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Land Suitability Assessment for Maize Production in Kuje Area Council, Abuja, Nigeria

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ABSTRACT

Achieving optimum yield of maize can meaningfully be supported by land suitability analysis in order to guarantee self-sufficiency for future production optimization. This study aimed to assess and map land suitability for maize production in Kuje Area Council, Abuja through analysis of parameters such as Landuse and landcover (LULC) classification, slope, elevation, temperature, soil reaction, soil texture, nitrogen, phosphorus and potassium using Geospatial Techniques. The objectives of the study are: (a) to identify and map various factors that determine the suitability of land for maize production in Kuje Area Council, (b) to examine the influence of the identified factors on maize production in the study area and, (c) to produce suitability map for maize production in the study area. Chemical elements influencing soil properties such as Nitrogen, phosphorus, potassium, soil texture and pH, and climate data were used to validate Land suitability analysis for maize production. Time series analysis was carried out to determine LULC classes as a determinant of land suitability for maize production using maximum likelihood algorithm of supervised classification in ArcGIS 10.8 software. Time series data set of Landsat and Shuttle Radar Topographic Mapping (SRTM), and soil data were used to generated LULC classes, slope and aspect, and soil mapping units in the study area. Soil characteristic was determined for suitability for maize farming in the study area using multi-criteria analysis of soil, geological composition, slope and aspect, precipitation, Land surface temperature and evapotranspiration. Suitability was categorized into highly, moderately and low categories based on Food and Agricultural Organisation of the United Nation (FAO) classification, using Analytical Hierarchy Process (AHP) technique. The study identified factors such as LULC classes, slope, elevation, temperature, soil reaction, soil texture, nitrogen, and phosphorus and potassium contents to be determinants of maize production. A suitability map for maize farming was produce for the study. The study revealed that LULC has the highest percentage of 0.304 (30.4%), while elevation has the lowest percentage of 0.043 (4.3%). The consistency ratio (CR) value was determined to be zero (0). Land suitability for maize production therefore showed that about 58% of the area is moderately suitable for maize production, 39% low suitable, why only 3% of the study area is less suitable for maize production. Location such as Leka, Tugba, Kabi, Shaji, Kujekwa are marginally suitable for cultivating maize. While Chukwuku, Gwagwalada, Pegi, and Kuje town are Less suitable areas for maize production due to the fact that they are located in built-up areas. Location within the study area with less than 3% is not suitable for maize production because of poor soil nutrient. Therefore, the study recommended soil conservation by the application of organic fertilizer, mulching and leguminous cover crops to enhance soil quality. The study has in store necessary information that farmers need for maize farming in the study area

Key Words: Maize, Production, Land, Suitability, Assessment, Soil

INTRODUCTION

Sustainable agricultural is what is required for the growth of Nigeria economy, irrespective of the debt profile of this country. The goal of sustainable agriculture involves achieving a balance between the inherent land resources and crop requirements, with a specific focus on optimizing resource utilization to ensure sustained productivity over an extended period [23, 27].

Recently, the most important and urgent problem in the world particularly in the developing countries is to improve agricultural land management with an effective and efficient land-use system for better socio-economic development [24]. The problem of selecting the correct land for the cultivation of a certain agricultural product is a long-standing and mainly empirical [4]. Food production is declining due wrong choices of economic development and use of land resources. However, the magnitude of the problem has not been clearly identified and studied as documented in previous review, [20, 3].

Human activities particularly in Nigeria have been gradually degrading land. Therefore, it is necessary that the potential and limitations of land, on a local scale, are identified and evaluated for farming a specific crop especially in Sahara soils conditions [29]. Research on combination of land attributes and cropping pattern or system that will give crops highest productivity is required [15]. Maximizing benefits derivable from land requires its proper utilization [27]

A significant limiting factor in the advancement of agriculture in Nigeria is the inadequate techniques employed in obtaining and managing data on crop conditions, agricultural land potential, and farming activities [11]. This led to a deficiency in knowledge and unreliable information for planning and formulating policies with regards to agriculture. Consequently, the imperative to enhance agricultural productivity is both genuine and time-sensitive [27].

Local biophysical conditions play a critical role in selecting soil suitability for crops production [16]. The choice of soil suitability will enhance fertile soil management and help to identify the main potentials and limitations of an area for a particular crop production. Land suitability evaluation is the first step for developing and promoting land-use planning and protecting sustainable agricultural lands.

Land evaluation and crop suitability analysis using GIS and remote sensing would provide better landuse options to farmers. Plan which incorporates different land characteristics is important. In current agricultural practices, remote sensing, geographic information systems (GIS), and global positioning systems (GPS) technologies have become indispensable [7]. These technologies have been used to assess the criteria required to define the suitability of land [29, 12, 30] and were also adopted in the study.

The utilization of GIS technology in capturing, retaining, and retrieving location and altitude data from multiple soil observations has facilitated investigations on the spatial variability of soil characteristics within subjectively defined landscape [22]. This marks a significant improvement compared to previous soil surveys which lacked location details of soil profiles [16, 26, & 27].

Maize is the 4th world most consumed cereal, ranked below sorghum, millet and rice [18] and the 3rd most crucial cereal, ranked after sorghum and millet [22]. Maize is an important grain because of its economic value, it is a multipurpose crop in which every part of it has great economic value. The grain, leaves, stalk, tassel and cob can all be used to produce a large variety of food and non-food products. Demand for maize is increasing at a faster rate because it is a major staple food for human and animals. Studies in maize production in different parts of Nigeria have shown an increasing importance of the crop amidst growing utilization by food processing industries and livestock feed mills [24].

In Nigeria, the area planted with maize has increased from 438,000 ha in 1981 to 3,335,860 ha in 2009 with an increase in production from 720,000 to 7,338,840 tons within the same period. In 2015, maize production was at 10.7 million metric tons [6] and 10.5 million metric tons in 2017 [25]. Domestic demand of 3.5 million metric tons outstrips production level of 2.0 million metric tons [3].

Hence, it is necessary to develop an advanced agro-ecological model to manage and determine land-use planning based on the local soil, climate and topography data to reduce the risk to the food supply without degradation to the land using Geospatial Technology.

Statement of Research Problem

Demand for maize is on the increase in Nigeria, but despite the economic importance of maize, it has not been produced to meet food and industrial needs of the country, and this could be attributed to low productivity due to lack of improved technologies for maize production [6]. One of the major limitations to maize production in

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Nigeria is the declining in soil fertility which is exacerbated by the high cost and sometimes unavailability of fertilizer [13] and poor selection of arable land and soil suitability for maize production [4].

In Nigeria, maize is one of the main food crops, but its yield is far below its agronomic and genetic potential mainly due to soil infertility. There has been report of widespread land degradation and soil infertility due to deficiencies of both macro and micronutrients in many parts of the country. Crops yields have been declining due to poor farming methods, land degradation and insufficiency of soil nutrients [14].

Over the past decades, it was observed that states like Niger, Nasarawa, Benue, and Plateau, are the highest supply of grains to other. The insecurity challenges in this area in recent time have limited capability of this States to meet up with the demand of grains in Nigeria. Based on this regard, it is imperative bring together a collaboration of farmers in FCT to work out plans and utilize the area mapped out for farming activities in the FCT master plan for effective food security in the country.

To guarantee both food security and environmental sustainability, it is essential to enhance crop yield method and land resource utilization effectively by cultivating crops in areas where they are most appropriate. This requires the implementation of land suitability analysis using Geo-informatics-based techniques. Land suitability is also indispensable in the decision-making processes for crop management systems that are aimed at augmenting land productivity. A feasible approach to attaining this objective is by using multi-criteria evaluation fused with GIS to identify suitable areas for maize production to help increase productivity, and categorize land for appropriate purpose [1].

The study investigated land suitability for maize production in Kuje area council to enhanced increase in maize production in the FCT using multi-criteria analysis.

MATERIALS AND METHODS

The study used data set from Landsat, SRTM, soil data, agriculture statistics data, and climate data downloaded from appropriate site for the study. ARCGIS 10.8 was used for data processing, analysis, database, and presentation. The study adopted investigation and observation design of data acquisition, data processing, and data analysis.

Study Area

The study area is Kuje Area Council and it is located on Latitude 8°30' 0' and 8°55' and Longitude 6° 55' and 7°30' as shown in Figure 1.1. It has an area extent of 1758.32 km square. It is bounded on the North by Gwagwalada Area Council and Abuja Municipal Area Council, to the West by Kwali and Abaji Area Council and to the Southeast, Nassarawa State (see figure 3.1) [11].

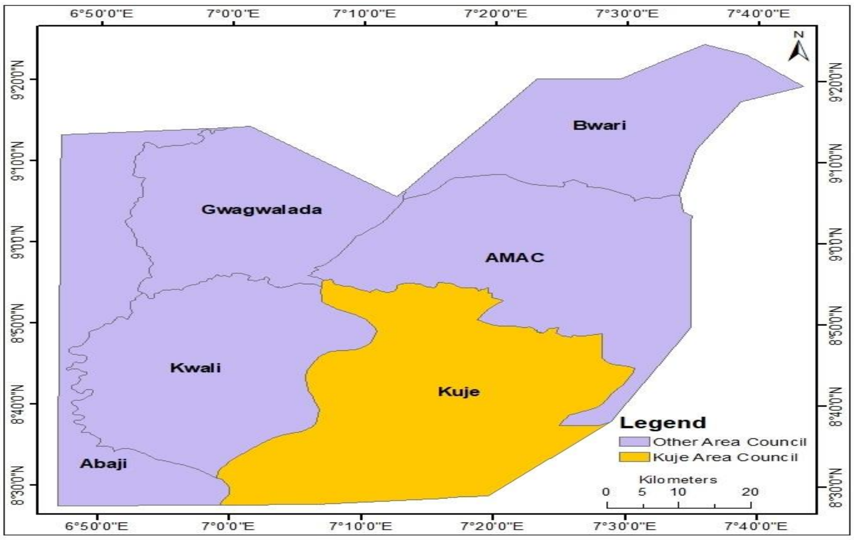

Fig 1 Kuje Area Council

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Reconnaissance Survey

Reconnaissance survey of the study area was conducted to investigate maize farming in the study area and access quality of yield across the area council using social survey and interactions with locals on the performance of maize production in the study area. Scientific interaction was engaged with the experts especially agronomists and soil scientists to get information on the basic land requirement for maize production.

The work plan for determining Land suitability for maize farming in Kuje area council is explained in figure 2.

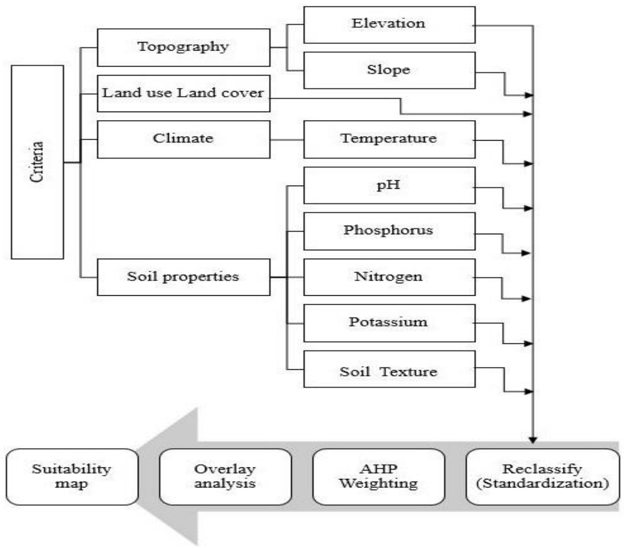

Fig. 2: Flow chart for Land Suitability Analysis

This flow chart explained the multi-criteria analysis of land topography, LULC, climate, soil properties, and soil elements and nutrients' influence on quality maize production in the study area.

Data Type and Acquisition

The secondary data are the administrative data and was collected from the office of the Surveyor General of the Federation. The primary data are the Landsat time series data set used for LULC classification, SRTM data for the determination of slope and aspect in the study area, soil for determining soil classification, properties, and suitability for maize production, and climate data for accessing precipitation quality, evapotranspiration (ET), and Land Surface Temperature (LST) in the study area as was carried out in [4].

Methods

The study adopted scientific investigation and observation design of multi-criteria analysis for data acquisition, processing and analysis

LULC Classification

The data set for LULC classification was acquires from USGS website for time series analysis. The downloaded data was pre-process to correct and remove errors in the data set and post process to generate LULC results using Maximum likelihood techniques, a supervised classification algorithm in ERDAS Imagine 2015 for the categorization process. Post-classification change detection methods were being used to examine LULC in the study area for the bare land, vegetation, water body, Built-up, farmland,

Elevation data

The SRTM data set that was downloaded from USGS website was used to generate slope and aspect data to determine elevation suitability for maize production in the study area using ARCGIS to generate slope and elevation results.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume IX Issue VI June 2024

Determination of ET and LST

The ET and LST are determined using the Landsat thermal band in ARCGIS 10.8 to generate ET and LST for the study area (Akpata & Okeke, 2021). The land surface temperature and Evapotranspiration was calculated using ARCGIS to compute ET and LST in the study area to monitor the rate of evapotranspiration by plants and soil across the study area. Landsat data was used to calculate the LST while MODIS was used to calculate ET. The LST was estimated using the surface radiant temperature. The calculated radiant surface temperatures were subsequently corrected for emissivity [4].

Soil Classification

The soil classification of Kuje was base on the Digital Soil map of Nigeria using ARCGIS to extract the Kuje soil details according to mapping units. Kuje Area Council has 21c, 15e, and 17a soil mapping unit which make it suitable for maize production [16].

Soil Suitability for Maize Production

The soil suitability for maize production was determined using information from the soil data base of Abuja [16] using ARCGIS to extract and delineate the mapping unit from the digital soil map. The suitability according to mapping units are: The 21c mapping unit is composed of undifferentiated basement complex geology with undulating dissected plains relief, and deep to very deep and very shallow to moderately deep well drained soils; sand, loamy sand to sandy loam surfaces over sandy loam to sandy clay loam and sometimes gravelly subsoils characteristics with 5.4 soil ph. The mapping unit 15e is composed of Nupe sandstone geology with nearly level to gently undulating plains relief and deep well drained and few somewhat poorly drained soils; loamy sand to sandy loam surfaces over sandy loam to sandy clay loam and sometimes gravelly subsoils characteristics with 6.0 soil ph. And the mapping unit 17a that is composed of shale geology with gently undulating plain relief and mostly deep well drained, few poorly drained soils; loamy sand to sandy loam surfaces over sandy clay loam to sandy clay and few ferruginised subsoil characteristics with 6.5 soil ph.

Multi-criteria Analysis for Land Suitability for Maize Production in Kuje Area Council

Several variables were considered to determine land suitability for maize production in the study area. Variables such as Land use land cover, slope, elevation, temperature, soil reaction, soil texture, nitrogen, phosphorus and potassium were investigated using GIS techniques

RESULTS

Suitability of LULC classification for Maize Production

Using information from LULC classes and soil classification in the study area, cross tabulation analysis was carried out to determine LULC classes for land suitability for maize production. The results from analysis in table 1 show that Water body and built-up are not suitable for maize production, while farmland and vegetation were highly suitable and moderately suitable for maize production, respectively. Table 1 show that vegetation covered about 54% of the study area, while bare land and farmland accounted for 27% and 17% of the total land area, respectively. The LULC maps explained the ratio of land use patterns in the study area as shown in figure 2.

Table 1: Land Use Land Cover Suitability

Class	Rank	Suitability Level	Area (Ha)	Percentage (%)
Water and Built Up	1	Not Suitable	4769.1	2.71
Bareland	3	Less Suitable	47501.64	27.02
Vegetation	7	Moderately Suitable	94097.07	53.52

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Farmland	9	Highly Suitable	29464.83	16.76
Total			175832.64	100

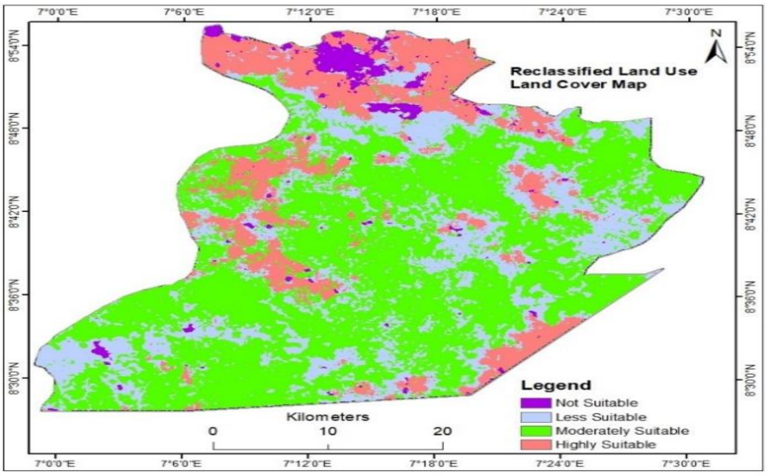

Figure 2: LULC Map

Suitability of Elevation for Maize Production

Elevation is an important variable that influences water runoff and is a determining factor for land suitability for maize production as detailed in table 2 and figure 3. Table 2 reveals that about 27% and 46% of the study area has elevations highly suitable and moderately suitable for maize production, respectively. Areas with higher elevations are not suitable for maize cultivation.

Table 2: Elevation Suitability for Maize Production

Class	Rank	Suitability Level	Area (Ha)	Percentage (%)
>700	1	Not Suitable	1576.98	0.90
550-700	3	Less Suitable	14493.15	8.24
400-550	5	Marginally Suitable	32209.11	18.32
250-400	7	Moderately Suitable	80878.68	46.00
<250	9	Highly Suitable	46674.72	26.54
Total			175832.64	100

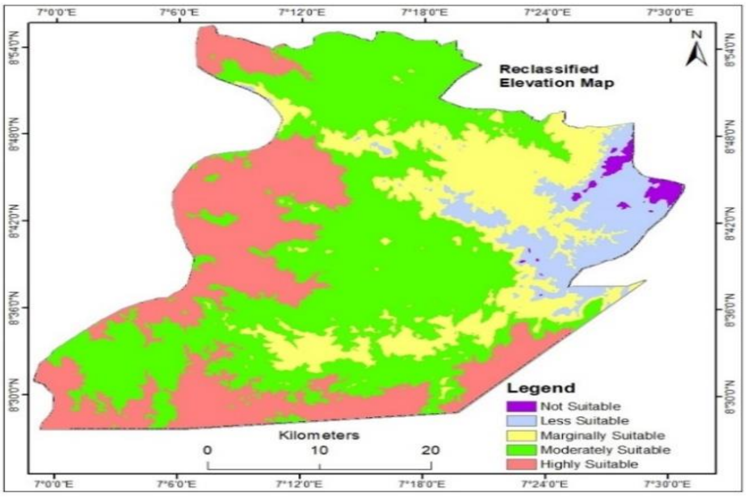

Fig. 3: Elevation Suitability Map

Slope Suitability for Maize Production

The slope, which influences the quality of the land, is one of the factors considered when determining whether a land is suitable for crop production. The SRTM data was used to generate slope of the study area using ARCGIS software. Slope gradient is one of the most significant factors in determining soil erosion because runoff typically increases with increasing slope gradient. According to Table 3, approximately 75% of the total land area has slope values between 0 and 10%, which is considered highly suitable for growing maize. See figure 4 for slope map.

Table 3: Slope Suitability for Maize Production

Class	Rank	Suitability Level	Area (Ha)	Percentage (%)
>25	1	Not Suitable	13616.66	7.74
20-25	3	Less Suitable	6862.5	3.90
15-20	5	Marginally Suitable	9650.34	5.49
10-15	7	Moderately Suitable	14357.28	8.17
0-10	9	Highly Suitable	131345.86	74.70
Total			175832.64	100

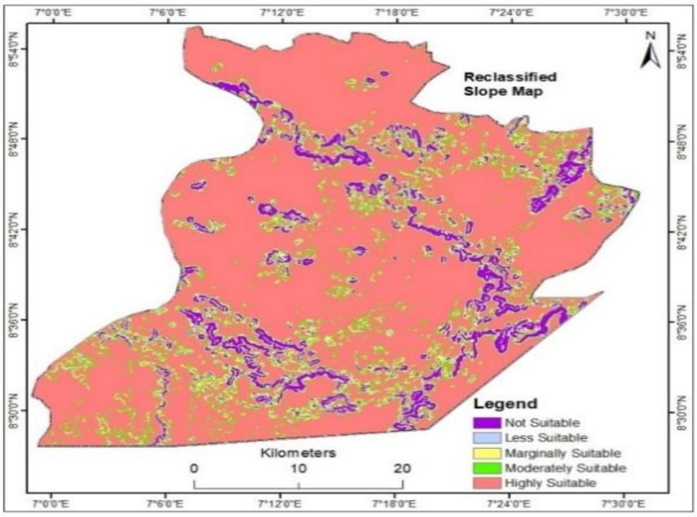

Fig. 4: Slope Map

Suitability of Phosphorus for Maize Production

The nutrient phosphorus (P) is essential for the early stages of maize development, grain formation, and grain maturation and was determined in the study area using geotechnical survey. It promotes the growth of the root system and, inadvertently, makes plants more resilient to intermittent soil moisture deficits. The land is more suitable for maize production due to the high availability of phosphorus in the soil. According to Table 4 and figure 5, respectively 77% and 23% of the area have phosphorus that is deemed marginally and moderately suitable for the growth of maize.

Table 4: Phosphorus Suitability for Maize Production

Class	Rank	Suitability Level	Area (Ha)	Percentage (%)
<6	5	Marginally Suitable	135041.04	76.80

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6-24	7	Moderately Suitable	40791.6	23.20
		Total	175832.64	100

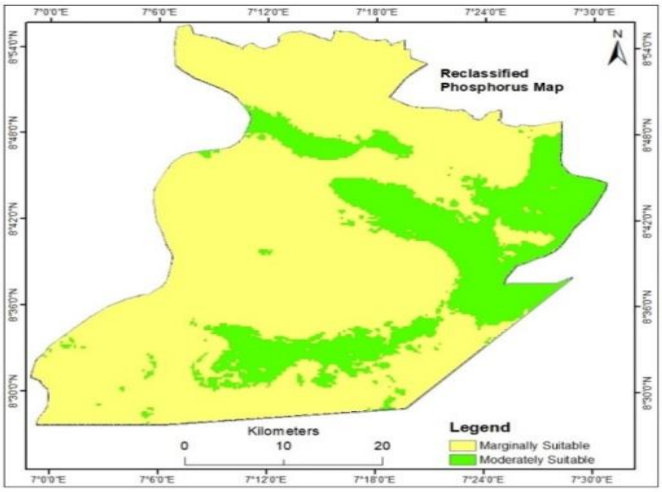

Figure 5: Phosphorus Suitability Map

Potassium Suitability for Maize Production

One of the most crucial ambient macronutrients for healthy growth, development, and long-term crop yield is potassium and it was determined in the study area using geotechnical survey. Overall, it raises the yield of maize. Additionally, it helps the plant regulate stomatal movement (Thomas and Thomas, 2009). According to Table 5 and figure 6, 36% of the study area is deemed less suitable for growing maize, and 64% of it has potassium levels that are considered to be marginally suitable.

Table 5: Potassium Suitability for Maize Production

Class	Rank	Suitability Level	Area (Ha)	Percentage (%)
<0.1	3	Less Suitable	63354.33	36.03
0.2-0.1	5	Marginally Suitable	112420.44	63.94
>0.2	7	Moderately Suitable	57.87	0.03
Total			175832.64	100

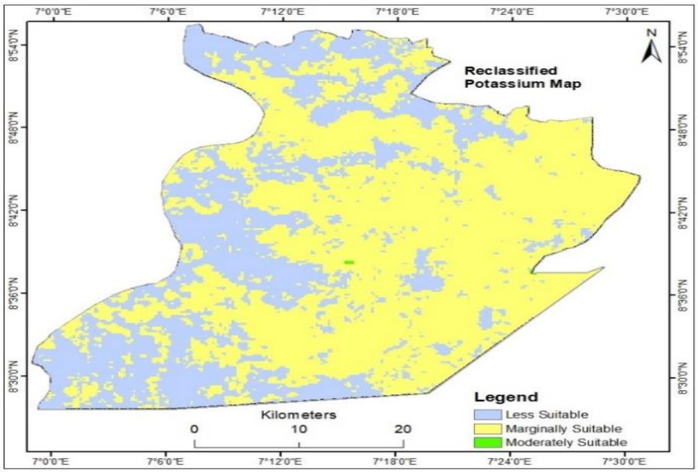

Figure 5: Potassium Map

Nitrogen Suitability for Maize Production

For the production of maize, nitrogen is a crucial plant nutrient and a factor in yield determination [28]. The availability of nitrogen promotes vegetative growth and increases yield. As shown in Table 4.7, the distribution of total nitrogen in the study area was categorized into two classes based on its suitability.

Table 6: Nitrogen Suitability for Maize Production

Class	Rank	Suitability Level	Area (Ha)	Percentage (%)
0.2-0.4	7	Moderately Suitable	1139.58	0.65
>0.4	9	Highly Suitable	174693.06	99.35
Total			175832.64	100

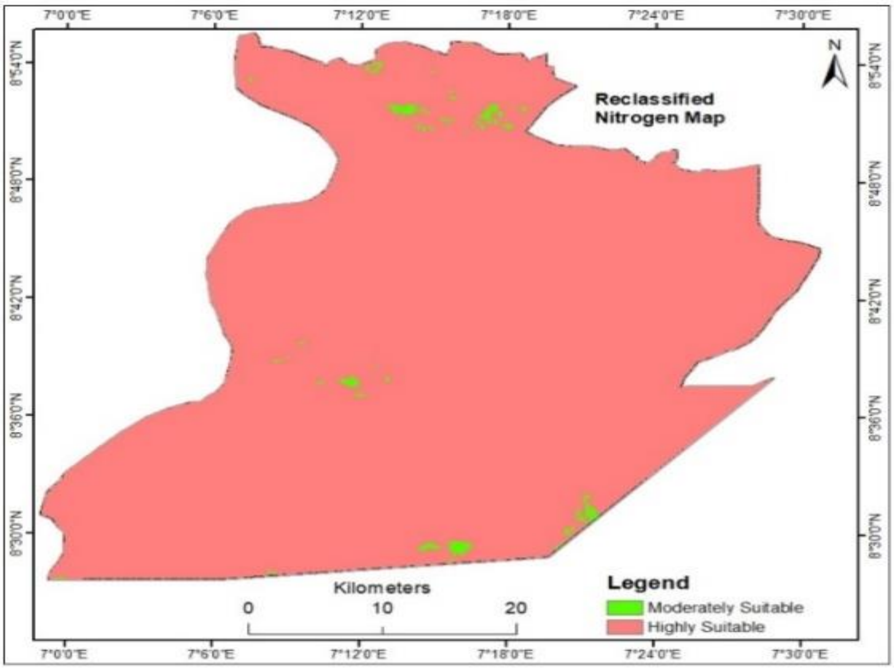

Fig.7: Nitrogen Map

Suitability of Soil Reaction (pH) for Maize Production

The term "soil reaction" denotes the extent of the soil reaction, which is related to the soil's level of acidity and alkalinity. It offers a range of indicators regarding the condition of soil properties. In order to ensure that nutrients are available to the crop in the proper amounts, it is therefore a crucial soil property that needs to be monitored. Table 4.9 demonstrates that 77% and 23%, of the total land area are categorized as marginally and less suitable for maize production, respectively.

Table 7: Soil Reaction (pH) Suitability for Maize Production

Class	Rank	Suitability Level	Area (Ha)	Percentage (%)
<5.5	3	Less Suitable	39909.15	22.70
5.5-6.3	5	Marginally Suitable	135923.49	77.30
Total			175832.64	100

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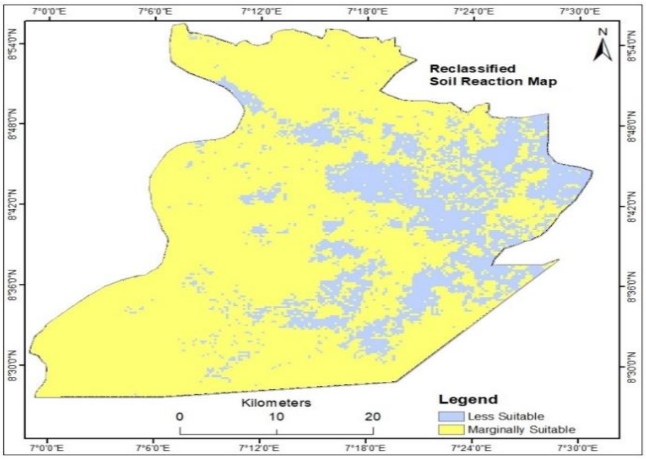

Fig. 8: Soil Suitability for Maize Production

Computation of Land Suitability Map for Maize Production

The land suitability map for maize production was calculated in ArcGIS 10.8 using the raster calculator tool as presented in Table 8 and depicted in Figure 9

According to Table 8, about 3% and 39% of the study area are less suitable and marginally suitable for maize production respectively. Approximately 58% of the study area is considered moderately suitable for maize cultivation. Generally, areas with gentle slopes, low elevations, and sandy loam soil, temperatures between 8ºC and 32ºC, and high concentrations of nitrogen, phosphorus, and potassium are moderately suitable for maize cultivation. In the study area, there are a number of settlements like Gumayi, Pasalli, Gbambo, Kabimangoro, and others that have moderately suitable land for growing maize. Marginally suitable areas for cultivating maize can be found in places like Leka, Tugba, Kabi, Shaji, Kujekwa, to mention but a few. Less suitable areas are generally located in built-up areas such as Chukwuku, Gwagwalada, Pegi, and Kuje town.

Table 8: Land Suitability Map for Maize Production

Suitability	Rank	Area (Ha)	%
Less Suitable	3	5010.48	2.85
Marginally Suitable	5	69346.48	39.44
Moderately Suitable	7	101475.68	57.71
Total		175832.64	100

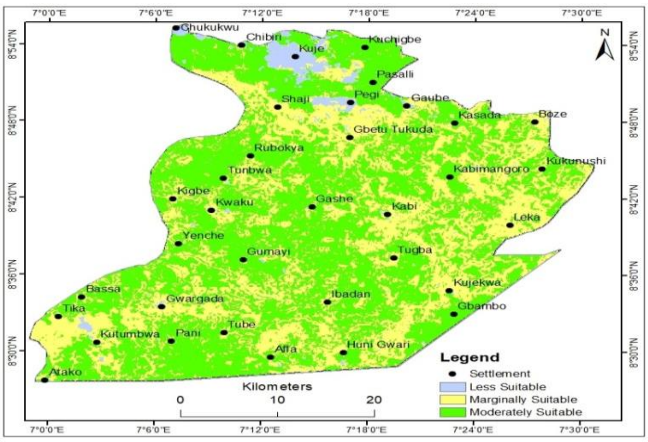

Fig..9: Land Suitability for Maize Production

Analysis of Results

The research results were analyzed using multi-criteria analysis of all the variables factors that influences land suitability for maize production in the study area. This analysis was carried out using zone analysis of cross tabulation in ACGIS and method of Analytical Hierarchical Process (AHP) pair-wise comparison matrix for the calculation, and the results are shown in Tables 8 and Table 9, the pair wise comparison matrix was normalized by dividing each value by the sum of the values in each column, and the weight of each criterion was calculated by averaging each row. Table 8 shows that LULC has the highest weight of 0.304 (30.4%), while elevation has the lowest weight of 0.043 (7.3%). The consistency ratio (CR) value was determined to be zero (0). Because the result is less than 0.1, it indicates a high level of consistency.

Table 8: Analytical Hierarchy Process Matrix

	LULC	**ST**	**EL**	**SL**	**TE**	**PH**	**N**	**P**	**K**
Land Use Land Cover (LULC)	1	9/5	8	5	9	4	8/3	8/3	8/3
Soil Texture (ST)	5/9	1	4	8/3	7/2	2	5/4	5/4	5/4
Elevation (EL)	1/8	1/4	1	3/5	3/2	3/5	2/5	2/5	2/5
Slope (SL)	1/5	3/8	5/3	1	3/2	3/4	3/5	3/5	3/5
Temperature (TE)	1/9	2/7	2/3	2/3	1	1/2	2/5	2/5	2/5
Soil Reaction (PH)	1/4	1/2	5/3	4/3	2	1	4/5	4/5	4/5
Nitrogen (N)	3/8	5/7	5/2	5/4	5/2	5/4	1	1	1
Phosphorus (P)	3/8	5/7	5/2	5/4	5/2	5/4	1	1	1
Potassium (K)	3/8	5/7	5/2	5/4	5/2	5/4	1	1	1

Table 9: Normalized Analytical Hierarchy Process Matrix Matrix

	LULC	**ST**	**EL**	**SL**	**TE**	**PH**	**N**	**P**	**K**	**Weight**
LULC	0.297	0.274	0.327	0.307	0.340	0.317	0.293	0.293	0.293	0.304
Soil Texture (ST)	0.165	0.152	0.163	0.164	0.151	0.159	0.137	0.137	0.137	0.152
Elevation (EL)	0.037	0.038	0.041	0.037	0.057	0.048	0.044	0.044	0.044	0.043
Slope (SL)	0.059	0.057	0.068	0.061	0.057	0.060	0.066	0.066	0.066	0.062
Temperature (TE)	0.033	0.038	0.027	0.041	0.038	0.040	0.044	0.044	0.044	0.039
Soil Reaction (PH)	0.074	0.076	0.068	0.082	0.075	0.079	0.088	0.088	0.088	0.080
Nitrogen (N)	0.111	0.122	0.102	0.102	0.094	0.099	0.110	0.110	0.110	0.107

Phosphorus (P)	0.111	0.122	0.102	0.102	0.094	0.099	0.110	0.110	0.110	0.107
Potassium (K)	0.111	0.122	0.102	0.102	0.094	0.099	0.110	0.110	0.110	0.107
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

DISCUSSION OF RESULTS

The LULC classification indicate the percentage of LULC classes in the study area which describe farmland, vegetation, built-up, and water body in the study area. The analysis from the LULC as explained in table 1 and figure 2 clarifies the impact of built-up, unorganized farming activities, and climate change effect on arable land degradation. The effect of deforestation and urbanization in the FCT has depleted land for maize farming. This study has compile approaches that would enhance proper management of the remaining land resource.

The elevation results analysis as detailed in the table 2 and figure 3 explained elevation suitability for maize production. High and undefined elevation is not suitable for maize production. The study has a defined elevation with little percentage of ot not suitable for maize production. The results from the elevation analysis specified accurate location in the study area that are suitable or non suitable for maize production.

Similarly, slope is a function of water run-off. In an open area, water run-off along a sloping terrain is high and as such steep slope is dangerous for maize farming. The analysis in table 3 and figure 4 shows slope suitability for maize production in the study area. The direction of water flow can be determine using slope and elevation results and can be use to modelled additives for farm preparation for maize production.

Also, the soil chemical properties as analyzed in table 4, 5, and 6, and figure 5, 6, and 7 are contributing factors for, maize production. The chemical property of phosphorus, hydrogen, and Nitrogen are chemical element that help sustains maize heath and growth; these elements must be available in appropriate quantities in the soil for maize production. This study modelled these elements in the study area and analyzed their suitability for maize production in Kuje, Abuja.

Tentatively, Soil texture, reaction, and both chemical and physical properties are the first priority to consider when choosing a site for maize production. The study modelled soil characteristics, properties according to soil mapping units in the study area and analyzed soil suitability for maize production. The combined effect of all considered variables in this study was used to analyse land suitability for maize production. The robost information provided in the study could be harnest by farmers to appropriately select farm site for maize production. This proper selection of farm site would increase yield and maize productivities in the study area. The study recommends that, concerned authorities should extract information from this study to model land suitability of maize production in the Study area.

CONCLUSION

This study has used multi-criteria analysis of data acquisition, data analysis, and presentation was adopted to map out land suitability for maize production in the study area using geospatial techniques. GIS techniques of data acquisition, manipulation, and presentation were adopted. Variables such as LULC classes, soil properties, and chemical properties were modelled to analysed land suitability for maize production in the study area. The results generated from the study were stored in a GIS database management system.

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