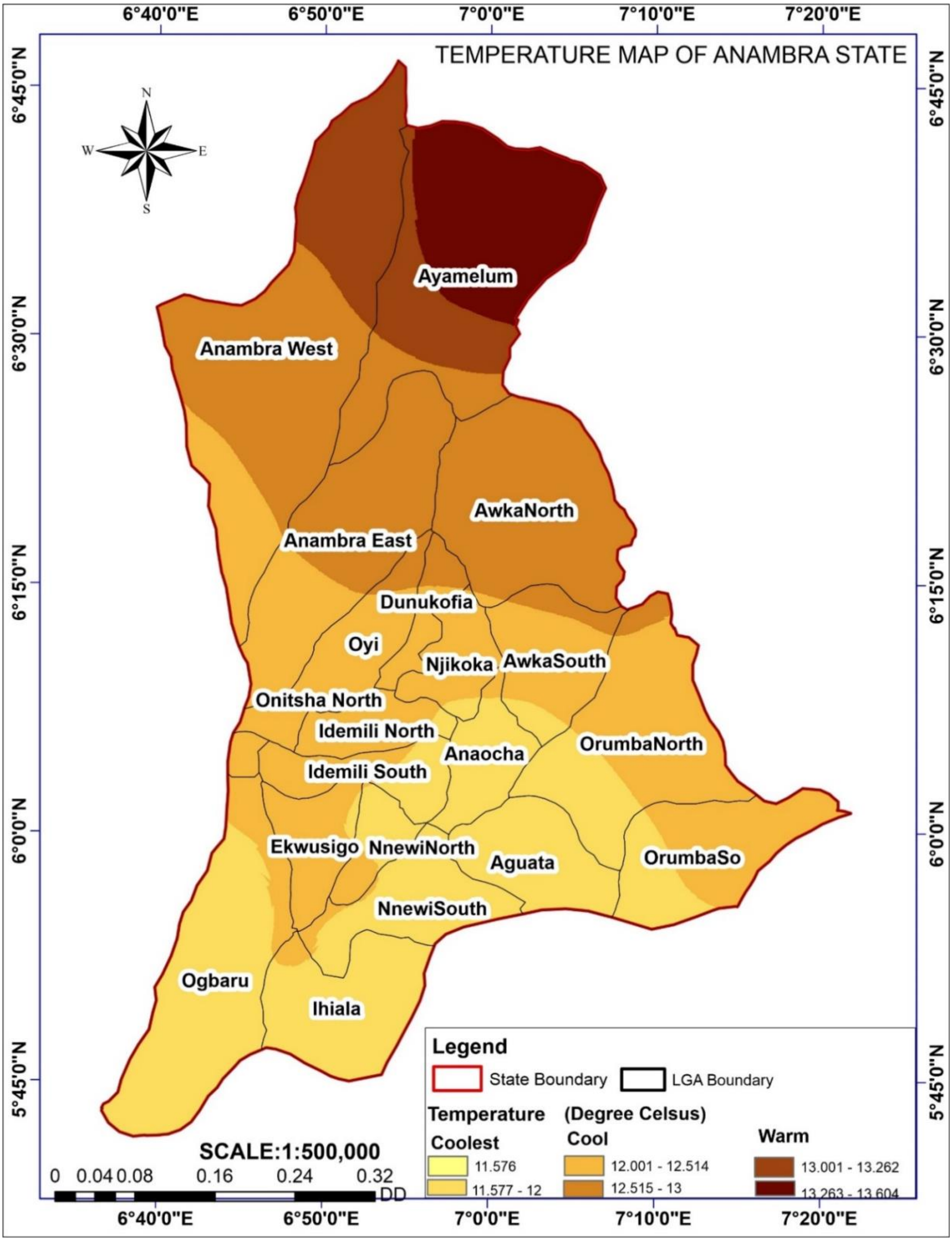

Fig 3.7b: Temperature Map of the Study Area

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Vol. 11 Issue 03
March 2024

3.3 Suitability results/findings

From the priority value derived from pairwise comparison result, the criteria were reclassified according to their suitability level and weighted overlay toolset was used to merge the criteria and the result was gotten. The Area of each factor was calculated as shown in Table 3.1.

The land suitability map for rice cultivation in Anambra State based on the combined analysis of the thematic layers of the suitability factors is presented in fig 3.9.

3.3.1 Statistical Analysis

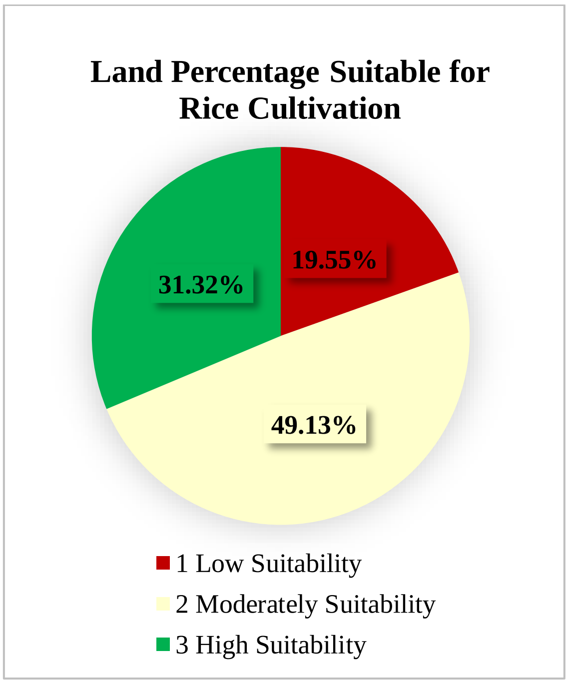

Fig 3.8a: A pie chart showing land percentage suitable for rice cultivation in Anambra State

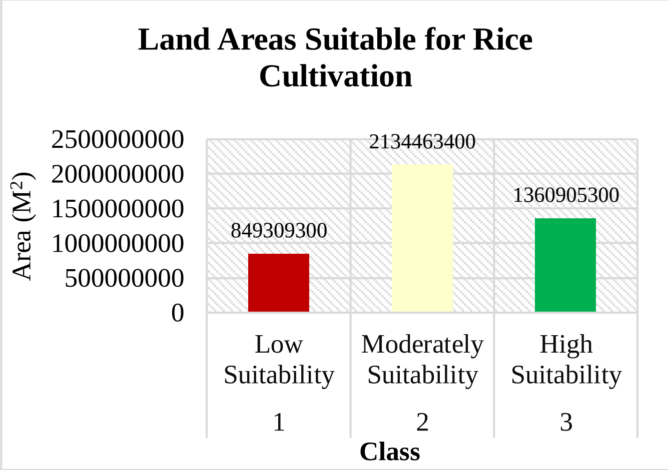

Fig 3.8b: A bar chart showing land areas suitable for rice cultivation in Anambra State

The result from the statistical analysis shows that 31.32% of the total land area is highly suitable for cultivating rice, 49.13% is moderately suitable while 19.55% is marginally suitable. Since 80% of land in the study area is either suitable or moderately suitable. This implies that rice cultivation potential is high in the study area. These percentages echo the sentiment expressed by [10] in their exploration of climate variability and its impact on food security in Edo State, Nigeria. The suitability map as in fig 3.9 shows that the most suitable land is found dominantly in the northern and southern parts (Ayamelum, Anambra West, Anambra East, Awka North) of the study area.

The suitability index ranges from highly suitable to moderately suitable and marginally suitable as shown in green, yellow and red colors respectively.

3.3.2 Rice Faming Suitability Map

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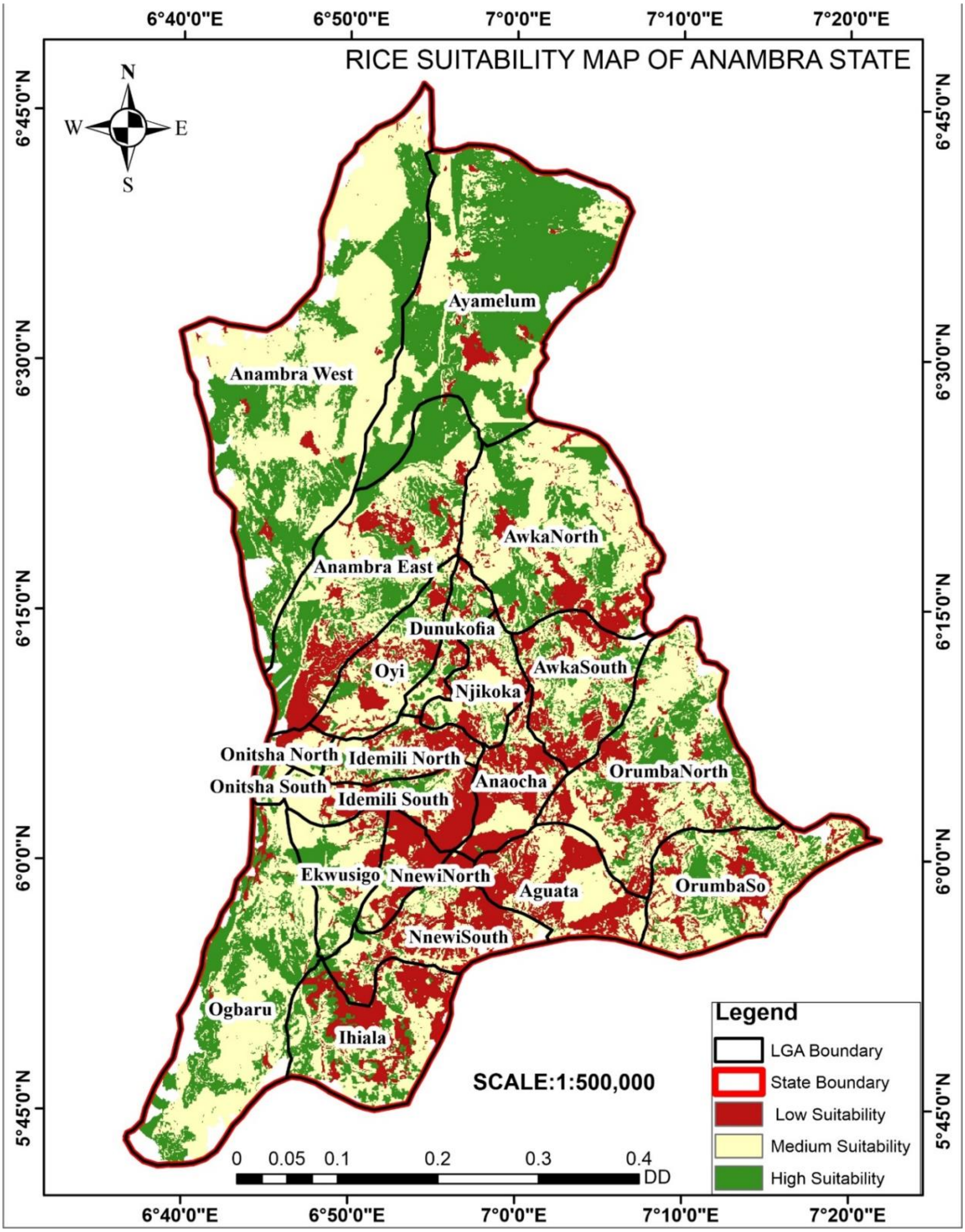

Fig 3.9: Suitability Map of Anambra State, Nigeria

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4.0 CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The GIS-based multi-criteria decision-making process proved effective in generating the suitability map for rice farming in Anambra State, Nigeria. The GIS-based multi-criteria decision-making process played a vital role in evaluating rice farming suitability in the study area. Through the integration of spatial data and diverse criteria, the study provides valuable insights into land suitability for rice cultivation.

The outputted Land suitability map would help in developing land use plans and formulating environmental planning policies that are capable of enhancing the sustainable development of rice farming in the study area. The study's emphasis on developing a land suitability map holds significant implications for agricultural planning and environmental policy formulation. Such maps serve as crucial tools for devising land use plans that align with the natural capabilities of the terrain. Furthermore, the study accentuates the potential of GIS in guiding sustainable development strategies.

The result revealed that the largest percentage of land area (49.13%) in the study area is moderately suitable for rice cultivation. Anambra State has highly suitable area of 31.32% for rice farming.

The research not only contributes to the academic discourse on agricultural (rice farming) suitability assessment but also provides practical recommendations that can guide policymakers, investors, and local communities in optimizing rice cultivation practices in Anambra State. The holistic approach employed in this study, integrating GIS, MCDP, and empirical data, positions it as a valuable resource for advancing sustainable agriculture and addressing food insecurity challenges in the region.

4.2 Recommendation

Building upon the results from this research using the GIS-based multi-criteria decision-making analysis, several recommendations emerge to guide future actions and policies aimed at optimizing rice cultivation in Anambra State. These include:

i. It is recommended that the Moderately Suitable Areas (49.13%) should be optimized by installing irrigation systems in water-deficient regions, promoting sustainable application of fertilizers and agricultural inputs and implementation of soil conservation measures to enhance rice productivity in the research area.
ii. Rice Farmers or investors should prioritize the Highly Suitable Areas (31.32%).
iii. Based on the suitability map produced, land use planning should be integrated to support

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sustainable rice farming/agricultural practice in the research area.

iv. Future researcher, using this GIS-based multi-criteria decision making process, can research on crop varieties suitable for different areas.

v. The sentinel-2 image resolution, judging from the output of the suitability map produced in this paper, is good and can be considered for future research of same or similar nature.

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