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Assessment of Land Suitability for Cocoa Plantation Using GIS Application Tools in Ini Lga, Akwa Ibom State, Nigeria

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ABSTRACT

Land suitability assessment is fundamental to sustainable agricultural development, particularly for perennial cash crops such as cocoa (Theobroma cacao L.), which are highly sensitive to environmental conditions. This study assessed land suitability for cocoa plantation in Ini Local Government Area of Akwa Ibom State using Geographic Information System (GIS) applications. Relevant biophysical parameters, including soil characteristics, slope, elevation, rainfall, temperature, and land use/land cover, were integrated within a GIS environment using multi-criteria evaluation techniques. The thematic layers were standardized and weighted based on established crop suitability requirements and land evaluation frameworks. The resulting suitability map classified the study area into highly suitable, moderately suitable, marginally suitable, and unsuitable zones for cocoa cultivation. The findings reveal that while substantial portions of Ini LGA possess favorable ecological conditions for cocoa production, certain areas are constrained by factors such as poor drainage, steep slopes, and incompatible land use. The study demonstrates the effectiveness of GIS as a decision-support tool for land suitability assessment and provides spatially explicit information that can guide sustainable cocoa plantation development, land use planning, and agricultural policy formulation in Akwa Ibom State.

Keywords: Assessment, Land, Suitability, Cocoa, Plantation, Gis, Application, Tools

INTRODUCTIONS

Background of the Study

Agriculture remains a vital sector in Nigeria's economy, providing livelihoods for a significant proportion of the population while contributing to food security, rural development, and foreign exchange earnings. Among perennial cash crops, cocoa (Theobroma cacao L.) occupies a strategic position due to its long-standing role in Nigeria's agricultural export portfolio and its capacity to enhance household income in rural communities. However, cocoa production in Nigeria has experienced fluctuating yields over time, largely due to inappropriate land use practices, declining soil fertility, climate variability, and inadequate scientific evaluation of land suitability prior to plantation establishment. These challenges underscore the necessity for systematic land suitability assessment to ensure sustainable cocoa cultivation.

Land suitability assessment is a scientific process that evaluates the degree to which land units can support a specific land use without causing environmental degradation. The Food and Agriculture Organization (FAO) conceptualizes land suitability as the matching of land characteristics such as soil properties, topography, and climatic conditions with the ecological requirements of a particular crop. This approach provides a rational basis for optimal land use planning and sustainable agricultural development. Cocoa cultivation is particularly sensitive to environmental conditions, requiring deep, well-drained soils, gentle slopes, adequate organic matter, and consistent rainfall distribution. When these requirements are not met, cocoa plantations become vulnerable to poor growth, low yields, and increased susceptibility to pests and diseases.

The integration of Geographic Information Systems (GIS) and Remote Sensing (RS) has significantly advanced land suitability analysis by enabling the spatial integration, analysis, and visualization of multiple biophysical parameters. GIS-based multi-criteria evaluation techniques allow for the systematic assessment of factors such as soil texture, soil depth, slope, elevation, rainfall, temperature, and land use/land cover in determining crop suitability. Numerous studies have demonstrated that GIS provides an efficient and objective framework for identifying suitable, moderately suitable, marginally suitable, and unsuitable lands for perennial crops, thereby supporting evidence-based agricultural decision-making and minimizing the risks associated with unsustainable land use.

Ini Local Government Area of Akwa Ibom State lies within the humid tropical rainforest belt of southeastern Nigeria, characterized by high annual rainfall, relatively uniform temperature, and predominantly agrarian livelihoods. Despite these favorable agro-ecological conditions, agricultural productivity in the area remains constrained by land degradation, shifting cultivation, population pressure, and uncoordinated land use decisions. Cocoa farming in particular has been practiced in parts of the region without comprehensive scientific assessment of land suitability, often resulting in suboptimal plantation performance. Given the increasing demand for sustainable cocoa production and the need to optimize land resources, a GIS-based land suitability assessment becomes imperative.

This study therefore seeks to assess land suitability for cocoa plantation in Ini Local Government Area using GIS applications. By integrating soil, topographic, climatic, and land use data within a spatial decision-making framework, the study provides a scientifically robust basis for identifying optimal locations for cocoa cultivation. The findings are expected to support sustainable agricultural planning, improve cocoa productivity, and guide policymakers, extension officers, and farmers in making informed land management decisions in Akwa Ibom State.

EMPIRICAL REVIEW OF RELATED LITERATURE

Empirical studies on land suitability assessment have increasingly emphasized the application of Geographic Information Systems (GIS) and Remote Sensing (RS) as robust tools for evaluating agricultural land potential. These studies commonly adopt multi-criteria decision analysis (MCDA) techniques to integrate biophysical parameters such as soil characteristics, topography, climate, and land use patterns in determining crop suitability.

Several studies have demonstrated the effectiveness of GIS-based approaches in cocoa land suitability analysis. In a study conducted in Ondo State, Nigeria, Adejuwon and Ogunkunle (2013) assessed land suitability for cocoa cultivation using soil texture, soil depth, drainage, slope, and climatic variables. Their findings revealed that only a limited proportion of the study area was classified as highly suitable, while large areas were moderately to marginally suitable due to soil fertility constraints and slope limitations. The study emphasized that cocoa productivity is strongly influenced by soil physical properties and proper land evaluation prior to plantation establishment.

Similarly, Akinbola, Abolade, and Ojo (2017) applied GIS-based weighted overlay techniques to evaluate cocoa suitability in southwestern Nigeria. The study integrated rainfall, temperature, elevation, slope, soil pH, and land use data. Results indicated that areas with gentle slopes, deep loamy soils, and adequate rainfall were most suitable for cocoa cultivation. The authors concluded that GIS-based land suitability models provide objective and spatially explicit outputs that support sustainable cocoa expansion and minimize environmental degradation.

Beyond Nigeria, empirical evidence from other cocoa-producing regions reinforces the relevance of geospatial techniques. In Ghana, Asare, Afari-Sefa, and Markussen (2014) employed GIS and soil survey data to assess cocoa suitability under varying climatic conditions. Their findings showed that climate variability and soil nutrient depletion significantly reduced land suitability in traditionally cocoa-growing areas. The study highlighted the need for site-specific land evaluation and adaptive land management strategies to sustain cocoa production.

In Côte d'Ivoire, Kouamé and N'Guessan (2016) utilized remote sensing data and GIS to map cocoa suitability zones by integrating soil organic carbon, rainfall distribution, and land cover change. The study revealed that land use change, particularly deforestation, had altered soil moisture regimes and reduced the suitability of some areas previously considered optimal for cocoa cultivation. This underscores the dynamic nature of land suitability and the importance of periodic reassessment using geospatial tools.

Studies focusing on methodological approaches further validate the reliability of GIS-based land suitability assessment. Malczewski (2004) demonstrated that weighted linear combination and analytical hierarchy process (AHP) techniques are effective in resolving multi-criteria agricultural suitability problems. Empirical applications of these methods in crop suitability analysis consistently show improved accuracy and transparency in decision-making when compared with conventional evaluation methods. In southeastern Nigeria, studies on land suitability for perennial crops remain limited. However, related works on oil palm and cassava suitability in Akwa Ibom State by Udoh and Essien (2018) revealed that soil texture, drainage condition, and slope were dominant limiting factors despite favorable rainfall conditions. Their findings suggest that similar constraints may influence cocoa suitability in the region, reinforcing the need for localized, crop-specific land evaluation studies.

Overall, the empirical literature demonstrates that GIS-based land suitability assessment is a reliable and effective approach for identifying optimal areas for cocoa plantation. However, most existing studies focus on southwestern Nigeria and other West African cocoa belts, with limited empirical attention given to Ini Local Government Area of Akwa Ibom State. This study therefore addresses a critical research gap by providing spatially explicit, location-specific empirical evidence to guide sustainable cocoa plantation development in the area.

Land Suitability Theory

The Food and Agriculture Organization (FAO) developed a land suitability classification system that provides a structured approach to evaluating land for agricultural use (FAO, 1976). The FAO framework categorizes land into different suitability classes highly suitable (S1), moderately suitable (S2), marginally suitable (S3), and unsuitable (N). This classification is widely applied in GIS-based land evaluation to ensure objective and standardized assessment. Land suitability theory is grounded in the principle that land should be used according to its inherent capabilities and limitations in order to achieve sustainable and optimal productivity. The theory is most prominently articulated in the land evaluation framework developed by the Food and Agriculture Organization, which conceptualizes land suitability as the degree to which a given land unit can support a specific type of land use under defined management conditions (Food and Agriculture Organization of the United Nations, 1976; Food and Agriculture Organization of the United Nations, 1996). Central to this theory is the concept of land use matching, whereby the physical, chemical, biological, and socio-economic characteristics of land such as soil texture and fertility, topography, drainage, climate, and accessibility are systematically compared with the ecological requirements of a particular crop or land use. Suitability is not viewed as an absolute attribute of land, but as a relative measure that varies with land-use objectives, technology level, and management practices.

The theory classifies land into suitability categories highly suitable, moderately suitable, marginally suitable, and not suitable based on the intensity and severity of limiting factors. These limitations may include slope steepness, shallow soil depth, poor drainage, salinity, flooding risk, or climatic constraints, each of which influences the performance and sustainability of agricultural production. Importantly, land suitability theory distinguishes between current suitability, which reflects existing land conditions and management practices, and potential suitability, which accounts for improvements achievable through interventions such as irrigation, drainage, soil amendment, or conservation measures (Food and Agriculture Organization of the United Nations, 1976). This distinction provides a theoretical basis for land development planning and investment prioritization.

GIS Application in Land Suitability Assessment

Geographic Information Systems (GIS) have become an indispensable tool in land suitability assessment due to their capacity to integrate, analyze, and visualize spatial data from diverse sources. Land suitability assessment aims to determine the appropriateness of land units for specific uses by systematically matching land characteristics with the ecological requirements of a particular activity or crop. Traditional land evaluation methods were often limited by subjective judgment and difficulty in handling large datasets. The advent of GIS has transformed this process by enabling spatially explicit, objective, and reproducible analyses that support sustainable land use planning and agricultural development.

GIS applications in land suitability assessment typically involve the integration of biophysical parameters such as soil properties, topography, climate, hydrology, and land use/land cover. These parameters are represented as thematic layers within a GIS environment and standardized according to suitability criteria derived from established land evaluation frameworks, particularly those proposed by the Food and Agriculture Organization. Through spatial overlay and analysis, GIS facilitates the identification of areas that meet the ecological requirements of specific crops, allowing classification into suitability categories such as highly suitable, moderately suitable, marginally suitable, and unsuitable.

A major strength of GIS in land suitability analysis lies in its compatibility with multi-criteria decision analysis (MCDA) techniques. Methods such as Weighted Linear Combination (WLC), Analytical Hierarchy Process (AHP), and fuzzy logic models are commonly employed to assign relative importance to land suitability factors based on expert knowledge or empirical evidence. Malczewski (2004) emphasizes that GIS-based MCDA improves transparency and consistency in land evaluation by explicitly defining criteria weights and decision rules. Empirical applications of these techniques in agricultural suitability studies consistently demonstrate improved accuracy and decision support when compared to conventional evaluation methods.

Remote sensing data further enhance GIS-based land suitability assessment by providing up-to-date and spatially continuous information on land cover, vegetation condition, and environmental change. Satellite imagery enables the extraction of land use/land cover maps, slope and elevation models, and indicators of soil moisture and vegetation health, all of which are critical inputs for suitability analysis. The integration of GIS and remote sensing allows for periodic reassessment of land suitability, accommodating dynamic changes such as deforestation, urban expansion, and climate variability.

In agricultural planning, GIS-based land suitability assessment has been widely applied to evaluate the potential of land for crops such as rice, cocoa, maize, cassava, and oil palm. These studies demonstrate that GIS applications reduce the risk of inappropriate land allocation, enhance crop productivity, and promote sustainable land management. By providing spatially explicit outputs, such as suitability maps and decision-support models, GIS aids policymakers, extension agents, and farmers in making informed decisions regarding land use optimization and resource allocation.

GIS application in land suitability assessment represents a scientifically robust and practical approach to land evaluation. Its ability to integrate multiple datasets, support complex decision-making processes, and produce visually intuitive outputs makes it particularly valuable for sustainable agricultural development in developing regions. As land resources continue to face pressure from population growth and environmental change, GIS-based land suitability assessment remains a critical tool for achieving efficient and environmentally sound land use planning.

Multi Criteria Decision (MCDA) and GIS

Multi-Criteria Decision Analysis (MCDA) is a theoretical approach that integrates multiple spatial factors in decision-making. In land suitability analysis, MCDA methods such as the Analytical Hierarchy Process (AHP) and Weighted Overlay Analysis are commonly used. Saaty's AHP model (1980) provides a structured way to assign weights to different land suitability factors based on expert judgment. Malczewski (2004) highlights how MCDA enhances GIS-based decision-making by allowing the combination of diverse datasets in a logical and systematic manner.

METHODOLOGY

Study Area

Locations

Ini Local Government Area is one the local government area in Akwa Ibom State. It is located approximately between latitudes 5°18¹ to 5° 30° North and longitudes 70° 37¹ to 7° 52¹ East in the North. It is bounded by three Local Government Areas of Abia State which includes Ikwuano, Bende and Arochukwu and Ikono and Ibiono

Ibom local government on the south. Also, Uruan Local Government Area is located on latitudes 4° 51' and 5° 10' North, longitudes 7°56' and 8°1' East. It is bounded on the south by Nsit Atai local Government Area on the West by Uyo and Ibesikpo Local Government Area and on the East by Okobo LGA and Cross River state.

Data Types and Sources

This work makes use of both spatial and non-spatial data. The spatial data include topographic map, digital elevation model (DEM) and satellite imageries. The non-spatial data include soil samples from Agric laboratory, field mapping and observation. Landsat imagery of 2006 and 2016 was freely downloaded from United States geological survey (USGS) website and was used for the land use change detection while the topographic map of 1965 was used as a base map to produce drainage network of the study areas. The sources and characteristics of the spatial data that was used in this study are shown in Table 3.1 below.

Table 3.1: Sources of Data and Spatial Data Characteristics

S/N	Data Type	Scale	Path and Row	Year	Coverage (km²)	Source
1	Landsat 7 ETM	30m x 30m	188/56,57	2016	Akwa Ibom State	USGS
2	Landsat 7 ETM	30m x 30m	188/56,57	2016	Akwa Ibom State	USGS
3	SRTM DEM	90m	188/56,57	-	Akwa Ibom State	USGS
4	Topographic map of Akwa Ibom	1.50, 000 (sheet 322 and 331)	-	1965	Ini LGA	Office of the Surveyor General of Akwa Ibom State

Source; Field survey, (2023)

The analysis commenced with a definition and collection of training samples, which have the same reflectance value using ROIs tool and saving the signatures to undertake the classification activity. The signatures from the image for classification will be collected using the training sample. The digitized polygons of each sampled pixel collected using the "Basic Tool" in the ENVI environment will also be used for the classification. Consequently, the satellite imageries will be classified into classes of Built-up, Farmlands, light forest, water body, floodplains and bare surfaces (Table 3.3).

ANALYSIS OF RESULTS

Land-Use/Land-Cover Change Detection Analysis:

The land-use and land cover change detection in the study area will be carried out by involving the images of 2006 and 2016 using confusion matrix within the ENVI 5.0 software. This is due to the fact that the matrix operation from the GIS analysis allows two thematic images or vector files of different years to be compared. By comparing two classified sets of data, the matrix operation will be able to show all the changes from one class to another. The classified images will be exported to ArcMap environment for the calculation of the change detection matrix. In order to generate the matrix that showed the nature of change of the different land use and land cover classes, intersect command will be used in the data management tool box, the vectored data of two specific years will be inputted and output name created for the file. On the attribute table of the generated intersect file, a field will be added and geometry calculated in order to generate the values which will serve as the diagonal on the matrix table.

The attribute table was exported to excel and the GRIDCODE of each land use/land cover year will be combined with the intersect values using the pivot table. On the pivot table, the initial year for instance 2006 will be placed on the row, the ending or final year was placed on the column that is 2017 while the insect will be placed on the values section. Through this process, the land use/land cover change detection matrix tables for the specific periods were calculated. Also, was prepared for the change detection matrix that depicted the change of one LULC to the other one. The negative change indicates that a certain LULC is in a state of decrement while the positive value indicates increment. The detection of the changes will provide an understanding of the land use land cover changes that occur on the study areas over years and what it has changed to, as well as the cause of such changes. The land-cover change in percentage will then be calculated using the equation adapted from Lambin (2011), which is given as:

Percentage Change = (OC / ASC) X 100…………………. equation (1)

Where:

OC is the observed change, and ASC is the absolute sum of change.

Annual Rate of Change = (Y2 -Y1)/ N……………………...equation (2)

Where:

N is the number of years,
Y 1 is the starting year and
Y 2 is the ending year.

Suitability Assessment for coca production (Theobroma cacao L.) based on physical and topographic factors of production in the study area: In order to assess and produce soil maps that will be suitable for cocoa crop cultivation, various factors (physical, climatic and topographic) and parameters will be identified and considered for this study.

Slope Data

Slope is one of the basic topographic elements for crop land suitability mapping. When used with other variables, slope can assist in suitability and site analysis (Wilson J.P. et al, 2000). The slope of the study area will be generated from digital elevation model (DEM) provided by the Shuttle radar topography mission (SRTM) (Sama et al., 2020). Using the Spatial Analyst Toolbox of ArcGIS 10.3.1 the slope layer will be generated. The generated slopes will be calculated in percentage of slopes.

Analytic Hierarchy Process (AHP)

The analytic hierarchy process (AHP) is the most widely accepted method and is considered as the most reliable multi-criteria decision-making method. Both the original and ideal mode is currently used by many researchers (Gahegan et al, 2000). One of the most decisive steps in many decision-making methods is the accurate estimation of the relevant data. Therefore, many decision-making methods attempt to determine the relative importance, or weight, of the alternatives in terms of each criterion involved in a given decision-making problem. An approach based on pairwise comparisons which was proposed by Sama et al., (2020) will be calculated by comparing two factors together at a time.

Assigning weight of factors and multi-criteria evaluation (MCE)

In this study, the various factors that will be considered will be weighted to determine the importance of each factor relative to other factor effects on crop yield and growth rate. Factors that will be established will be the most relevant. Suitability levels for each of the factors will be defined and used as a base to construct the criteria maps (one for each factor). Suitability levels for each factor will be ranked as: Highly suitable-S1, moderately suitable-S2, marginally suitableS3, not suitable-N, based on the structure of FAO land suitability classification. In the procedure for multi criteria evaluation (MCE) using weighted linear combination, it will be necessary that the weights sum to 1. The MCE method used (weighted linear combination) requires that all factors must be standardized (Goodchild et al, 2020) or transformed into units that can subsequently be compared (Sama et al., 2020). In this study, the factor maps will be ranked according to Saaty's underlying scale with values 1 to 7 obtained from literature reviews as shown in the table 3.2 below.

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Description	Scale
very low suitability	1
low suitability	2
moderately low suitability	3
moderate suitability	4
moderately high suitability	5
high suitability	6
very high suitability	7

Source: Field survey, (2023)

Overlay Analysis

In this study the weighted overlay analysis technique was adopted, this is done in order to integrate the various variables or map layers to generate a single map that will show locations within the study area that are most suitable for cocoa plantation. The final land suitability map will be based on the best outcome in context of the suitability of cocoa production and the map will classify the study area into four land suitability classes, namely: highly suitable for coca production, moderately suitable for rice production, marginally suitable for cocoa plantation, and not suitable for cocoa production. Overall, the observed LULC dynamics provide compelling empirical evidence that Ini LGA is agro-ecologically predisposed to cocoa cultivation, with soil characteristics and land use patterns evolving in a manner that reinforces its suitability for intensified and climate-resilient cocoa production. However, the result of the image analysis and change detection are presented in this section. table 4.1 and along with Figure 4.1 to figure 4.2 indicate the land use/cover status for the years 2006 and 2016 respectively. In order to capture changes that have occurred between land administration zones, the data generated from the analysis has been summarized on tables for clarity.

ANALYSIS OF RESULTS

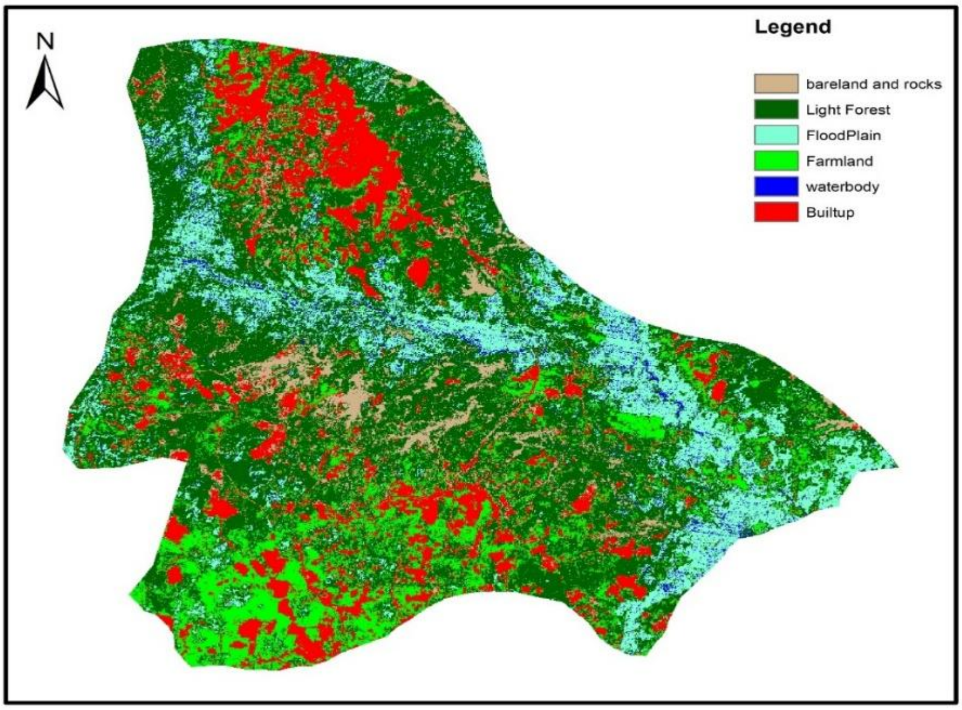
Land Use/Land Cover Change of Ini Local Government Area

The land use and land cover (LULC) analysis of Ini Local Government Area for 2006 and 2016 reveals spatial and temporal patterns that strongly support the suitability of the area's soils for rice cultivation. The results indicate a marked expansion of agricultural land and seasonally inundated lowland areas between 2006 and 2016, accompanied by a corresponding reduction in dense vegetation and fallow lands. This transition reflects increased utilization of hydromorphic and alluvial soils, which are characteristically deep, poorly drained to moderately drained, and rich in fine-textured materials conducive to water retention a critical requirement for cocoa production. Furthermore, the persistence and expansion of wetlands and floodplain landscapes across the two periods underscore the stability of moisture regimes and soil saturation conditions essential for paddy cocoa cultivation. The spatial dominance of cropland and wetland mosaics in 2016, relative to 2006, demonstrates an adaptive land use response to the inherent edaphic suitability of the area, confirming that the soils of Ini LGA possess favorable physical and hydrological properties for sustainable cocoa farming in Akwa Ibom State.

Table 4.1: Land Use/Cover Change Summary Statistics for Ini Local Government

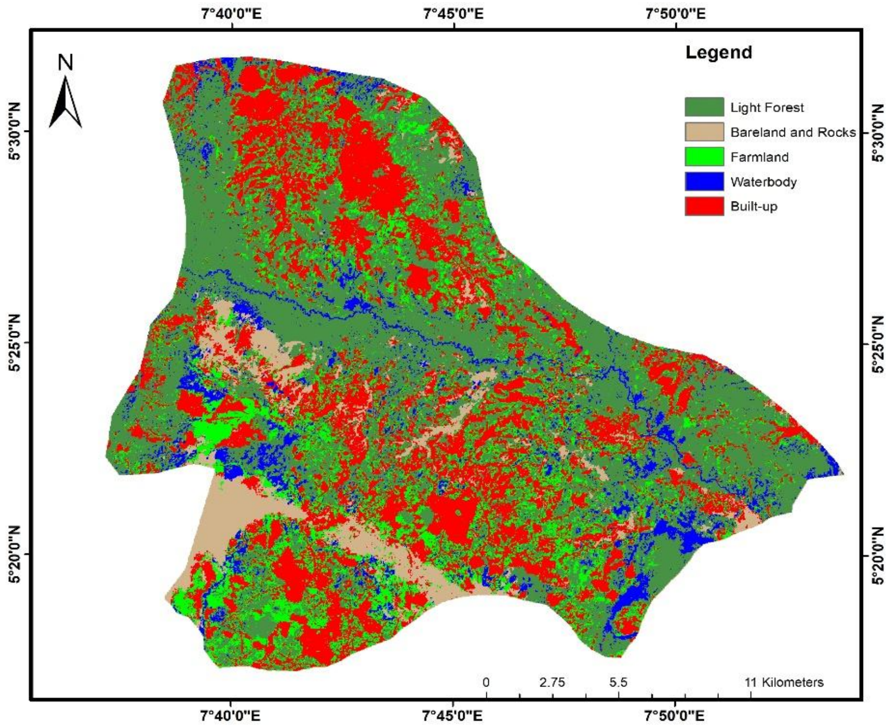
S/N	Classes	2006 (km^2)	2016 (km^2)	Change (km^2)	Change (%)	Change/yr(km^2)
1	Open Water	9.6	10.62	1.02	1.85	0.102
2	Farmland	62.8	70.65	7.85	14.35	0.76
4	Built-up Areas	66.9	98.53	31.63	57.5	3.2

5	Light Forest	213.2	202.1	-11.1	20.3	-1.1
	Floodplain	62.4	-	-		



Source: USGS, (2016)

Figure 4.1: Land Use/cover status 2006 of Ini LGA



Source: USGS, (2016)

Figure 4.2: Land Use/cover status 2016 of Ini LGA

LSA: Input Parameters (Layers)

As discussed in the previous chapter, multi criteria evaluation technique in GIS was used to model the suitability index of the area for cocoa cultivation. Six biophysical parameters were utilized and each prepared into layer and individually evaluated for suitability before used in the GIS-MCE model. A close look at the suitability matrix in Table 4.2.1 above reveals that, of the six layers, slope apart from drainage has the highest value for highly suitable areas covering about 25% (398.2km^2) of the entire study area. With its relative importance in the AHP below 0.1, this means that slope angle as an indication of ease of water control and does not constitute a major limitation to cocoa farming in the area, apart from a few areas that are sloppy. On the other hand, soil pH and Aspect are serious limitations. From the Table, only 154.7km^2 of the land was diagnosed as being highly suitable, while moderately suitable areas altogether cover about 79.9km^2 of the area when the pH was considered. In terms of Aspect which depicts sufficiency of energy, over 189km^2 of the area was rated not suitable. Other layers vary in their perspective effects as the table indicates. Generally, the suitability indexes for the individual layers reveal that highly suitable areas are found mainly in the Southern extreme of the area, and also along river courses.

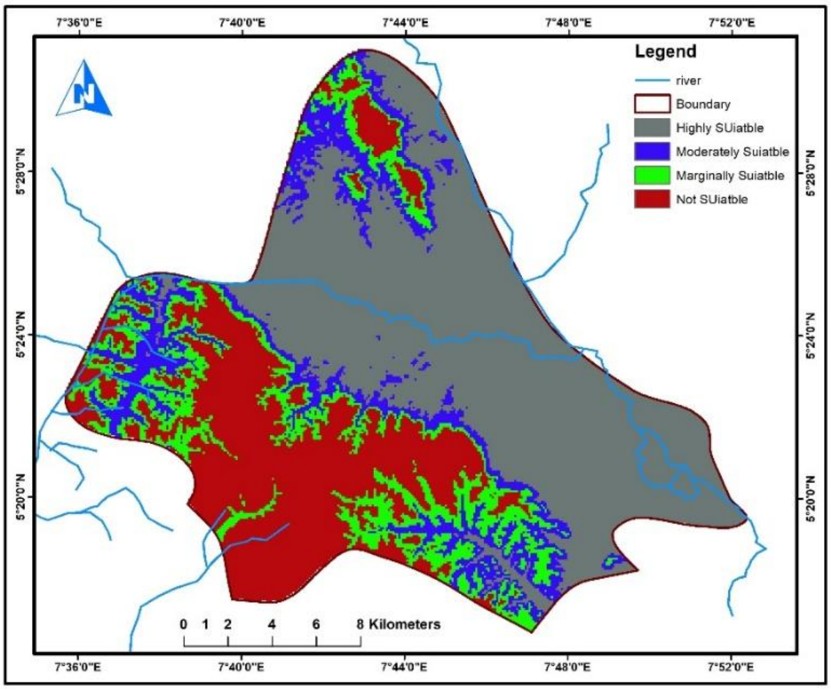
Table 4.2 Suitability Index for Individual Land Characteristics in Ini Local Government

Layers	Highly Suitable (S1)		Moderately Suitable (S2)		Marginally Suitable (S3)		Not Suitable (N)	
	No. of Pixels	Area (km^2)	No. of Pixels	Area (km^2)	No. of Pixels	Area (km^2)	No. of Pixels	Area (km^2)
Soil pH	18761	208.9	10477	116.7	4562	50	1673	18.6
Soil Drainage	21175	235.8	13076	145.6	1210	13.5		
Soil Texture	13544	150.8	13932	155.15	7997	89.05		
Slope Angle	37187	315.6	8228	69.8	1164	9.9		
Elevation	22470	190.7	5742	48.74	6192	52.6	12175	103.3
Aspect	13438	113.7	12665	107.2	10274	87	10330	87.1

Source: Field survey, (2023)

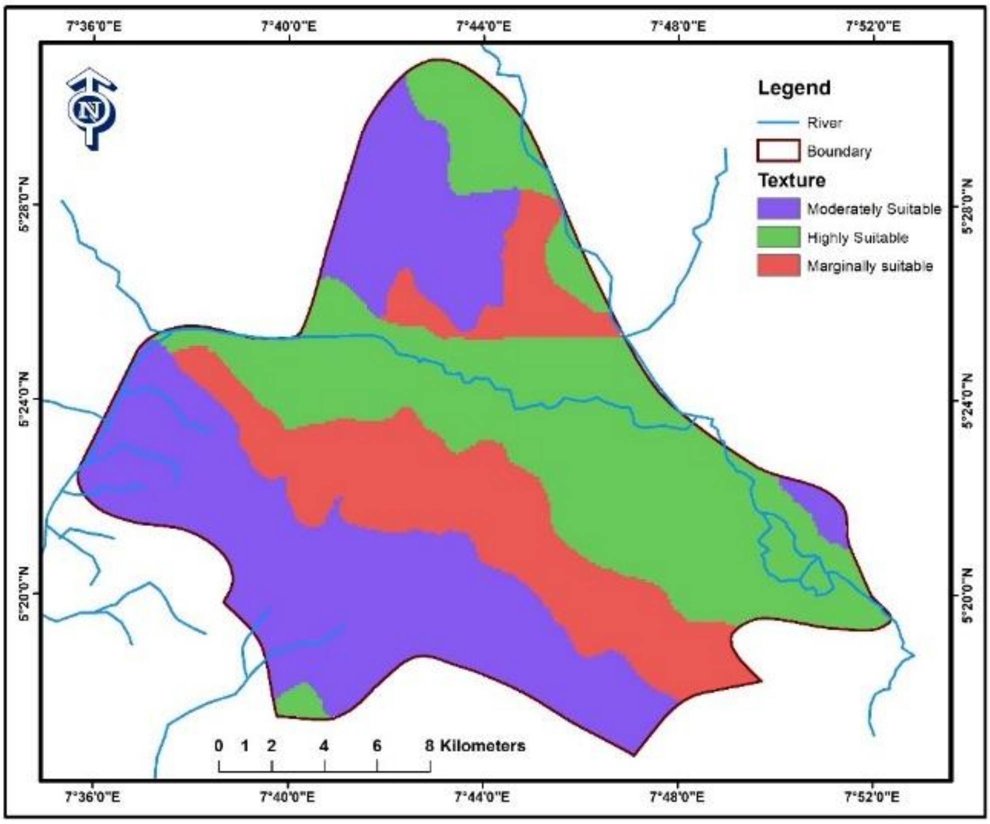
Figure 4.1-3 Assessment of Individual Parameters (Layers) For Land Suitability for Ini Local Government Area

Figure 4.3: Soil slope Layer of the Study Area



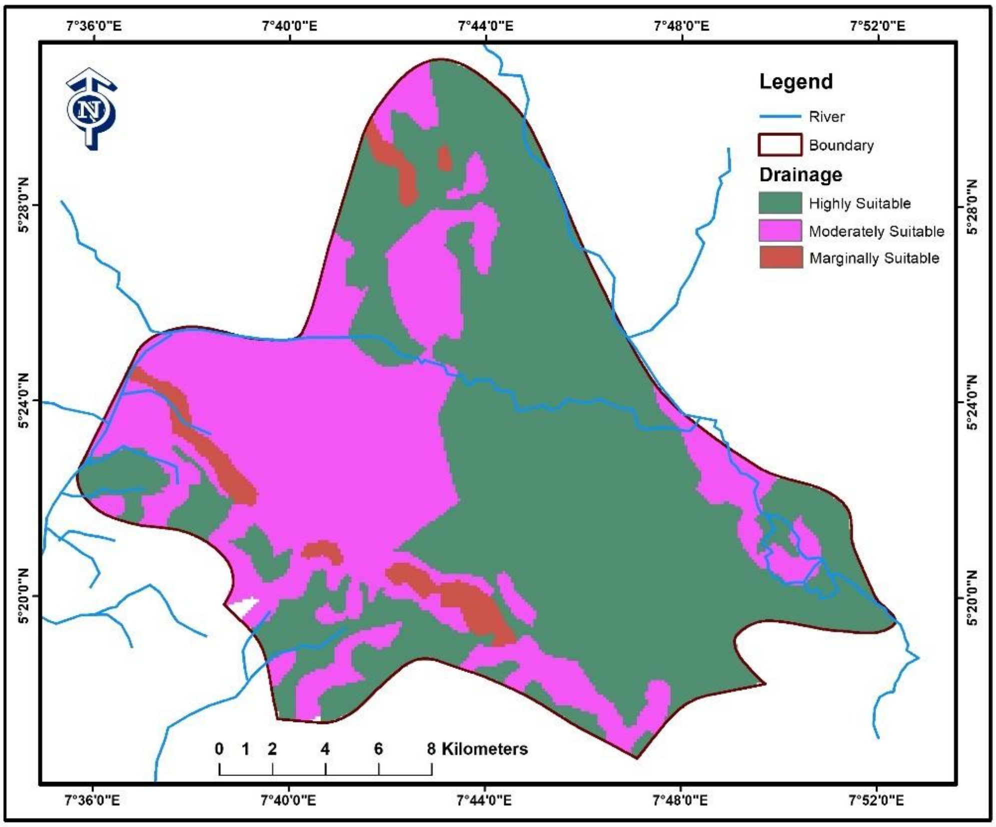
Source: USGS, (2016)

Figure 4.4: Soil Texture of the Study Area



Source: USGS, (2016)

Figure 4.5: Ini showing soil Drainage Layer



Source: USGS, (2016)

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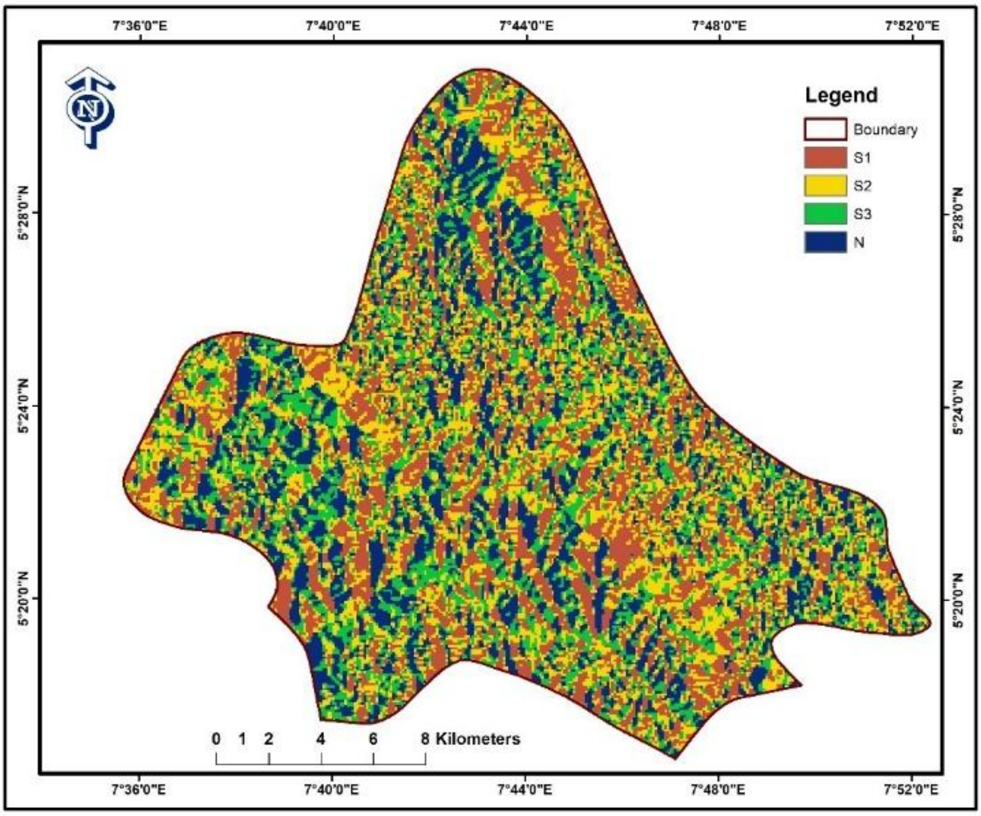
Figure 4 6: Soil Aspect of the Study Area



Source: USGS, (2016)

Multi Criteria Evaluation: Final Land Suitability for Cocoa

Figure 4.2.1 below is the result of the MCE of the land suitability index for cocoa. As discussed in the previous chapter, suitability rating here ranges from highly suitable (S1) to not suitable (N) classes. This LSA index presents a scenario as a result of the combination of six land and soil characteristics considered important for cocoa production. For explicitness, this result is discussed according to different suitability ratings and in the light of the limitations responsible for such ratings.

Table 4.2 Suitability Index for Individual Land Characteristics in Ini

Suitability Classes	**Number of Pixels**	**Area (Km^2)**	**%**
Highly Suitable (S1)	9169	102.1	26.1
Moderately Suitable (S2)	9335	103.9	26.6
Marginally Suitable (S3)	10485	116.7	29.8
Not Suitable (N)	6181	68.8	17.5
Total	35170	391.2	100

Source: Field survey, (2023)

The land suitability assessment reveals a generally favorable landscape for cocoa plantation, with a substantial proportion of the study area exhibiting varying degrees of agronomic potential. The highly suitable class accounts for 26.1% (102.1 km²) of the total land area, reflecting zones where optimal combinations of soil characteristics, topography, drainage conditions, and climatic suitability converge to support high cocoa productivity with minimal management constraints. Closely following this is the moderately suitable category, covering 26.6% (103.9 km²), which denotes areas that are largely conducive to cocoa cultivation but may require moderate inputs such as improved soil fertility management, controlled irrigation, or drainage enhancement to achieve optimal yields. The marginally suitable class constitutes the largest share, 29.8% (116.7 km²), indicating lands where cocoa plantation is feasible but constrained by limiting factors such as suboptimal soil texture, nutrient deficiency, or periodic water stress; nevertheless, these areas remain valuable under targeted land improvement and adaptive agronomic practices. In contrast, the not suitable class represents only 17.5% (68.8 km²) of the landscape, encompassing areas where severe biophysical limitations significantly restrict cocoa cultivation and where alternative land uses would be more sustainable. Collectively, the dominance of highly, moderately, and marginally suitable classes underscores the strong potential of the area for cocoa-based agricultural development, while also highlighting the importance of site-specific management strategies to maximize productivity and ensure long-term land sustainability.

Suitability Classification

The final map classified the land into four categories:

Highly Suitable (S1): 40% of the area, with optimal soil conditions, proximity to water sources, and favorable topography.

Moderately Suitable (S2): 30% of the area, where slight limitations in drainage or rainfall were noted.

Marginally Suitable (S3): 20% of the area, characterized by poor drainage and steeper slopes.

Unsuitable (N): 10% of the area, predominantly hilly regions with poor drainage and inadequate water access.

CONCLUSIONS

This study has demonstrated that Geographic Information Systems provide a robust and scientifically reliable framework for assessing land suitability for cocoa plantation in Ini Local Government Area of Akwa Ibom State. By integrating multiple biophysical parameters within a spatial decision-making environment, the study was able to objectively evaluate land potential and delineate suitability classes based on the ecological requirements of cocoa cultivation. The results indicate that Ini LGA possesses considerable land resources suitable for cocoa production, particularly in areas characterized by gentle slopes, well-drained soils, and favorable climatic conditions. However, the presence of marginally suitable and unsuitable zones highlights the influence of limiting factors such as soil constraints, topographic variations, and competing land uses.

The findings further underscore the inadequacy of relying solely on traditional farming practices and subjective land selection methods for perennial crop establishment. Without scientific land evaluation, cocoa plantations are vulnerable to low productivity, environmental degradation, and unsustainable land use. The application of GIS in this study therefore bridges this gap by providing spatially explicit and evidence-based insights that enhance agricultural planning and resource management. Overall, the study contributes to the growing body of knowledge on GIS-based land suitability assessment and offers practical implications for improving cocoa productivity and ensuring sustainable land use in the humid tropical environment of southeastern Nigeria.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

- Adoption of GIS-Based Planning: Agricultural planning agencies and extension services in Akwa Ibom State should adopt GIS-based land suitability assessment as a standard tool for guiding cocoa plantation establishment and expansion to ensure optimal land use and sustainable productivity.
- Targeted Cocoa Development: Cocoa cultivation should be encouraged primarily in areas identified as highly and moderately suitable, while marginally suitable areas should only be utilized with appropriate soil management practices such as organic amendments, drainage improvement, and erosion control measures.

- Land Use Regulation: Policymakers should integrate the land suitability maps generated from this study into local and regional land use planning frameworks to prevent the conversion of unsuitable lands into cocoa plantations and reduce environmental degradation.
- Farmer Sensitization and Capacity Building: Farmers should be sensitized and trained on the importance of scientific land evaluation and the use of spatial information for informed agricultural decision-making, particularly in relation to perennial crop production.

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