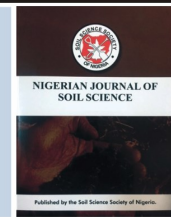




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Digital mapping of cultivated land in two Peri-urban areas of Ibadan, Nigeria

Tobore,¹ A. O., Alabi², K. O., Ogundiyi¹, T., and Bamidele¹, P.,

Department of Soil Science and Land Management, College of Plant Science and Crop Production, Federal University of Agriculture, P. M. B. 2240, Abeokuta, Ogun State, Nigeria

*Department of Crop Production, College of Agriculture, Kwara State University,
P. M. B 1530, Malete, Ilorin, Kwara State, Nigeria.*

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ABSTRACT

The need to save time, money and enhance quality as well as precise soil survey information through improved methodologies calls for digital soil mapping: hence, this study was conducted to map the peri-urban soils of Ajibode and Lade in Ibadan metropolis with digital method. Detailed soil survey using grid method was employed to cover the entire representative area for the study. Observation points were taken at a 100-meter interval. Six profile pits were dug, each at the three predominant land types viz: upper, middle and valley bottom in both locations. Profile pits were described and sampled for physical and chemical analyses following standard methods. Soil samples were collected at 0 -15cm and 15 - 30cm and further subjected to geospatial techniques for maize and cassava soil suitability production. Soils in Ajibode were classified as Iwaji Balogun and Oba series and fitted into Quartz-udic psamment according to USDA (2010) soil taxonomy system but correlated as Fluvisols following (FAO/UNESCO 2006). At Lade, soils were classified as Iwo, Balogun and Matakoko series. Iwo and Balogun series fitted into Rhodic-ustalf according to USDA (2010) and fitted as Lixisol in FAO/UNESCO (2006), while Matakoko series fitted into Dystric-fluvaquent (USDA, 2010) but qualified as Fluvisol FAO/UNESCO, (2006). Soils in Ajibode varied between moderately to marginally suitable for maize and cassava. In contrast, at Lade, it varied between moderately to marginally suitable for cassava and non-suitable for maize production. Mapping of soil using geospatial method helps to increase the efficiency of soil mapping, and thus recommended for precision and sustainable agriculture.

Corresponding Author's E-mail Address:

alabioyebisi@gmail.com +2348055741813

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1.0. Introduction

Peri-urban areas tend to undergo dramatic changes over a given period; however, peri-urban agriculture would be achieved if lands are categorized and utilized based upon their different uses (FAO.1983). However, the benefits that accrue from peri-urban agriculture, such as contributions to food security and sustainable livelihoods, are often under estimated (United Nations 2012). One of the essential factors of peri-urban agriculture is the need to increase crop yield through the proper management of soils resources to support the growing population which could help to attain a higher standard of living (Aldington, 1997). Hence, with the growing population and increase in

food products such as maize and cassava, there is need to adopt modern techniques such as geographic information systems which will help to record, store, analyze and retrieve data from many observations within the subjectively delineated landscape units and tend to increase food production (Burrough, 1991). The purpose of soil survey and mapping is to generate baseline information on soils including its genesis, characteristics, distribution and potential uses. The need to understand the soil and represent the soil individually, accurately on maps is known as soil survey. Conventional soil survey is limited when quick, accurate and up-to-date information about soil is required. Furthermore, traditional soil mapping serves as a means of understanding information about soil. Still the information

about the soil map will be quick, accurate and easy to update when it is complemented with a digital method. Digital soil mapping is a spatial soil information system created by numerical models that account for the spatial and temporal variations of soil properties based on soil information and related environmental variables (LagacherieMcBratney, 2014). However, the use of digital soil mapping, which is said to be a better alternative to conventional soil mapping needs to be explored, especially when a large area of lands are involved (Goodchild 1992). However, land suitability evaluation involves the identification and characterization of soils in a given area for specific land use type (Rossiter, 1990). Furthermore, the soil is likely to show considerable variability in their physical,

chemical, biological properties because the soil is a different unit. The study was designed to digitally map cultivated lands in two peri-urban areas of Ibadan which will assess the insignificant balance of food security and insecurity, thereby leading to food sufficiency.

1.1. The study areas

The city of Ibadan is located in South-Western, Nigeria. It is the capital of Oyo State. Ibadan lies substantially in a zone of transition between the humid and sub-humid tropical climates and lies between latitudes $7^{\circ} 16'$ North and $7^{\circ} 34'$ North, Longitudes $3^{\circ} 44'$ East and $4^{\circ} 02'$ East approximately 145 Kilometres North of Lagos (Fig. 1)

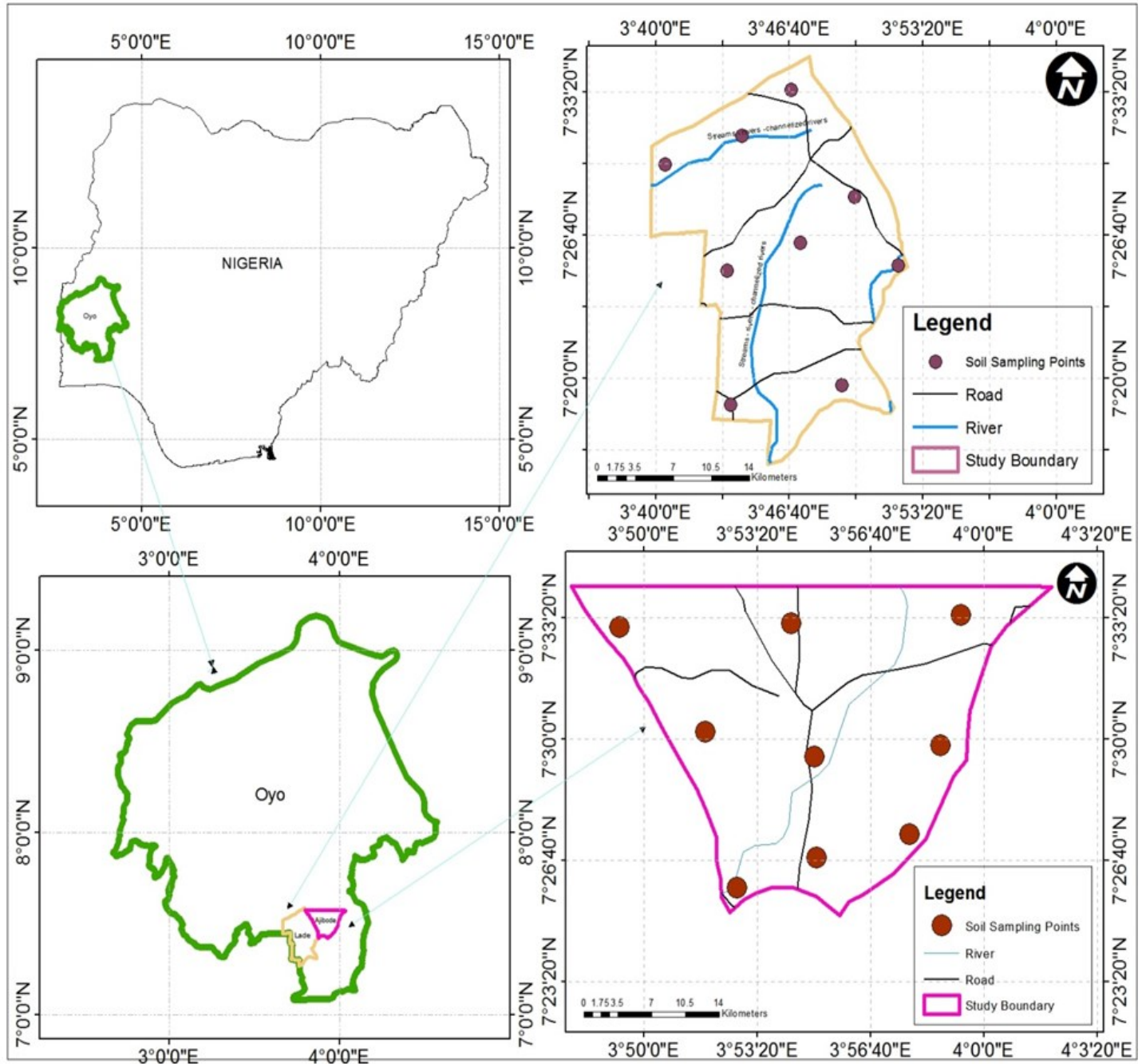


Figure 1: Map of the Study Area.

2.0. Methodology

2.1. Ancillary Data

For this study, Landsat satellite images of Ibadan were acquired for 1984, 2000, and 2015. All were obtained from the Global Land Cover Facility (GLCF), an Earth Science Data Interface. Ibadan falls into to Universal Transverse Mercator projection in zone 31N – Datum WGS84 and the pixel size is 28.5 meters. The band combinations used for this study were 4, 3, and 2 (RGB). Four categories of land use and land cover information were derived from the remotely sensed data. Thematic maps such as a base map and soil maps were also used. The ground control points were super-imposed using grid cell-based overlay-modeling technique.

2.2. GIS and remote sensing assessment

The ancillary data were assessed in ArcGIS 10.2 and ENVI 4.2. These include topographic maps (1:50,000), remote sensing imagery such as Shuttle Radar Topographic Mapper and Google Earth image of the year 2015. The topographic map was digitized to extract some features such as road, river and some settlement while the Google Earth was used to identify features for adequate classification. Satellite imagery and topographic map information were integrated to prepare the base map for the study area. After that, digital terrain and contour map was generated from the remote sensing imagery of shuttle Radar topographic mapper (SRTM) of 90-meter resolution which guides in soil unit identification. The land use and land cover of the year 1984, 2000 and 2015 of the study area was assessed in Envi 4.8 remote sensing using Landsat enhanced thematic mapper, supervised classification algo-

rithm of maximum classification algorithm were done and region of interest were used to identify land use and land cover features of the study area and this is bareground, vegetation (sparse and dense), waterbody, and built –up were identified using supervised classification algorithm, after that, post-classification of the land use and land cover were carried.

2.3. Soil mapping

The area was sampled using rigid grid sampling to cover the entire representative area selected for the study. A reconnaissance survey was carried out to have a general knowledge about the study area. After the reconnaissance, the base map was produced with the aid of a global positioning system and a topographic map of the study area. Soil samples were collected with the aid of soil auger at 100 m interval on predominant encountered land types (viz: Upper, middle and valley bottom). At each of the selected site, an area of 3 hectares were map Surface (0-15 cm) and sub-surface (15-30 cm). The surface soil samples were used for maize production since maize is a shallow crop while 15 -30 cm were used for cassava. Co-ordinates of the individual soil sampling points were documented. Representative profile pits (2 x 1.5 x 2 m) were dug, each at predominant land types or slope segments of the toposequence encountered on the site. A total of 6 profile pits were dug with 3 profile pits per location. The profile pits were described morphologically in line with the FAO, (2006) standard. Soil samples were collected from the different pedogenic horizons as well as core samples using core sampler into well labelled polyethene bags and then processed in the laboratory after air-drying at room temperature. Soil map of the study area as shown in figure 2

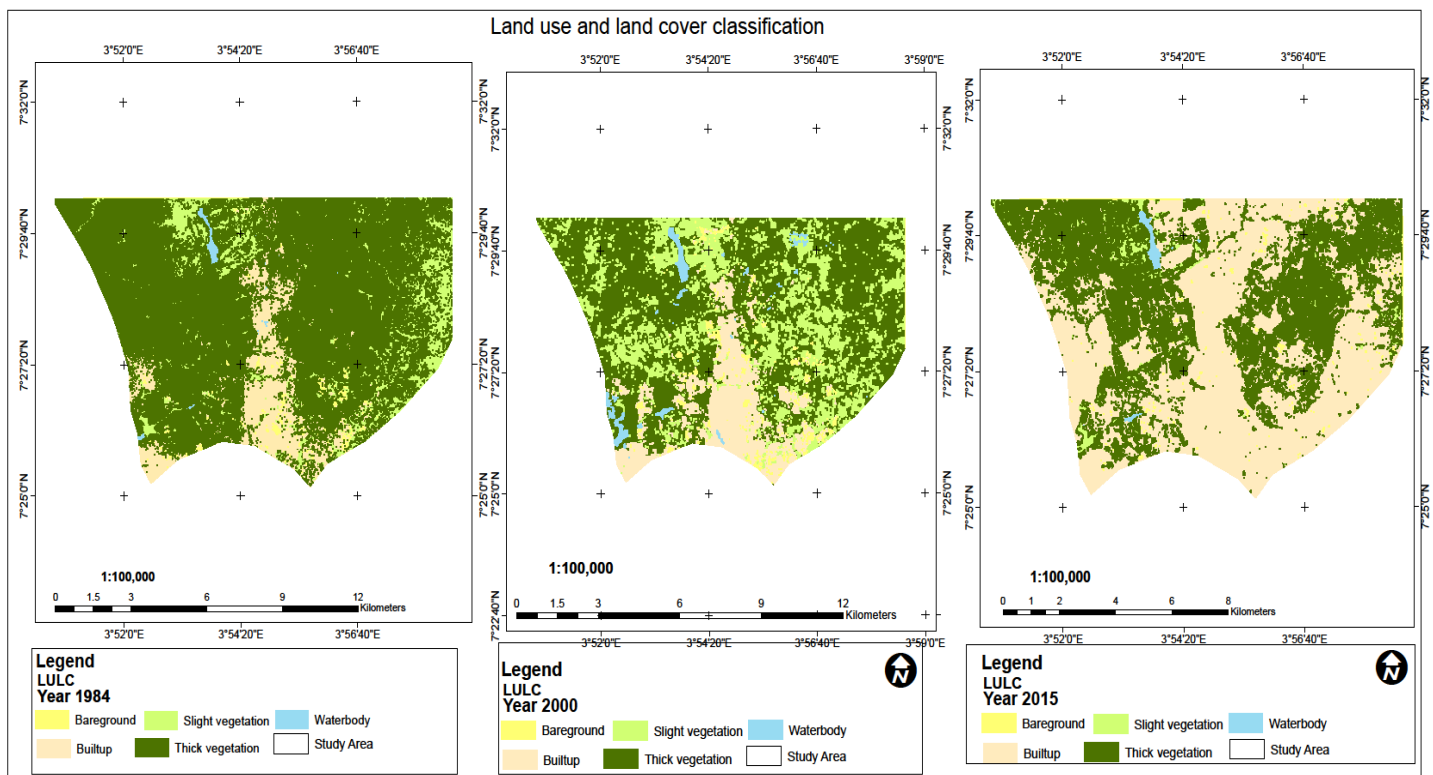


Figure 2: Supervised classification of Ajibode land use and land cover (Envi 4.8 and ArcGIS 10.2 software)

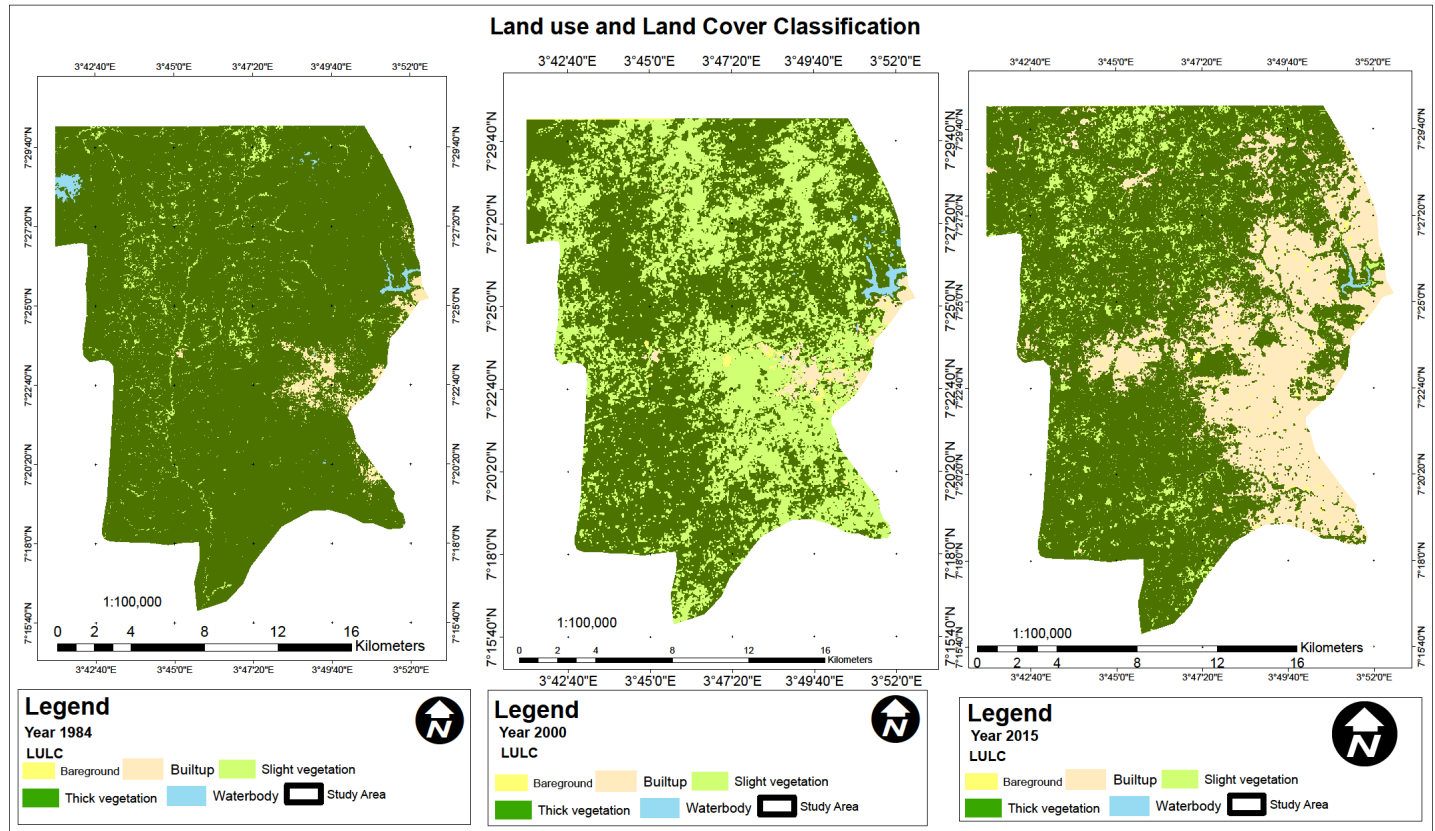


Figure 3: Supervised classification of Ajibode land use and land cover (Envi 4.8 and ArcGIS 10.2 software)

Laboratory Analysis

The following soil parameters were determined: nitrogen, potassium, phosphorus, cation exchanged capacity, soil texture, soil structure, hydraulic conductivity, bulk density and soil pH. The particle size was determined by the hydrometer method (Bouyoucous, 1962). Total N was determined calorimetrically. Available P was determined by Bray 1 method (Anderson and Ingram, 1993). Soil organic matter was determined by dichromate oxidation procedure (Walkley and Black, 1934). Exchangeable bases (Ca, Mg, K, and Na) were extracted. Soil pH was determined in a 1:2 soil to water suspension using a pH meter (Maclean, 1982) available P was determined by Bray 1 method (Anderson and Ingram, 1993). Bulk density (BD) was determined by the core method. This sample was oven-dried to constant weight at 105°C.

Suitability Analysis

The study area is divided into four suitability classes: highly suitable moderately suitable, marginally suitable and not suitable based on crop requirement of maize and cassava. Interpolation of the soil (Physical, and chemical) data were carried and this was done with the aid of tied ground control points and analyzed using inverse distance weighted techniques in spatial analyst tools in ArcGIS. After interpolation, the raster data obtained was classified, Group according to land requirements and suitability of maize and cassava soil nutrient rating using Oluwatosin and Ogunkunle (1991) and Ande (2011) and after that, the required soil nutrient was overlaid in order to produce

maize and cassava soil suitability map using maize and cassava suitability model of the dent and young (1981).

3.0. Results and Discussion

3.1. Assessments of Ajibode Land use/land cover (LU/LC) classification

The dense vegetation appears to be the most predominant land cover in 1984, covering 59.95% and sparse vegetation covered 32.12 % while built-up accounted for 6.49%, water-body covered 0.89% and the bare-ground covered 0.55%. In the year 2000, the dense vegetation covered 39.87% and sparse vegetation covered 19.95%. However, there was the sudden increase in the built-up and this showed the evidence of the encroachment of farmland into built areas, and this accounted for 30.12%, while the bare-ground was 5.83 % and water-body was 4.24%. However, it was observed in the year 2000 that the built-up were dominant than the Bareground. In the year 2015, fifteen (15) years from the previous year, the built-up increased further. However, the built-up areas increased to 79.66% which was 6.49% in 1984 and 30.12% in the year 2000. However, it was also observed that the dense vegetation decreased to 14.15% from 59.95% in the year 1984 and that of the sparse vegetation decreased to 1.70 % from 19.95% in 1984, while in the year 2000, dense vegetation accounted for 39.87 % and sparse vegetation covered 19.95%. However, bare-ground accounted for 2.26% was 0.55% in 1984, and in year 2000 it was 5.83% while water-body covered 2.23% which was 0.89% in 1984 and 4.24% in the year 2000 and this is shown in table 1.

Table 1: Ajibode Land use and land cover

LU/LC	Class-id	1984 sqKm	%	2000 sqKm	%	2015 sqKm	%
Built-up	1	16.29	6.5	75.64	30.1	200.07	79.7
Water-body	2	2.26	1.0	10.64	4.2	5.61	2.2
Bareground	3	1.37	1.0	14.64	5.8	5.67	2.3
Sparse Vegetation	4	80.67	32.0	50.09	19.9	4.26	1.7
Dense vegetation	5	150.55	59.9	100.13	39.9	35.53	14.1

3.2. Assessments of Lade Land use/land cover (LU/LC) classification

In 1984, the vegetation also appeared to be the most dominant land cover, having the dense vegetation to be 64.51%, while the sparse vegetation-covered 29.93%. However, the built-up accounted for 3.17 %; water-body covered 0.96% while the bare-ground covered 1.75%. It was further observed from the result of the year 2000 classification that the dense vegetation decreased from 64.51%, to 48.96% while the sparse vegetation also decreased from 29.93% to 16.43%. However, it was observed that built up increased in the year 2000 and this accounted for the 28.95% thereby decreasing in the year 1984, while the water-body also increased from 2.77% which was 0.96% in the year 1984 and the bare ground increased further to 3.35% which was 1.75%. In year 2015, fifteen years from the previous year, the built-up increased further. The evidence of the high density of the built-up areas is attributed

to the encroachment of farm land and conversion of farm-land into residential, industrial and commercial building having the built-up covering 58.21% which was 3.17 %, in 1984 and 28.95% in the year 2000. Furthermore, it was also observed that the dense vegetation decreased further to 19.21 % which was 64.51% in the year 1984 and that of the sparse vegetation decreased to 6.61% which was 29.93% in 1984, while in 2000, the dense vegetation accounted for 48.96% having the sparse vegetation to be 16.43%. However, bare-ground accounted for 6.54% which was 1.75% in 1984, and in the year 2000 it was 3.35% while water-body covered 9.52% which was 0.96% in 1984 and 2.77% in the year 2000 and this is shown in table 2. The Google earth image and a false colour composite of the studied locations of the year 1984, 2000 and 2015 are shown in figure 4, 5 and 6, while the land use and land cover classification were shown in figure 8. However, the confusion matrix was used to validate the accuracy of the classification, and this is shown in table 3 and 4.

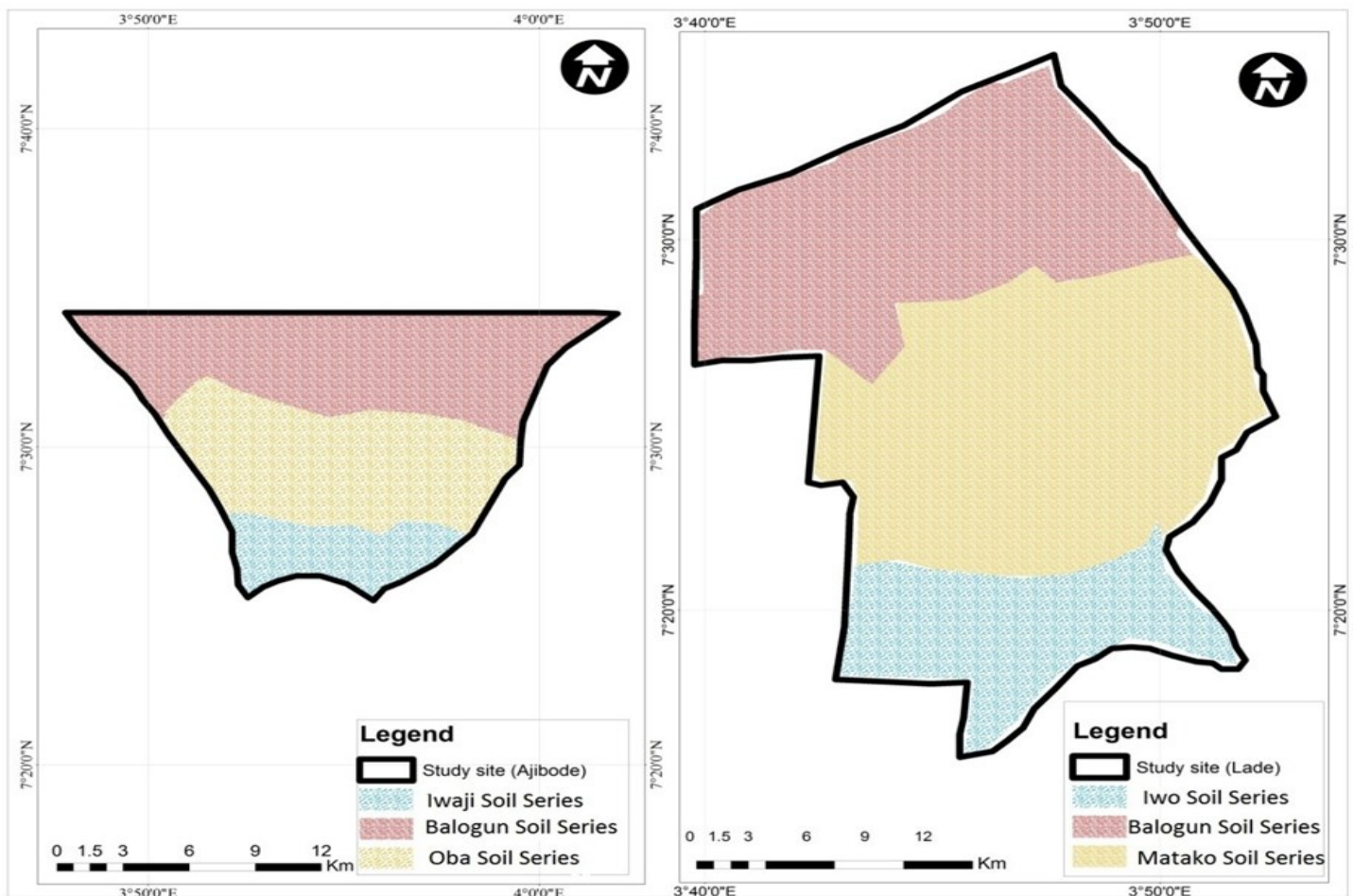


Figure 4: Soil map of the study area

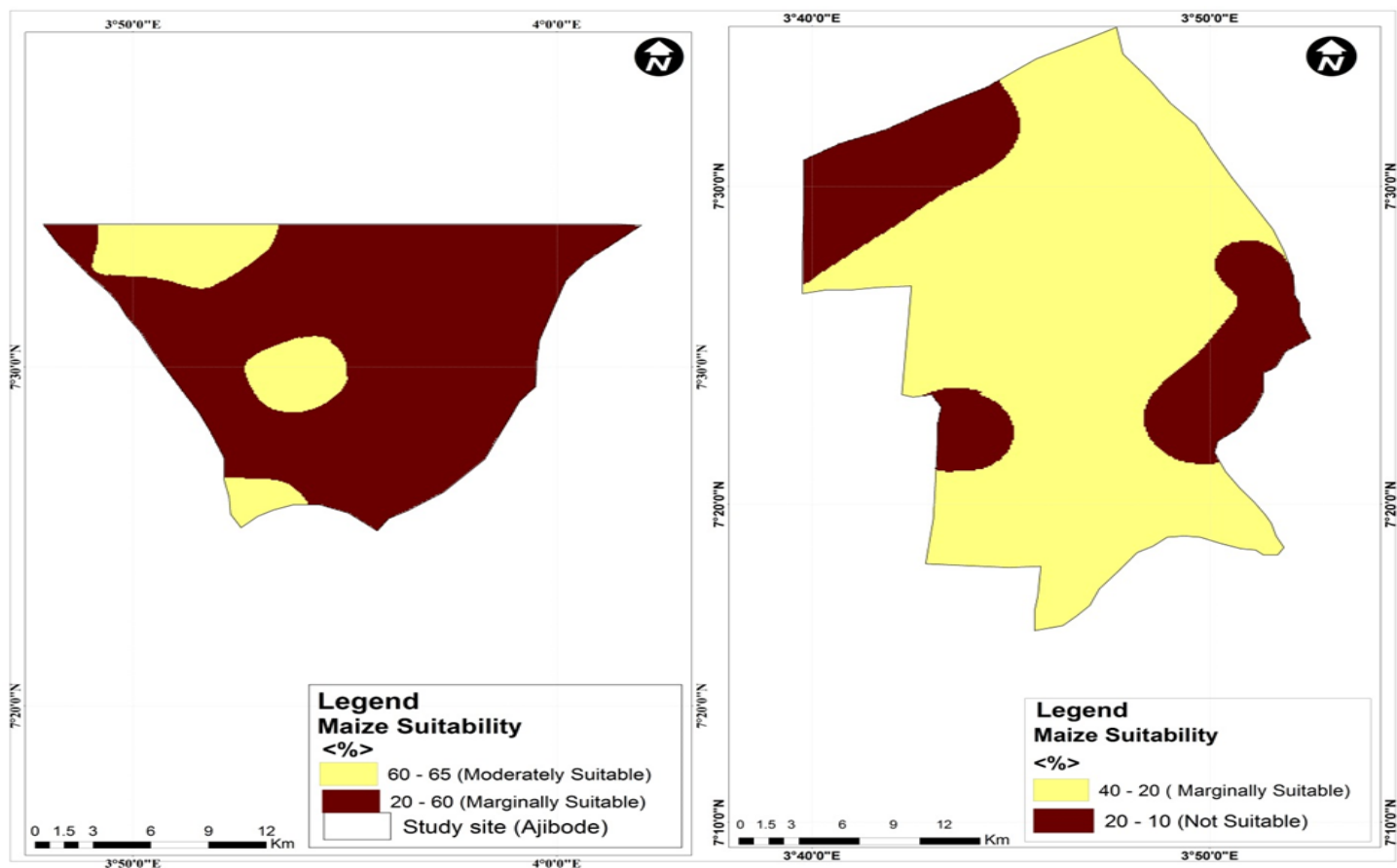


Figure 5: Maize suitability

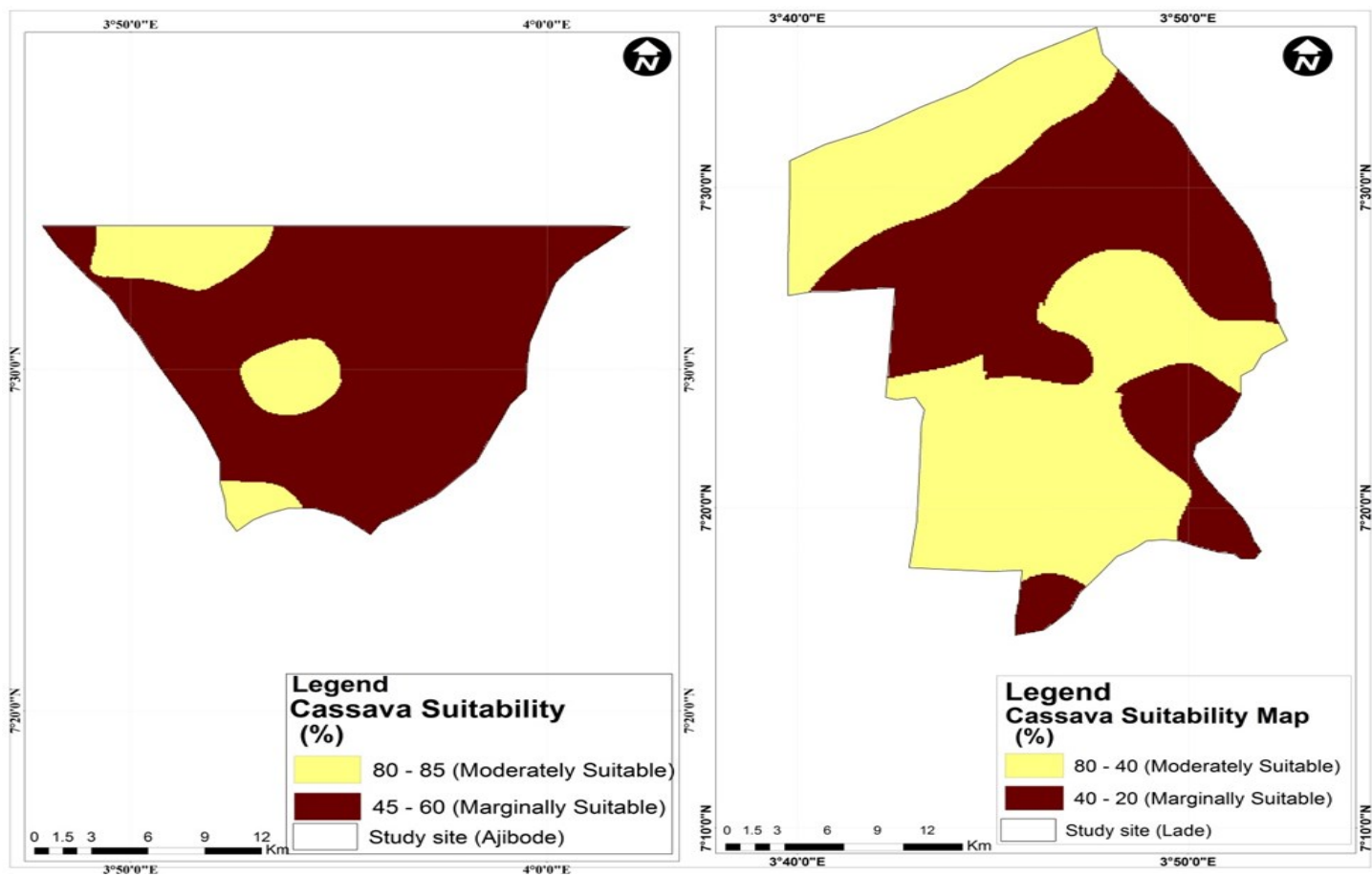


Figure 6: Cassava Suitability

Table 2: Lade Land use/land cover

LU/LC	Class-id	1984 sqKm	%	2000 sqKm	%	2015 sqKm	%
Built-up	1	9.89	3.2	90.49	29.0	181.9	58.3
Water-body	2	3.01	1.0	8.65	2.8	29.58	9.5
Bareground	3	5.47	1.8	10.46	3.4	20.46	6.6
Sparse Vegetation	4	93.53	30.0	51.33	16.5	20.77	6.7
Dense vegetation	5	201.56	64.3	151.52	48.6	60.01	19.2

Table 3: Ajibode Supervised Classification (Confusion matrix) Accuracy of the study site.

LU/LC	Class-id	Ground truthing (%)		
		1984	2000	2015
Built-up	1	23.76	39.66	57.00
Water-body	2	3.23	7.21	4.00
Bareground	3	0.48	2.01	13.00
Sparse Vegetation	4	27.23	26.55	12.00
Dense vegetation	5	45.31	24.56	14.00
Total		100	100	100
Overall Accuracy		96.52	95.31	97.71
Kappa Coefficient		0.95	0.95	0.96

Table 4: Lade Supervised Classification (Confusion Matrix) Accuracy of the Study site

LU/LC	Class-id	Ground truthing (%)		
		1984	2000	2015
Built-up	1	15.09	37.00	53.00
Water-body	2	5.23	13.00	15.03
Bareground	3	2.48	10.00	13.00
Sparse Vegetation	4	25.53	16.00	8.91
Dense vegetation	5	51.12	24.00	10.00
Total		99.45	100	99.94
Overall Accuracy		97.07	96.95	98.71
Kappa Coefficient		0.96	0.95	0.97

3.3. Physical and chemical properties of the studied soils

The physical and chemical distributions of the surface and sub-surface soils are shown in tables 5 and 6. The properties varied from one land type to another in the two locations to colour, texture, structure and consistency. The hydraulic conductivity has no definite sequence down the profile while the bulk density decreases with depth within the profile of the two study site. The texture varied from loamy sand to sandy clay from the surface horizon down to the sub-horizons across the land uses types in Ajibode while that of the soil texture in Lade varied from sandy loam to sandy clay loam. The soils colour varied from very dark brown (7.5 YR 2.5/2), dark reddish-brown (5 YR 3/3), dark yellowish-brown (10YR 4/6) to red-brown (5 YR 4/4) in the toposequence in Ajibode. In contrast, that of Lade varied from very dark greenish-brown (10YR 3/2), dark reddish-brown (7.5 YR 4/2) to yellowish-red (5YR 5/8) with the inclusion of yellowish-brown (10 YR 5/8). The two study site values have a basement complex indicating the origin of the study soils. The pH ranges between 4.61 – 5.88 (distilled H₂O), and for the pH (in KCl) ranges between 3.00 to 4.01 while that of the pH (Distilled H₂O) of the soil of Lade was acidic and it ranges between 5.69 to 6.21 at the surface and sub-surface, while that of the pH (in KCl) ranges from 4.00 to 5.51. The area receives yearly deposition of materials which make up for any nutrient loss due to cultivation and environmental is-

sues of degradation. The total nitrogen of the surface and sub-surface soil (Ajibode) ranged from high to very high (0.6 to 3.1 %) while that of the (Lade) surface and sub-surface soil ranged from medium to very high (0.03 – 3.1%) at the surface and sub-surface. The available phosphorus (Lade) concentration ranged from low to medium (1.32 – 8.89 mg/kg) at the surface and that of the sub-surface while that of the Ajibode ranged from low to medium (1.59 to 8.14mg/kg) at the surface and that of the sub-surface. Potassium ranged from very low to low (0.01 to 0.3 cmol/kg), copper (Cu) ranged from high to very high (1.33 to 6.48 mg/kg) at the surface and the sub-surface across the (Lade) profile pit, while that of the Ajibode ranged from high to very high 1.84 to 3.56 (mg/kg)) at the surface and sub-surfaces while that of the iron (Fe) ranged from high to very high (130.60 – 233.85 ppm) in Lade while that of the Ajibode surface and sub-surface ranges from high to very high (100.64 - 208.08 mg/kg). The high concentration of iron (Fe) content is as a result of deposition of industrial effluent or discharge to the river which flows across both study sites. Zinc (Zn) ranged from low to high (1.26 to 5.05 mg/kg) at the surface and sub-surface while that of the Ajibode ranges from low to high 1.70 to 4.20 (mg/kg)) at the surface and that of the sub-surface. The result of the micro-nutrients in the study site shows that the distribution of these elements was irregular down the soil profile. The Ajibode soil organic matter (SOM) content ranged from low to high (1.60 - 4.09 %) while

Lade ranged from low to high (1.22 – 4.21%) from the surface and sub-surface across the two-study site. It was also noticed that the SOM was higher in the soil surface

than the sub-soil and this could be an indication of the presence of deposition on the waste bin that was deposited by the people living around the study area.

Table 5: Morphological descriptions of the soils in Ajibode (Akinyele LGA)

Soil Series	Horizon Designation	Depth (cm)	Soil Colour	Munsell Colour	Texture	Structure	Consistence	Root Conc.	Boundary
IWO	Ap	0 – 5	db	10 YR2/1	SL	msab	h,vf,ns,np	af	cs
	B1	5 - 15	db	7.5YR 5/4	SL	msab	h,vh,vf,ss,p	mf	cs
	B2	15 -29	drb	2.5 YR ¾	SC	msab	vh,vf,ss,p	mf	wb
	B3	29 - 60	sb	7.5 YR 5/6	SC	msab	vh,f,vs,p	ND	ND
	Bt	60 - 110	Yr,g	5 YR 5/8, 10YR 5/1	SC	wsab	vh,f,np,ss	ND	ND
Balogun	Ap	0 - 11	dgb, vdgb	10 YR 4/2, 10 YR 3/2	SL	msab	l,f,np,ns	mcf	wb
	A1	11 - 33	yb, dyb	10 YR5/4, 10 YR 3/2	SC	wsab	l, f,sp,ss	mcf	cs
	B1	33 - 40	yb	10 YR 5/8	SC	wsab	sh,f,ss,sp	ccf	cs
	B2	40 - 80	rb	5YR 4/6	SC	msab	vh,f,ms,sp	ND	cs
	B3	80 - 100	rb	5YR 4/6	SC	wsab	vh,f,np,ss	ND	ND
Matako	Ap	0 - 10	db	10YR 3/3	SC	msab	h,vf,ss,np	mf	cs
	A1	10 - 47	db	7.5YR 3/2	SC	msab	h,vh,vf,ss,p	mf	gv
	B1	47- 60	b,drb	7.5YR 4/2, 2.5 YR ¾	SL	msab	vh, vf,ss,p	ff	cs
	B2	60 - 80	sb,g,yr	7.5YR 4/2, 2.5YR ¾	SL	mab	vh, vf,vs,p	ND	cs
	B3	80 - 90	g	10YR 5/1,	SL	wsab	vh, f, np,ss	ND	cs

Texture: sl = sandy loam, sc = sandy clay, cs =clay sand, scl= sandy clay loam, s=sandy; bStructure: msab= medium sub angular blocky, wsab =weak

sub angular blocky;°Consistence: h =hard, vh =very hard, ns = non sticky, npl= non plastic, h= hard, vh=very hard, vf= very firm, ss=slightly sticky,

p=plastic, f=friable, nst =non-sticky, spl = slightly plastic, dConcretion: af = abundant fibrous, mf=many fibrous, ff-few fibrous, mcf= many coarse fibrous,..ccf=commoncoarse-fibrous.Boundary:cs=clear-smooth,wb=wavy-boundary,ND=not-determined

Table 6: Morphological description of the soils in Lade (Ido LGA)

Soil Series	Horizon Designation	Depth (cm)	Soil Colour	Munsell Colour	Texture	Structure	Consistence	Root Conc.	Boundary
IWO	Ap	0 – 5	db	10 YR2/1	SL	msab	h,vf,ns,np	af	cs
	B1	5 - 15	db	7.5YR 5/4	SL	msab	h,vh,vf,ss,p	mf	cs
	B2	15 -29	drb	2.5 YR 3/4	SC	msab	vh,vf,ss,p	mf	wb
	B3	29 - 60	sb	7.5 YR 5/6	SC	msab	vh,f,vs,p	ND	ND
	Bt	60 - 110	Yr,g	5 YR 5/8, 10YR 5/1	SC	wsab	vh,f,np,ss	ND	ND
Balogun	Ap	0 - 11	dgb, vdgb	10 YR 4/2, 10 YR 3/2	SL	msab	l,f,np,ns	mcf	wb
	A1	11 - 33	yb, dyb	10 YR5/4, 10 YR 3/2	SC	wsab	l, f,sp,ss	mcf	cs
	B1	33 - 40	yb	10 YR 5/8	SC	wsab	sh,f,ss,sp	ccf	cs
	B2	40 - 80	rb	5YR 4/6	SC	msab	vh,f,ms,sp	ND	cs
	B3	80 - 100	rb	5YR 4/6	SC	wsab	vh,f,np,ss	ND	ND
Matako	Ap	0 - 10	db	10YR 3/3	SC	msab	h,vf,ss,np	mf	cs
	A1	10 - 47	db	7.5YR 3/2	SC	msab	h,vh,vf,ss,p	mf	gv
	B1	47- 60	b,drb	7.5YR 4/2, 2.5 YR 3/4	SL	msab	vh, vf,ss,p	ff	cs
	B2	60 - 80	sb,g,yr	7.5YR 4/2, 2.5YR 3/4	SL	mab	vh, vf,vs,p	ND	cs
	B3	80 - 90	g	10YR 5/1,	SL	wsab	vh, f, np,ss	ND	cs

Texture: sandy loam, sc = sandy clay, cs =clay sand, scl= sandy clay loam, s=sandy; bStructure: msab= medium sub angular blocky, wsab =weak sub angular blocky; cConsistence: h =hard, vh =very hard, ns = non sticky, npl= non plastic, h= hard, vh=very hard, vf= very firm, ss=slightly sticky, p=plastic, f=friable, nst =non-sticky, spl = slightly plastic, dConcretion: af = abundant fibrous, mf=many fibrous, ff-few fibrous, mcf= many coarse fibrous ccf=common coarse fibrous. Boundary: cs=clear-smooth,wb=wavy-boundary,ND=not-determined.

Table 7: Chemical soil properties of soil sampling at 0 -30 cm (Ajibode study Area).

Soil depth	Horizon designation	Sand	Silt	Clay	Texture	pH (H ₂ O)	pH (Kcl)	Na (cmol/kg)	BS %	CEC (cmol/kg)	K (cmol/kg)	P (mg/kg ¹)	N g/kg	OM g/kg
Upper Slope (Iwaji Soil series)														
0 – 11	Ap	76.02	9.20	14.80	SL	5.27	4.27	0.51	98.11	3.28	0.64	4.16	2.25	44.1
11 - 30	Bt	80.60	9.00	10.40	SC	5.56	4.40	0.39	96.58	4.52	0.87	3.64	2.32	24.0
30 -50	B1	74.40	12.40	13.20	SL	5.78	4.95	0.59	98.33	4.45	0.99	3.04	2.15	25.2
50 - 85	B2	80.00	9.60	10.40	SC	5.23	4.61	0.43	97.24	3.24	0.61	0.94	2.99	32.1
85 - 110	C	73.20	12.80	14.00	SL	5.76	4.41	0.98	97.42	3.49	0.94	1.32	2.00	32.8
Middle Slope (Balogun soil series)														
0 - 9	Ap	80.00	9.20	10.80	SL	5.34	4.59	0.52	95.51	3.66	0.72	0.85	3.22	32.8
9 - 24	Bt	71.20	14.00	14.80	SC	5.78	5.56	0.44	98.17	3.82	0.76	4.68	2.76	40.3
24 - 38	B1	72.40	14.40	13.20	SL	5.94	4.89	0.32	96.58	3.33	0.65	4.95	2.87	24.3
38 - 79	B2	80.60	8.40	11.00	SC	5.00	4.33	0.44	97.09	3.24	0.56	4.07	3.12	34.2
79 - 112	C	72.00	13.20	14.80	SC	5.40	4.45	0.74	95.66	4.37	0.77	3.74	2.99	21.0
Valley bottom (Oba soil series)														
0 - 4	A	79.00	9.20	11.80	SL	5.53	4.59	0.51	96.35	4.66	0.99	0.98	3.22	31.1
4 - 13	A1	74.40	12.00	13.80	SC	5.88	4.61	0.49	97.49	5.30	0.92	3.24	2.89	33.4
13 - 24	B1	72.80	13.20	14.00	SL	5.23	4.67	0.59	96.45	4.49	0.74	0.47	2.67	23.4
24 - 42	Bt	73.20	12.00	14.80	SC	5.40	5.65	0.74	97.34	4.88	0.87	4.69	2.69	41.1
42 - 90	C	73.30	12.70	13.59	SC	5.00	5.55	0.79	97.65	4.26	0.98	2.32	2.32	31.2

Table 8: Chemical soil properties of soil sampling at 0 -30 cm (Lade study Area).

Soil Dept (cm)	Horizon Designation	Sand	Silt	Clay	Texture	pH (H ₂ O)	pH (Kcl)	Na (cmol/kg)	BS %	CEC (cmol/kg)	K (cmol/kg)	P (mg/kg)	N g/kg	OM g/kg
Upper (Iwo soil series)														
0 – 5	Ap	86.00	9.20	13.80	SL	5.71	4.27	0.49	97.09	4.29	0.77	1.90	3.21	35.1
5 - 15	B1	80.60	8.00	11.40	SL	5.56	4.75	0.53	96.45	4.56	0.67	1.64	1.32	44.0
15 -29	B2	84.40	12.00	14.60	SC	5.23	4.81	0.60	95.51	3.87	0.75	1.04	2.52	30.1
29 - 60	B3	80.60	9.00	10.40	SC	5.87	4.61	0.23	96.60	3.45	0.60	1.94	1.61	29.1
60 - 110	Bt	83.10	11.10	14.80	SC	5.34	4.43	0.34	96.36	4.65	0.60	1.43	3.21	30.8
Middle (Balogun soil series)														
0 - 11	Ap	74.00	10.20	14.80	SL	5.76	4.54	0.65	98.07	4.56	0.59	2.74	3.32	29.0
11 - 33	A1	80.00	8.20	11.80	SC	5.09	4.98	0.87	97.42	3.56	0.84	1.85	1.91	23.8
33 - 40	B1	80.20	9.00	10.80	SC	5.75	5.08	0.98	97.26	4.34	0.64	2.34	2.51	34.3
40 - 80	B2	72.00	10.80	13.20	SC	6.32	4.32	0.54	96.65	3.76	0.84	2.95	2.94	44.3
80 - 100	B3	80.60	7.40	12.00	SC	5.87	4.87	0.98	97.45	4.02	0.97	1.07	3.31	31.2
Valley (Matako soil series)														
0 - 10	Ap	79.00	9.20	11.80	SC	5.55	4.43	0.65	98.17	4.92	0.71	2.92	2.51	29.1
10 - 47	A1	74.20	9.00	14.80	SC	5.43	4.65	0.43	96.58	3.95	0.78	2.24	3.62	23.4
47- 60	B1	72.80	10.20	14.00	SL	5.75	4.76	0.87	96.65	3.23	0.88	3.47	3.11	27.4
60 - 80	B2	73.20	9.00	14.80	SL	6.21	5.51	0.60	98.87	4.72	0.72	5.69	3.52	39.1
80 -90	B3	77.10	10.00	12.90	SL	6.13	5.12	0.78	98.12	4.21	0.87	5.56	3.23	37.9

Table 9: Land requirements and suitability classes for rainfed maize production

Land characteristics	SI1 100	SI2 95	S2 85	S3 60	N1 40	N2 25
Topography (t)						
Slope (%)	0-2	2-4	4-8	8-16	16-20	>20
Slope (%)	0-4	4-8	8-16	>16	-	-
Moisture availability (c)						
Total rainfall during the growing season (mm)	800-1200	700-800	600-700	500-600	<500	-
Oxygen availability (w)						
Drainage	Good	Moderate	imperfect/rapid	poor/very excess	poor but drainable	poor but not drainable
Nutrient availability (0-20cm) (f)						
Total N (%)	>0.15	0.08-0.15	0.08-0.04	0.02-0.04	<0.02	any less
Avail P (mg/kg)	>22	13-22	6-13	3-6	<3	any less
Potassium (Cmol/kg -1)	>0.5	0.3-0.5	0.2-0.3	0.1-0.2	<0.1	Any
CEC (Cmol/kg -1)	>15	10-15	5-10	3-5	<3	-
Base saturation						
(c) (%)	>80	30-50	35-50	20-50	<20	-
(%)	>70	50-70	35-70	<35	-	-
Organic matter						
(c) (g/kg)	>3	1-3	0.8-1	0.4-0.8	<0.4	-
Physical soil characteristics						
Texture/structure Gravel	CL	SC, SCL, L	SL, LS	LS, fS	Cm, S, cS	-
(ac) (%)	<15	15-40	40-60	60-75	75-90	>90
(b) (%)	<40	40-75	75-80	80-90	>90	-
(%)	<20	20-40	40-75	>75	-	-
Soil depth (cm)	>90	50-90	30-50	20-30	10-20	<10
Bulk density (g/cm ³)	<1.0	1.0-1.21	1.22-1.51	1.51-1.63	1.63-2	>2

Source: Oluwatosin and Ogunkunle (1991) L = Loamy; SC= Sandy clay; LS =Loamy sand; S = sand; SCL =Sandy Clay Loam

Table 10: Land requirements and suitability classes for cassava production

Land qualities	SI1 100	SI2 95	S2 85	S3 60	N1 40	N2 25
Climate (c)						
Annual rainfall (mm)	>1000	900-1000	800-900	600-800	500-600	<500
Temperature (°C)	>25	22-25	20-22	18-20	16-18	<16
Topography (t)						
Slope (%)	<2	2-4	4-8	8-16	16-20	>20
Drainage (w)						
Wetness	WD	MWD	MD	ID	PD	P
Soil physical properties (s)						
Texture	L	LS	SCL	SC	S	-
Gravel (%)	<10	10-20	20-30	30-40	>40	-
Soil depth (m)	>100	80-100	60-80	50-60	35-50	<35
Nutrient availability (f)						
pH	>8	7-8	4.5-7	3.5-4.5	<3.5	-
Total N (%)	>0.15	0.08-0.15	0.04-0.08	0.02-0.04	<0.02	-
Avail P (mg/kg)	>15	10-15	8-10	5-8	3-5	-
Extract. K (cmol/kg)	>0.25	0.20-0.25	0.15-0.20	0.10-0.15	<0.10	-
Cu (mg/kg)	>5	1-5	0.3-1	0.1-0.3	<0.1	-
Mn (mg/kg)	>250	100-250	10-100	5-10	<5	-
Fe (mg/kg)	>120	100-120	10-100	1-10	<10	-
Zn (mg/kg)	>50	5-50	1-5	0.5-1	<0.5	-
Nutrient retention (n)						
Organic matter (%)	>4	3-4	2-3	1-2	<1	-
CEC (cmol/kg)	>15	10-15	5-10	3-5	<3	-
Base saturation (%)	>80	50-80	35-50	20-35	<20	-

WD = Well Drained; MWD; = Moderately Well Drained; ID = Imperfectly Drained; PD = Poorly Drained; L = Loamy; SC= Sandy clay; LS =Loamy sand; S = sand; SCL =Sandy Clay Loam. Source: Ande (2011)

3.4. Classification of the studied soils

The topographic position, soil morphology and mode of formation of parent materials were the main criteria used in classifying the soils into the series level as reported by Smyth and Montgomery (1962). The soils of Lade toposequence were classified as Iwo (upper), Balogun (mid-slope) and Matako (Lower slope) series. In contrast, that of Ajibode was classified as Iwajii (upper), Balogun (mid-slope) and Oba (Lower slope) series. The soil moisture regime of the study area is ustic, the soil temperature regime was classified as Isohyperthermic (USDA, 2010). The Iwo and Balogun soils series are classified as Entisols. In contrast, Matako, Oba and Ekiti soil series were classified as Inceptisols and Entisols (Order) based on minimal horizon development within the profile. The Iwo and Balogun soil series fitted into Ustalf at sub-order due to the clay illuviation at the B horizon. At the great-group the Balogun is fitted into Rhodiudicstalf due to Rhodic colour grade. The Iwo and Ekiti series parent material is coarse-grained granite gneiss and this is due to the granite stone present at the 60 -110 cm depth while that of the Balogun series is plinthic and this is due to the presence of hard pan at 100cm depth. Therefore, it was classified as Rhodicudistalf (USDA, 2010) and correlated as Lixisol (FAO/UNESCO, 2006). The parent material of Matako is fluvic and this is due to the presence of water or river body in the study area and Dystric which is as a result of low base saturation which is less than 99%. Therefore, it was classified as Dystric-fluvaquent (USDA, 2010) and correlated as Fluvisol (FAO/UNESCO, 2006).

3.5. G.I.S soil suitability assessment

Tables 9 and 10 below show the land requirement and soil suitability rating for maize and cassava and soil suitability scale model used in the study area. The study shows that suitability of maize and cassava can be achieved by assessing soil qualities that are nitrogen, potassium, phosphorus, organic matter, base saturation, annual temperature, relative humidity, cation exchanged capacity, soil texture, slope, drainage, rainfall and land management techniques. The study area was divided into four relative suitability classes, namely; highly suitable as (S1), moderately suitable as (S2), marginally suitable (S3) and not suitable (N4). The maize production in Ajibode study site covered 60% – 65% (moderately suitable) and 20% – 60% for marginally suitable, while the cassava production was covered with 80% – 85% (moderately suitable) and 45 – 60% (marginally suitable). Lade maize production were covered with 20% -40% (marginally suitable) and 10% - 20% (not suitable) while the cassava production was covered with 40% - 80% (moderately suitable) and 20% - 40% (marginally suitable). The Ajibode suitability reveals that most of the area is dominated by moderately and marginally suitable. It was observed during the study that the farmers in the study sites were found to be operating the bush burning and shifting cultivation and homestead farming systems which includes the addition of animal waste/crop residues to the soils. The suitability assessment results showed that certain qualities or characteristics such as mean annual temperature, relative humidity and base saturation were optimum for maize cultivation, the result

of the maize suitability showed that Lade is marginally (S3) and not suitable (S4) while that of Ajibode were moderately (S2) and marginally suitable (S3), there was however, no highly suitable (S1) land for maize cultivation in both study areas. For the cassava soil suitability, Lade and Ajibode were moderately (S2) and marginally suitable (S3). The suitability of the study soil was classified to moderately, marginally and not suitable. However, the suitability is attributed to the low nutrient of potassium and phosphorus, which affect the physiological growth and tends to reduce crop yield. However, to increase the yield of maize and cassava production in the study site, there must be appropriate agricultural management techniques (erosion control, leaching, and application of appropriate rate of fertilizer) that must be taken into consideration when these soils become under cultivation to have certainties in the yearly production of maize and cassava, and thus leading to farmer's risk of crop failure in the study sites. Lade soil suitability reveals that the not suitable for maize production area shows, the limitation in the soil nutrients which could be attributed to the continuous use of the land for farming. However, to address the soil nutrient deficiency in Lade study site there is need to increase the fertility status of the study sites by adding adequate fertilizer such as Nitrogen, phosphorus and potassium and also by integrating organic and inorganic fertilizer which will increase the yield of maize and cassava production. Besides, the not suitable area in Lade study site could also be as a result of the deposition or discharged of effluents or waste of industries and communities to Ona river which flows through the study sites which tends to have the tendency of the study sites been waterlogged.

4.0. Conclusion

There should be an active land use policy that will guide agricultural land for future use. The use of satellite imagery will also help to facilitate the assessment of land use and land cover leading to the judicious and appropriate use of land. However, to address the challenges of increased in food production, to meet the nutritional needs of the teeming population, and to diversify the economic base through the provision of raw materials for the local agro-based industries, and export income, hence there is need to adopt modern methods and technologies of agricultural products such as precision farming that could be facilitated using remote sensing and geospatial techniques with the use of remote sensing and GIS which will help in regular update of soil data and remove limitations in their uses.

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