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Mapping and Assessment of Cashew Plantation in Nassarawa State, Nigeria Using Geo Spatial Technology

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ABSTRACT

The world demand for cashew and its by-products leads to increase expansion of the cultivation across West-African countries especially in Nigeria. It has generated wealth for many smallholders and contributed to cashew economy success. This study aimed at mapping existing cashew plantations for better management of rural farmland and assessing the soil suitability to future cashew expansion in the study area. GIS and multi-criteria analysis were used to analyze the natural vegetation and soil suitability for future cashew expansion in Nasarawa state. Data collection was done through structured questionnaire administered to cashew farmers in the study area, GPS coordinates and soil samples were collected for suitability test. Results showed that despite a very suitable soil for plantation cashew, its expansion is slow with implication in conservation and carbon emissions. This implies that there is need for a sustainable management of cashew agriculture practices to ensure optimum production for farmers and stakeholders in cashew value chain should address relevant factors affecting low yield via a holistic government intervention program.

Keywords: cashew plantation, geo spatial, mapping, Nasarawa State.

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I. Introduction

Cashew (*Anacardium occidentale L.*) is an important industrial and export crop whose potential is yet to be fully exploited in Nigeria [1], [2]. A tropical nut tree crop which serves as a source of food, income, industrial raw materials, and foreign exchange for many countries of the world. In Nigeria, current cashew trading and exports is worth 24 billion naira ($160 million) and over one million people depend on the industry. Commercial cultivation of cashew in Nigeria dates back to more than 60 years, while research and development into its production, processing and marketing started in 1972. [3], [4].

Apart from being used for food and income generation, it has also been used for afforestation purposes (e.g., in Nigeria, Cote d'Ivoire, and Madagascar) to control soil erosion. Cashew tree is found useful in making live fence, shade trees, firewood, and charcoal. From the bark extract, a black dye can be made that is used locally for tattooing and tanning. Among 13 countries involve in cashew production [5] in the African zone, Nigeria ranks fourth after Tanzania, Cote d'Ivoire and Guinea Bissau, having a total area of 100,000ha and an average annual production of 80,000MT contributing almost 16% of the total production of this particular zone (Its production is 5% of the global situation) in Nigeria, cashew grows successfully in virtually all agro-ecological zones including the semi-arid areas but with high concentration in the middle belt areas in small-holder farms and plantations. Cashew production comes from over 20 States. These include: Kogi, Kwara, Oyo, Edo, Ondo, Anambra, Enugu, Benue, Cross River, Imo, Sokoto, Ogun, Osun, Plateau, Kebbi, most especially in Nassarawa among others [2], [6], [7].

Nasarawa State as mentioned above is one of the producing States in Nigeria. Agriculture is traditionally the main occupation of the people of Nasarawa state and important food crops grown in the state include yam, maize, guinea corn, rice, sugarcane, beans, soya beans, groundnuts, and assorted fruits such as cashew. The state harboured some solid minerals like, granite, limestone, salt and sundry precious stones. [8], 9].

Geospatial technology is a combination of four essential tools: remote sensing, geographic information systems (GIS), global positioning systems (GPS), and information technology or data management [10]–[12]. The use of Remote Sensing (RS) has become an important tool for the detection of fruit trees growth and healthiness index on a larger scale. Similarly, digital imaging technology is increasingly being used for intensive site-specific management of orchards [13]–[15]. With an adequate database, GIS can serve as a powerful analytic and decision-making tool for fruit culture development particularly in a country like Nigeria, where agro-ecological zones are so diverse. [16], [17]. GIS is one of the most widely used techniques for mapping fruit trees and determination of land use/land cover (LULC) and normalised differential vegetation index (NDVI) in cashew growing areas helps in determining changes that occurred on the vegetation overtime as well as the health of cashew and influence on a large extent in both directions of crop production and crop quality respectively. Hence delineation and assessment of cashew plantation using geospatial technology can enhance the productivity and increase income for Nasarawa state, thereby providing information for decision making, such as prediction of yield, quantification and scheduling of precise and proper fertilizer, irrigation needs, and the application of pesticides for pest and disease management. Ultimately, this improves profits for producers [13]. This study employs geospatial technology capabilities for effective mapping of cashew plantation to improve its quality and increasing production in Nasarawa state as well as the nation at large.

A. Study Area

The study area covers two LGAs in Nasarawa State which lie between latitude 7° and 9° North and longitude 7° and 1° East with a landmass of 27,862 km2 and estimated population of 1,863,275 (NPC, 2006). The study area is accessible through Benue State to the South, Kogi State to the West, the Federal Capital Territory (FCT), Abuja to the Northwest, Kaduna, and Plateau States to the North-East and Taraba State to the South-East [18].

TABLE I: DATASET AND SOURCES USED FOR FIELD WORK

Data	Type	Sources
Rainfall	Raster	Tropical Rainfall Measuring Mission (TRMM) 2019.
Soil	Vector	Harmonized World Soil Database (HWSD) 2019
Road Network	Vector	NASRDA 2019
Slope (SRTM)	Raster	https://glovis.usgs.gov/
Organic matter	Raster	Global Soil Organic Carbon Database (30 ARCSEC)
pH	Raster	,,
Nitrogen	Raster	,,
Bedrocks	Raster	,,
LULC	Raster	,,

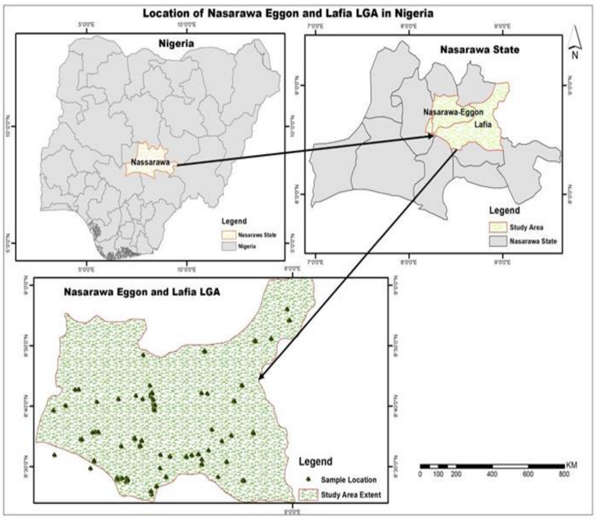

Fig. 1. Location of the area under study area.

II. MATERIALS AND METHODS

Both primary and secondary data were collected for this study in order to enable the examination, delineation and determination of most suitable sites for siting cashew plantations in the study. Table II contains an overview of the data used during the field work including the source and type.

TABLE II: DATA TYPES AND SOURCES

S/N	Dataset	Type	Source
1	CCI Land Cover (LC) high-resolution map at (20m)	Secondary	Sentinel-2A, European Space Agency
2	GLCF Landsat Imagery (30–90m)	Secondary	University of Maryland, College Park
3	Soil Samples	Primary	Fieldwork
4	Cashew Plantation coordinates (GPS, Garmin 87)	Primary	Fieldwork
5	Respondent submission (farmers) via Questionnaire	Primary	Fieldwork

A. Data and Sources

The data used for the analysis include rainfall, soil, road network, slope, organic matter, pH, and Nitrogen, bedrock and vegetation (LULC). The spatial data of soil class was compiled from FAO guideline (Daliya, Ljungqvist, Brindle, and Lobo, 2020).

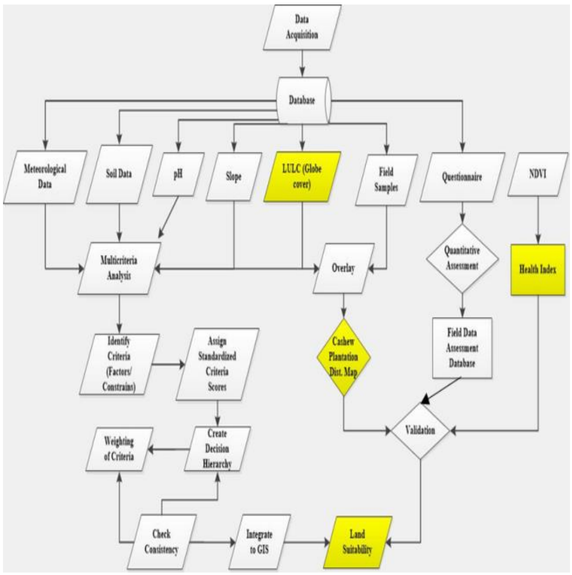

Fig. 2a. Flow chart for the study

B. Soil Properties

A total of fifty-soil samples were collected during the conduct of the field work on some selected designated cashew farms based on random sampling. In each sample unit, a soil profile was described following the FAO guidelines [19] and classified according to the World Reference Base for Soil Resources [20]. The samples collected content bulked sub-samples taken evenly from each horizon air-dried and taken to the laboratory for analysis which was carried out according to the methods presented in Table III.

TABLE III: ANALYSIS METHODS FOR SOIL SAMPLES

Property	Method
pH (H2O) and pH (KCl)	1:2.5 soil solution to ratio of distilled water and 1 M KCl
Organic Carbon	Wet oxidation method after Walkley and Black
Available Phosphorus	Bray 1 method
Particle Size	Pipette after Hydrogen peroxide treatment
Electrical Conductivity	1:2.5 soil: distilled water suspension with a conductivity bridge
Cation Exchange Capacity	Percolation with 1 M ammonium acetate at pH 7
Exchangeable bases (Ca, Mg, K, Na)	After percolation, atomic absorption spectrophotometry (Ca, Mg), flame spectrophotometry (K, Na) followed.

C. Land Suitability Analysis

This method is generally used for site selection. Field survey was carried out to obtain soil properties, in addition to the field work FAO soil classification data was used for the analysis of land suitability for the site for cashew production. This will help in determination of appropriate criteria for the analysis, delineation and establish cashew production and land suitability for high yield in cashew plantation relationship as an objective which reflects the cashew productivity requirement.

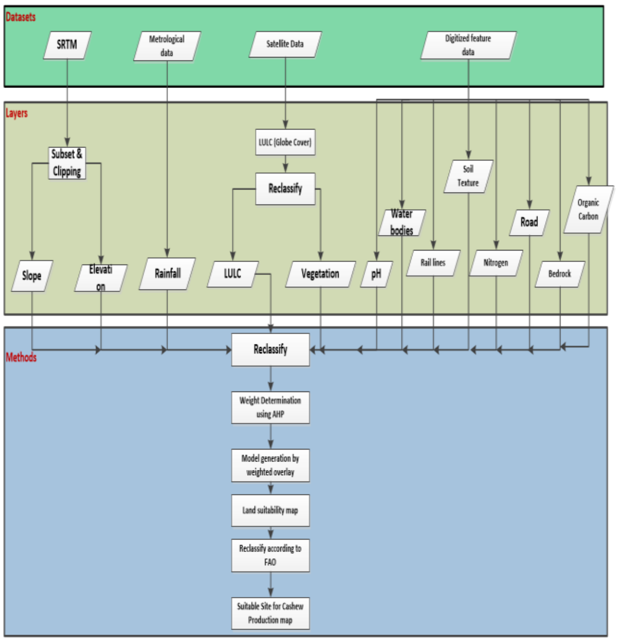

Fig. 2b. An overview of all laboratory analysis carried out.

D. Spatial Multi Criteria Evaluation (Mce)

Exploratory methods were used in carrying out analysis of cashew growth regions. Site selection was based on bio geophysical variability distribution. Regions under studies vary considerably in terms of climate, soil, geological, and geomorphological conditions. Likewise, collected data were based on land characteristics and plant growth, demonstrating a diversity of land characteristics. The parameters to be analyzed include soil texture (pipette method), cation exchange capacity (CEC) (NH4OAc method), exchangeable Na, K, Ca, Mg (NH4OAc, atomic absorption spectrophotometry), soil pH (pH-meter, 1:1), organic carbon content (organic-C) (Walkley-Black combustion method), total nitrogen (total-N) (Kjeldahl method), available phosphorous (available-P) (Bray-1 method), and exchangeable potassium (exchangeable-K) (NH4OAc method). [21].

Land suitability analysis was performed using Multi-Criteria Decision Method (MCDM). The Analytic Hierarchy Process (AHP), which is a well-known multi attribute decision-making process was carried out for computing weights relative to the criteria with several parameters which are considered influential for land suitability as mentioned earlier. These parameters were further grouped into 3 namely: soil/land, topographic and land management parameters. The parameters for soil/land includes soil, bedrock, Nitrogen, organic matter and vegetation; while that of topographic includes, slope and elevation; for land management includes, road, rail lines, rainfall and water bodies/LULC. The AHP was conducted involving one expert [22]. Weights are not assigned directly but represent a “best fit” set of weights derived from reciprocal matrix used to compare all possible pairs of criteria. Each pair of weight was assessed based on their importance ranking from 1 to 5. The result of the process is valid because the consistency ratio is less than 10% [22]. Table IV shows the criteria and weight of influence for each parameter.

TABLE IV: WEIGHT AND PERCENTAGE OF INFLUENCE

Raster Parameter	Percentage Influence (%)	Field Value	Scale Value
Rainfall (mm)	30	1256–1420	5
		1420–1457	5
		1457–1498	5
		1498–1587	5
		1587–1773	5
Soil Texture	16	Sandy loam	5
		Loam	4
		Silt loam	1
		Silty Clay	3
pH	16	5	4
		6	5
Organic Carbon (%)	11	0	1
		0–1	3
		1–2	5
		2–3	5
		3–5	5
Nitrogen	10	0.034–0.058	3
		0.058–0.067	4
		0.067–0.078	4
		0.078–0.103	5
		0.103–0.301	5
Slope (%)	7	0-3.04	5
		3.04–7.22	5
		7.22–14.29	4
		14.29–23.57	4
		23.57–70.53	3
Vegetation	6	Tree cover	4
		Croplands	5
		Bare lands	1
		Built up Area	3
		Open Water	1
Bedrock (%)	4	7–12	5
		12–13	5
		13–14	5
		14–15	4
		15–17	4
Total	100		

TABLE V: RATING FOR PAIRWISE COMPARISON ACCORDING TO SAATY (2008)

1/9	1/7	1/5	1/3	1	3	5	7	9
Extremely	Very strongly	Strongly	Moderately	Equally	Moderately	Strongly	Very strongly	Extre-mely
		Less important				More important		

For each field value, the scores were assigned in accordance with the degree of contribution for cashew production with the consideration of the expert opinion. The percentage of influence for each criterion is presented in Table IV. Rainfall was prioritized against the soil texture based on the available information provided by the expert and that is why an influence of 30% is reflected for rainfall while 16% was assigned to soil texture. Since the required soil properties for cashew is sandy loam, a scale (Table V) of 5 was assigned to sandy loam while loam, silt loam and silty clay are given lower scale. Similarly, for the LULC class types, tree crop types and crops land are scored 5 and 4 respectively (see Table V). For slope, lower altitude is considered more suitable for cashew production according to the criteria. At altitude less than 12 is satisfactory for the production of cashew. Therefore, a score of 5 was given to the class range between 0.4–7.22.

The land suitability map was created by multiplying the weight of criteria and score of each sub-class. This was then divided into four classes: unsuitable, marginally suitable, moderately suitable, and very suitable according to the equation below:

$$S = \sum_{i=0}^{n} wici \quad (1)$$

where:
S – land suitability,
wi – weight of land suitability criteria,
ci – score of sub-criteria,
n – number of land suitability criteria.

III. RESULTS AND DISCUSSION

Results are presented in accordance to each objective as itemized earlier. Land use- land cover classes were reclassified based on the location to suit the characteristic of the area under study. Fig. 3 and 4 shows farm location land cover (that most of the lower lying areas are occupied by trees, crops and shrubs as illustrated) respectively.

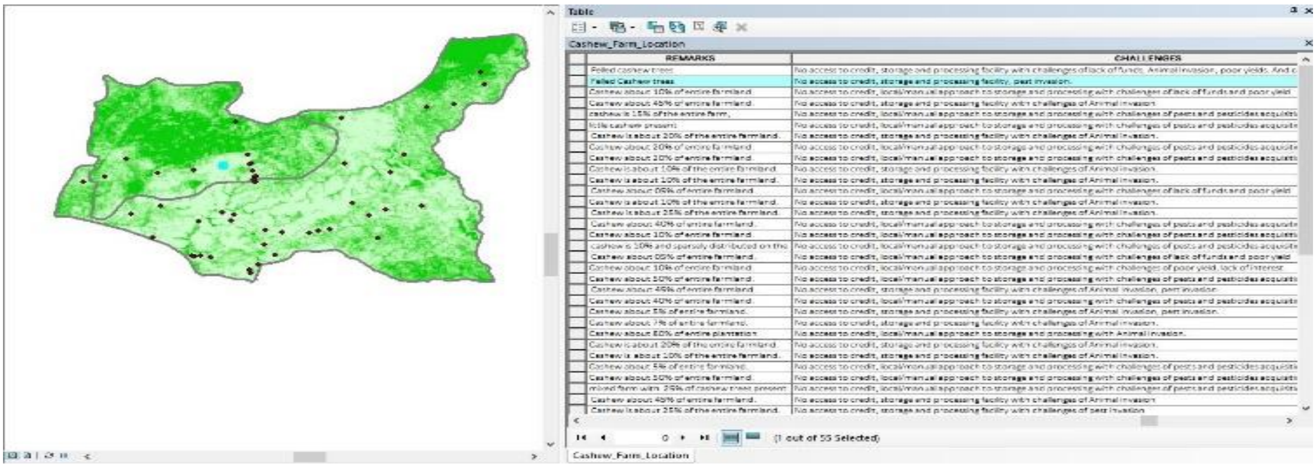

Fig. 3. Location of farmlands visited.

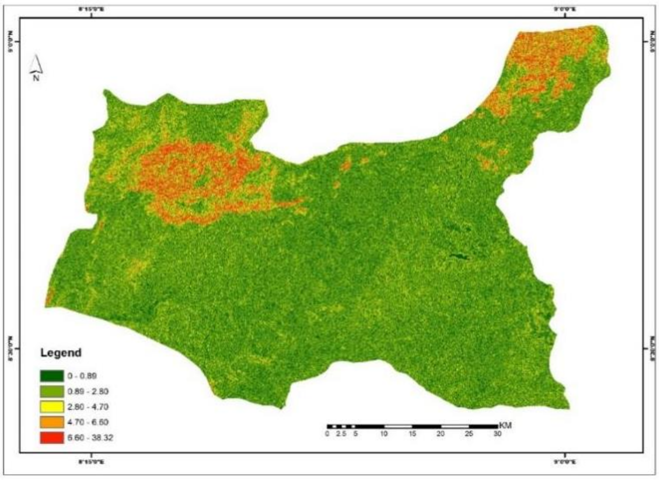

Fig. 4. Land use land cover types.

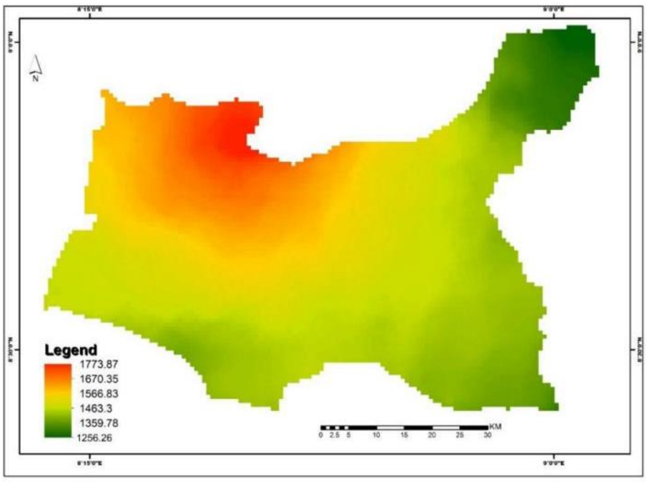

Fig. 5. Variation of soil texture.

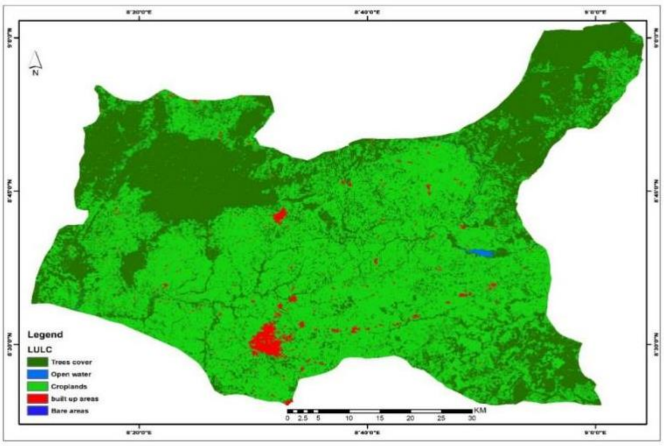

Fig. 6. Slope aspect of the area under study.

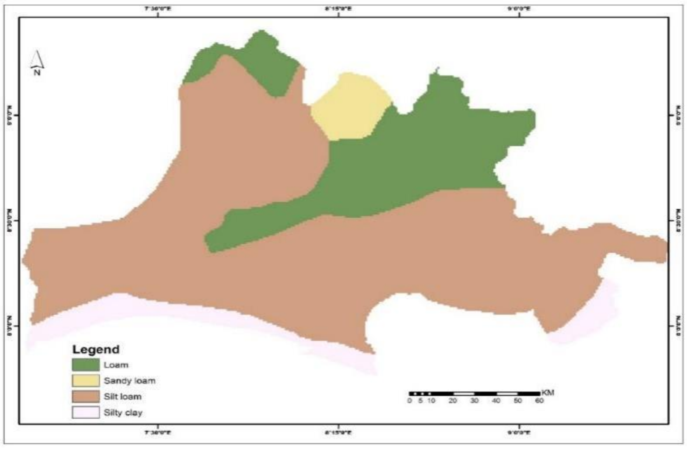

Fig.7. Rainfall pattern of the study area.

A. Soil texture

The soil texture was reclassified based on the score assigned on Table V. However, Fig. 5 shows high yielding trees correlated on deep, highly weathered soils.

B. Slope

The slope aspect of the area is generally undulating as most landforms are basically similar. The altitude varies from 0 to 38 meters with higher elevation visible around Lafia and the Northern axis of Nasarawa Eggon. The spatial distribution and extent of each variation is presented in Fig. 6.

C. Rainfall Pattern

The rainfall pattern in Fig. 7 shows a variation of rain distribution over a period of time. It appears that the higher the amount of rainfall, in correlation with dry and wet months, the higher the calibrated production, up to a certain extent and then decreases with certain land characteristics [21].

D. NDVI of the Area

Normalized Difference Vegetation Index in Fig. 8

measures the health and vitality of plants by rating the amount and movement of chlorophyll. This quantifies vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health. Global data archives such as those based on imagery acquired by Moderate-Resolution Imaging Spectroradiometer (MODIS) are key to understanding ecosystem changes as a result of vegetation health measured by NDVI for regional to global scales [23]. Using NDVI, monitoring agricultural change trajectories over long time periods became critical to gain a better understanding of the Earth System's carrying capacities [24]. Thus, gradual, or long-term change processes, such as ecosystem degradation due to agricultural over-use can only be detected and characterized with confidence from time series [24], [25]. It is hence necessary to establish a long enough time series to reliably capture vegetation trends in agricultural ecosystems [26].

MODIS-based NDVI data between 2001 and 2019 from the MODIS-Terra Vegetation Index (VI) products (MOD13Q1, Collection 6) was collected and processed. The data were acquired from the United States Geological Survey (USGS) Land Processes (LP) Distributed Active Archive Centre (DAAC) at the Earth Resources Observation and Science (EROS) Data Centre. Its archive is available at a nominal 250m spatial resolution and composited with a time interval of 16-days. NDVI is calculated as a ratio between the Red (R) and Near Infrared (NIR) values:

(NIR-R)/ (NIR+R) which shows a very healthy vegetation for cashew plantation (Fig. 8).

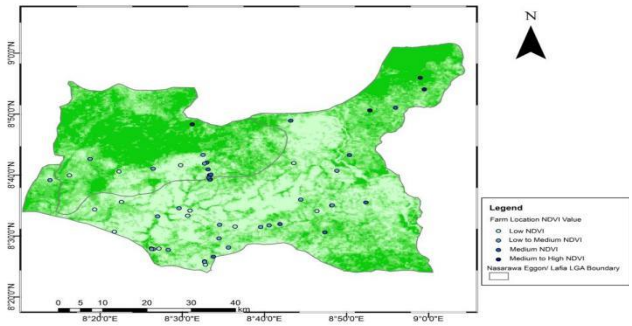

Fig.8. NDVI value for the area under study

E. Soil Suitability

From the map in Fig. 9 and 10, conclusion can be drawn that the landmass around Nasarawa eggon and lafia are highly suitable for the production of cashew. In addition, the selection of most suitable parcel for land production based on the conditions and criteria in Table II, III and V using the optimal conditions from appendix 2 led to the interpolation of the categories of land that are either unstable, marginally suitable, moderately suitable, and very suitable. Figure10 shows a map that describes the representation of the most suitable areas and point location of cashew plantation. However, areas that are sandy occur mostly in the inland plains and more clayey. [27] However, soil texture is critical for cashew production.

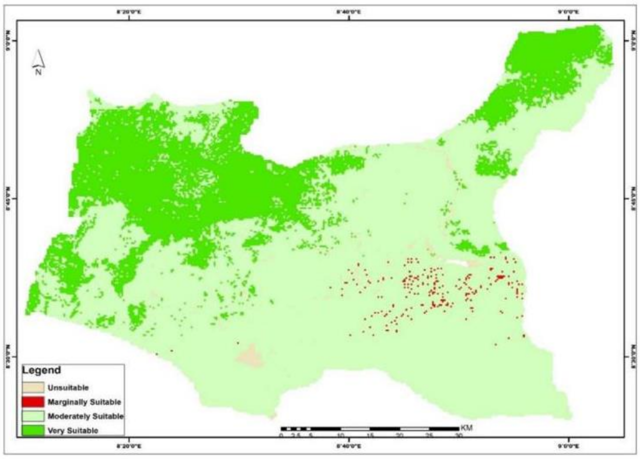

Fig. 9. Selection of the most suitable parcel for the production of Cashew.

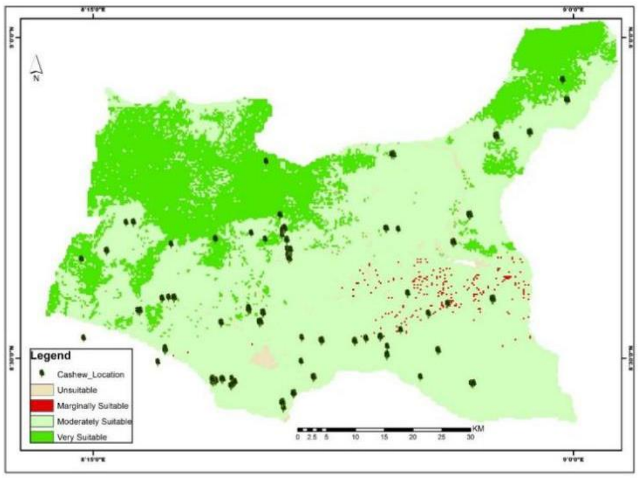

Fig. 10. Suitable land for cashew overlaid with location points of cashew.

IV. Conclusion

In Nigeria, cashew production may be lacking economic importance in the agricultural framework of the country unless a vigorous campaign is carried out to encourage and attract cashew growers through provision of suitable land and improved planting materials. This should be supported by strong research (Geo spatial techniques) and extension efforts. It is only such a consolidated effort based on scientific management techniques that can assist farmers to increase production and productivity of cashews.

Conflict of Interest

Authors declare that they do not have any conflict of interest.

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