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Properties and land suitability evaluation of selected soils of Umueje, south- east Nigeria for yam (*Discorea spp*.) and oil palm (*Elaeis guinensis*) cultivation

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ABSTRACT

The study was conducted to characterize and assess land suitability of selected soils of Umueje, Ayamelum LGA, Anambra State Nigeria with a view to making adequate management practices for sustainable production of yam (*Discorea spp*.) and oil palm (*Elaeis guinensis*) in the area. Three mapping units (ANU1, ANU2 and ANU3) were delineated using the transect method with several auger investigations. Five representative profile pits were dug and described *in situ* for morphological properties. Soil samples were collected from the identified horizons and analyzed for physical and chemical properties. The results showed that ANU1, ANU2 and ANU3 were imperfectly, moderately and well drained respectively. Textural classes observed were sandy loam, loam sandy clay loam, clay loam and clay with irregular distribution of soil separates down the pedal depths. Bulk density was below the critical limit (1.75–1.85kgm^{-3}). The soils were strongly acid (5.08–5.95) with moderately low values of total nitrogen (0.06 – 0.11%), available phosphorus (10.65 – 12.83mgkg^{-1}) and exchangeable potassium (0.14 – 0.21cmolkg^{-1}) but high in organic matter (1.44 – 2.24%). Base saturation was generally high (67.72 – 72.97%) and cation exchange capacity was low (6.14 – 7.51cmolkg^{-1}). Aggregate suitability evaluation showed that optimal performance of ANU1 was constrained by poorly drained condition and thus, currently marginally suitable (S3) for the cultivation of yam and oil palm. The current suitability of ANU2 was moderate (S2) for the cultivation of yam and oil palm while ANU3 was moderate (S2) for yam but marginal (S3) for oil palm cultivation with fertility (f) as limitations. Adequate soil management practices such as drainage, liming, organic manuring and use of fertilizers should be encouraged for optimal production of the selected crops.

1.0 Introduction

Adequate information on the land resources and distribution followed by the suitability evaluation of the resources for specific uses has been reported as the starting point towards sustainable soil management for sustainable crop production (Ogunkunle 2004; Aderonke and Gbadegesin, 2013). Regrettably, this direction is not followedin the developing world where the use to which a land is put is often not related to its carrying capacity.

Soil is an important non-renewable land resource that determines the agricultural potential of a given area (Buol *et al.*, 2003) thus, its sustainable use is necessary for a successful agriculture to meet the increasing demand of food from the decreasing per capital land. Fasina *et al*., (2007) reported that the ability to maximally harness the potential of any soil is anchored on the correct interpretation of the survey report (evaluation) of that soil. Therefore, a comprehensive diagnosis of the production potentials of natural resources (climate, soil, topography and hydrology) dictates the use to which land may be put.

Land evaluation interprets soil survey reports and provides information on the soils' potentials and responses of the soils to manipulative management for the sustained agricultural production (Esu, 2004; Fasina and Adeyanju, 2006). Thus, land evaluation is very essential for land use planning as it guides decisions on land utilization for sustainable land management.

Poor knowledge and appraisal of suitability of parcels of land for sustainable agricultural production has been reported to constitute the current major problem of agricultural development in Nigeria,leading to poor farm management practices, low yield and unnecessary high cost of production (Udohand Ogunkunle, 2012). The knowledge of soil limitations arising from land evaluation reports aims at ameliorating such limitations before, or during cropping period (Lin *et al.,* 2005). The performance land fitness for specific purpose is based on matching qualities of the land in specific area with the requirements of actual or potential land utilization types.

Yam (*Dioscorea spp*), a staple tuber crop of the Nigerian and West African diet provides some 200 calories of energy per capita daily (Aighewi *et al.,* 2015). The current domestic production of yam in Nigeria seems not to meet the growing demand. The shortfall has been consequent upon low yielding varieties and more importantly, poor (low fertility) soils used for yam production among others(Aighewi *et al.,* 2015).

Oil palm is a tropical tree crop which is mainly grown for the industrial production ofvegetable oil. For optimal growth and production the crop requires a high and yearroundrainfall with little or no dry season and stable high temperatures; soils should bedeep and well drained (Ogunkunle, 1993). Declining yields in oil palm fresh fruit bunch overthe past years in the southeast Nigeriahave been attributed to lack of detailed pedological information to guide plantation establishmentand management (Udoh, 2008).Due to lack of guidance, many farmers cultivate crops on soils that may not be suitable for their sustainable production of oil palm. Ineffective and unplanned use of agricultural land has posed a serious challenge to the sustainability of agricultural productivity in Nigeria (Fasina *et al*, 2007). Therefore, there is need to have an effective land conservation for appropriate allocation of each parcel of land to its suitability.

In view of this, the study was carried out to characterize and assess land suitability of selected soils of Umueje, Ayamelum Local Government Area of Anambra State, Nigeria with a view to making adequate management practices for sustainable production yam (*Discorea spp*.) and oil palm (*Elaeis guinensis*) in the area.

2.0 Materials and Methods

2.1. Study Area

The study was conducted on a 12.45 ha of land inUmueje, Ayamelum Local Government Area of Anambra state, South-eastern Nigeria. It lies roughly between latitudes 6˚ 40' 55'' and 6˚ 41' 25'' N and longitudes 6˚ 55' 50'' and 6˚ 56' 15'' of the Greenwich Meridian with altitudes ranging between 28 and 42 meters above sea level (m asl). The topography is gentle with slope gradient not more than 5 %. The terrain generally slopes gradually towards the River Anambra which is the major river in the area.

The geology consists mainly of Imo clay shale formation, which is predominantly composed of cretaceous shale of tertiary age and alluvium which were previously laid down by River Niger but later reworked and redeposited by River Anambra (Ngede, *et al*., 2020). The general climate of the area is humid tropical with bi-modally distributed annual rainfall (2000 mm) and mean annual temperature of about 27°C (NOAA/NCEP (2021). Vegetation is largely woody savanna with grassy and herbaceous undergrowth and has been influenced by man activities through bush burning, clearing and land cultivation. The large forest trees known to have been dominant vegetation have given way to shrubs and grasses. The Some varieties of tree crops found in the area include: 'ogbono' (*Irvingia spp*), oil palm (*Elaeis guinensis*), ukpa-ka (*Pentacletra microphylla*) and mango (*Mangifera indi-ca*). The grasses and weeds in the area include: gambia grass (*Andropogon gayanus*), spear grass (*Imperata cylin-drica*) and siamweed (*Chromolaena odarata*). The common arable crops in the area are, rice (*Oryza sativa*), maize (*Zea mays*), cocoyam (*Colocasia esculenta*), yam (*Dioscorea Spp*) and cassava (*Manihot Spp*).

2.2. Field method

Reconnaissance visit was conducted to obtain relevant information about the project area through physical observation of different physiographic features. A perimeter survey of the land area was thereafter carried out and the project site geo-referenced using Global Positioning System (GPS) receiver (Fig. 1). Traverses were created through the area. The soils were augered at 0-20 and 20-40 cm depths. At each auger point, observations including colour, texture, slope, and drainage status were used to delineate the site into three mapping units namely ANU 1, ANU 2 and ANU 3 and a total of five profile pits were dug across the three mapping units. The profile pits were described for their morphological attributes, in line with the procedure recommended by FAO (2006).

The soils were examined by horizons and described for colour, mottling, texture, structure, soil depth and consistence. The landform, vegetation/land use, drainage status and slope were described at each site. Profile sampling was done after the soil profile had been horizonated and described. Soil samples were collected from the identifiable horizons of the profile pits for physical and chemical analyses. Undisturbed core samples were collected from each horizon of the profile pits for bulk density determinations.

(Thomas, 1996). Organic carbon was determined (from the soil passed through 0.5 mm sieves) by the dichromate wet oxidation method (Udo, *et al*., 2009).

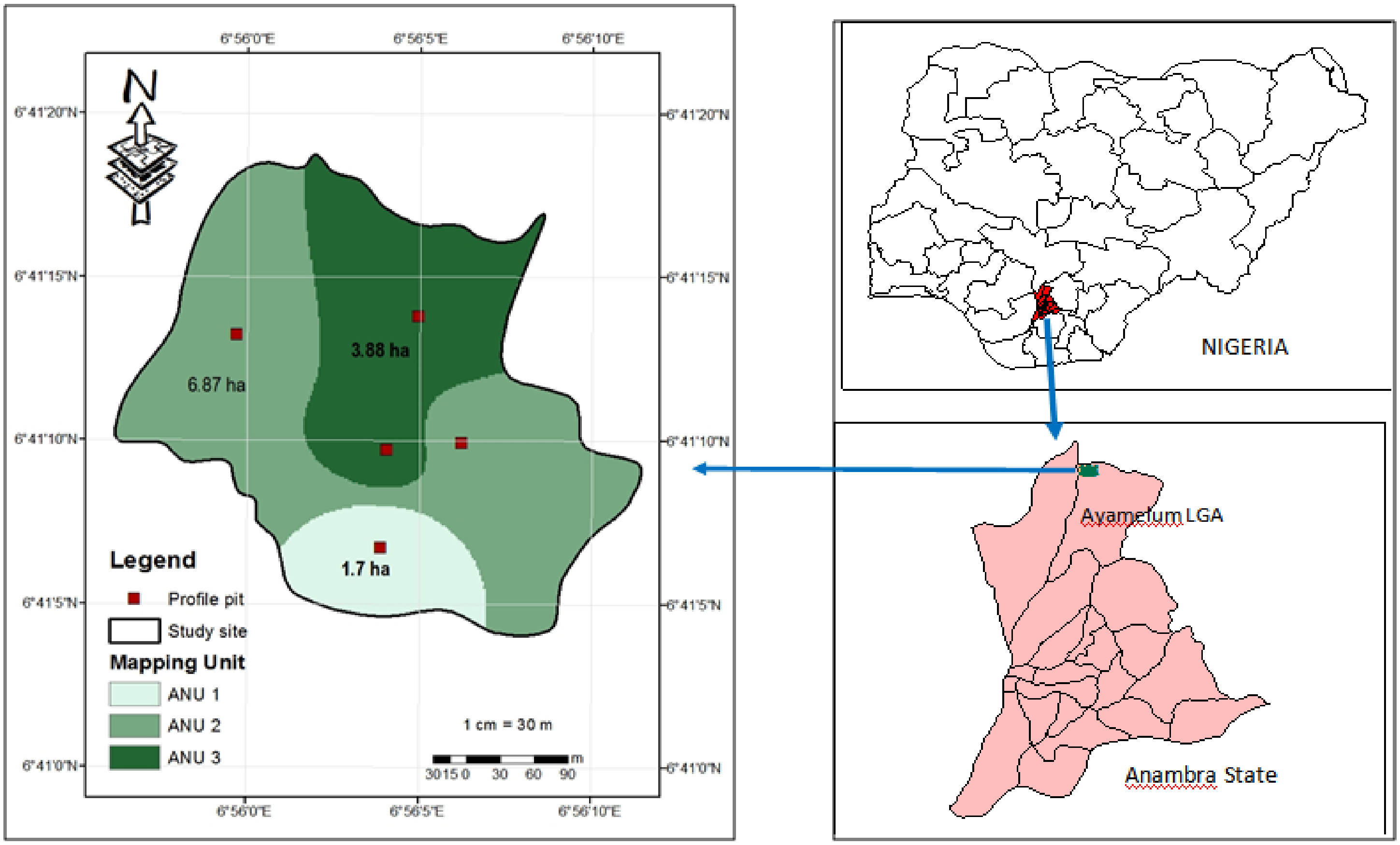

Fig.1: Map of the study site

2.3. Soil analysis and data interpretation

The disturbed soil samples collected were air-dried under laboratory conditions and sieved through a-2 mm wire mesh sieve. The fine earth fractions (< 2 mm) were subjected to routine soil analyses using standard procedures described by Udo, *et al*.(2009): Particle size distribution was determined by Bouyocous method using sodium hexametaphosphate as dispersant and selenium tablets as catalysts (Gee and Or 2002).

Undisturbed soil core samples were oven-dried at 105ºC to a constant weight and bulk density was calculated using the formulae:

$$bd = m \div v \ldots\ldots\ldots\ldots\ldots 1$$

Where: bd = bulk density (gcm^{-3}), m = mass of oven dry soil (g), v = volume of core sampler {v = π r ^{2} h} {where r and h are radius (m^2) and height (m) of the core sampler}.

Total porosity was computed as:

$$Tp = 1 - \{Bd \div Pd\} \times 100 \ldots\ldots\ldots\ldots 2$$

Where: Tp = total porosity, Bd = bulk density, Pd = particle density assumed to be 2.65 mgm^{-3} for tropical soils.

Soil pH was measured potentiometrically in a soil: water suspension (ratio 1:2.5) using a glass electrode pH meter. Total nitrogen was determined on soil (through 0.5 mm sieve) by the regular mico-Kjeldahl method described by Bremner (1996). Available phosphorus was extracted with Bray number II solution of HF and HCl and the P in the extract was determined spectrophotometrically. The cation exchange capacity (CEC) was determined by the summation method (buffered at pH 8.2) in which all exchangeable cations including exchange acidity (Al^{3+} and H^+). The exchangeable bases were extracted by saturating the soil with neutral 1N KCl. Ca^{2-}, Mg^{2+}, Na^+ and K^+ displaced by $NH4^+$ were measured by Atomic Absorption Spectrometer (AAS) (Udo, *et al*., 2009). Exchangeable acidity was extracted with 1N KCl and estimated in the extract by titration (Udo, *et al*., 2009).

ECEC = Exchangeable acidity +Total exchangeable bases (TEB)…………. 3

Base saturation was obtained by expressing the sum of exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+, and K^+) as percentages of the effective cation exchange capacity:

$$\% BS = \frac{TEB}{ECEC} \times 100 \ldots\ldots\ldots\ldots\ldots 4$$

Data were interpreted based on Chude, *et al*. (2011) and Hazelton and Murphy (2015).

2.4. Land suitability evaluation

The pedons were first placed in suitability classes by matching their characteristics with theagronomic requirements of the test crops (yam and oil palm). Based on the extent to which the land characteristic meets the requirements of the crops (Tables 1 and 2), scores were allocated as S1 (100-95 %), S2 (95-85 %), S3 (84-60 %), N1 (59-40) and N2 (39-0 %).The suitability class of a pedon is that indicated by its most limiting characteristic. This follows the well-known “Law of the Minimum” in agriculture, which states that crop yield will be determined by the plant nutrient in lowest supply (FAO, 2016; Ogunwale, *et al., 2009*).

Where: IP= Index of Productivity (%), A = Overall lowest characteristic rating and B, C, D, F are the lowest characteristic ratings for each land quality group (Udoh and Ogunkunle, 2012).

2.5. Geo-spatial analysis

The spatial data of the perimeter and notable physiographic features of the site were input into the ArcMap 10.3 software in Geographic Information System (GIS) application to produce the map of the project site showing the identified mapping units and profile pits locations (Fig. 1). Following the Framework for land evaluation, multi-criteria evaluation technique in GIS was used to model land quality indices of the study area (FAO, 2016).

Each of the land qualities was matched with the agronomic requirements of the tested crops (yamand oil palm) to produce individual thematic layer of land quality. Based on the extent to which the land qualities meet the requirements of each crop, the thematic layer was created according to the rating scale

Table 1: Land Use Requirements for yam

Land qualities	Land characteristics	Unit	S1 100-95	S2 94-85	S3 84-40	N1 39-20
Climate (c)						
Water Availability	Mean annual Rainfall	(mm)	1600-1100	1100-900	900-500	<500
Temperature regime	Mean annual Temp.	(^{O}C)	18-30	>16	>12	<12
Wetness (w)						
Oxygen Availability	Soil drainage		Well drained	Moderate or Imperfectly drained	Poorly drained	Very poorly drained
Fertility (f)						
Nutrient Availability	Total N	(gkg^{-1})	>0.2	0.1-0.2	<0.1	-
	Avail P	(mgkg^{-1})	>25	6-25.	<6	-
	Exch. K	(cmol/kg)	>6	3.-6.	<3	-
	pH		6.1-7.3	7.4-7.8or 4.8-6.0	>8.4or <4.0	-
Nutrient retention	**CEC**	(cmol/kg)	>16	3-16.	<3	-
	Base saturation	(%)	>35	20.35	<20	-
Soil physical characteristics (s)						
Water retention Capacity	Soil texture		L, SC, CL	LS, SiCL, SL	S, SCL	C
Rooting Condition	Soil depth	(cm)	>100	100-75	75-50	<50
Topography (t)	Slope	(%)	0-5	5-12	12-20	>20

Modified from Sys (1985)

Key: S_1 = highly suitable, S_2 = moderately suitable, S_3 = marginally suitable, N_1 = currently not suitable, C = Clay, CL= clay loam, L = loam, SiC = silty clay, LS = loamy sand, SL= sandy loam, SCL = sandy clay loam, S = sand, SC = sandy clay, EC = electrical conductivity

The second stage was the integration of all the selected land characteristics representing the selected land qualities used for the evaluation, using the parametric square –root method. The values obtained werecompared with aggregate suitability class score to determine the suitability/productivity index such as: SI (100-75); S2(74-50); S3: (49-25); N (24-0) (Udoh and Ogunkunle, 2012; Ogunkunle, 1993).

The index of productivity (IP) for each pedon was calculated as follows:

$$IP = A \, x \sqrt{\frac{B}{100} \, x \, \frac{C}{100} \, x \, \frac{D}{100} \, x \, \frac{E}{100} \, x \, \frac{F}{100}} \qquad \ldots\ldots\ldots\ldots\ldots 1$$

(S1, S2, S3, and N1). All the scaled thematic layers were assigned weighted values and integrated using map algebra in GIS to produce land suitability maps of the farmland for the cultivation of the selected crops.

3.0 Results and Discussion

Table 2: Land use Requirements for Oil palm

Land Quality	SI (100 - 95%)	S2 (94 - 85%)	S3 (84 - 40%)	N1 (39 - 20%)	N2 (19- 0%)
Climate (c): Annual rainfall (mm)	> 2000	1450 - 1700	1250 - 1450	< 1250	< 1250
Mean annual temperature. (°C)	25 - 35	22 - 25	20- 22	18 - 20	< 18
Topography (t): Slope (%)	0 - 4	4 - 8	8 - 16	16 - 30	> 30
Wetness (w): Drainage	Imperfect	Well drained	Poor, drainable	Not drainable	Very poor
Soil Physical Properties (s):Texture	CL, SCL, L	SC, SCL	SL	LS	C, S
Depth (cm)	> 100	90 - 100	50 - 90	25 - 50	< 25
Fertility (f):pH	5.0 -5.8	4.5-5.0/6.0-7.0	4.0 -4.5	< 4/> 7.0	< 4/> 7.0
CEC (cmolkg^{-1})	>8.0	8 - 6	<6	-	-
Base saturation (%)	> 35	20 - 35	< 20	-	-
Organic carbon (%), 0-15cm	> 1.2	1.2 - 0.8	< 0.8	-	-
Total N (%)	>0.2	0.15-0.2	0.1-0.15	<0.15	-
Aval. P	>25	25-6	< 6	-	-
Exch. K (cmolkg^{-1})	> 1.2	0.6-1.2	0.3 - 0.6	< 0.2-0.3	< 0.2

CL, clay loam; SCL, sandy clay loam; L, loam; LS, loamy sand; C, clay; SC, sandy clay.

Source: modified by Sys (1985); Ogunkunle (1993)

3.1 Morphological and physical properties of the soils

The soils were generally deep (> 150 cm), well drained and non-concretionary. Matrix colour (mottle free) ranged from dark brown surface overlying yellowish brown subsurface (Table 1). However, soils under mapping unit ANU Iwere shallower (< 120 cm) and

imperfectly drained compared to other mapping units (ANU II and III). The surface horizons of all the units were crumb-structured over sub-angular blocky endopedons. Consistence (moist) varied from friable surface to firm subsurface. Roots concentrated in the upper 30 cm of the soil surface. There was no definite pattern of distribution of the soil separates (sand, silt and clay) down the soil depth. For instance, clay fractions increased from the surface soil to upper subsurface and suddenly decreased down the depth. This may be attributed to a marked pedogenic (soil forming) process – fauna pedoturbation (soil mixing) attributable to the activities of ants in the mid-subsurface horizons (Brady and Weil, 2010).The lithologic discontinuity observed in the area may be attributed to the Imo clay shale geology, predominantly composed of cretaceous shale of tertiary age and alluvium which were previously laid down by River Niger but later reworked and redeposited by River Anambra (Ngede, *et al*., 2020).

Bulk density values (1.17-1.62 g/cm^3) were lower than the critical limit values (1.75 – 1.80 gcm^{-3}) for root penetration (Chude et al., 2011) consequently, there will be no excessive compaction inhibiting root development (Ojeniyi, 2002). The sustainable productivity of this mapping unit will be anchored on adequate drainage for improved soil aeration.

Table 3: Morphological and physical properties of the soils

Mapping Unit/Pedon	**Horizon**	**Depth (cm)**	**Colour (moist)**	**Drainage**	**Slope %**	**Structure**	**Consistence**		**Sand**	**Silt**	**Clay**	**T/Class**	**BD**	**TP (%)**
							moist	**wet**		**g kg^{-1}**			**mgm^{-3}**	
ANU I	Ap	0-12	7.5YR 4/2	Imperfect	2	2CCr	vfr	ns-np	440.00	300.00	270.00	L	1.17	56.00
Pedon I	Bt1	12-35	5YR 5/6			2msbk	Fm	s-p	280.00	300.00	430.00	C	1.62	39.00
	Bt2	35-68	5YR 6/4			2msbk	Fm	s-sp	320.00	280.00	410.00	CL	1.59	40.00
	BC	68-114	5YR 6/4			2msbk	Fm	s-sp	380.00	320.00	310.00	CL	1.52	43.00
ANU II	Ap	0-24	5YR 4/2	Good	3	2CCr	Fr	ss-np	160.00	250.00	140.00	SL	1.35	49.00
Pedon 2	AB	24-75	5YR 5/2			2MSbk	Fm	ss-np	380.00	360.00	290.00	L	1.46	45.00
	Bt	75-112	5YR 5/3			2MSbk	Fm	ss-np	450.00	320.00	330.00	CL	1.72	35.00
	BC	112-158	5YR 6/4			2CCr	Fr	s-sp	460.00	340.00	140.00	L	1.78	33.00
Pedon 3	Ap	0–18	10YR 4/3	Good	4	2CCr	Fr	ns-np	560.00	300.00	150.00	SL	1.12	57.00
	B	18-66	10YR 5/6			1MSbk	Fm	ss-np	320.00	420.00	270.00	L	1.28	52.00
	BC	66-177	10YR 6/8			2MSbk	Fr	ss-sp	560.00	300.00	150.00	SL	1.62	39.00
ANU III	Ap	0-13	5YR 5/3			2CCr	Fr	ns-np	580.00	320.00	110.00	SL	1.45	45.00
Pedon 4	Bt	13-40	5YR 6/4			2msbk	Fr	ss-np	360.00	360.00	290.00	CL	1.51	43.00
	B	40-120	7.5YR 6/4	Good	5	2msbk	Fm	s-sp	340.00	340.00	270.00	L	1.46	45.00
	BC	120-200	10YR 6/8			2CCr	Fr	ns-np	840.00	90.00	90.00	S	1.82	32.00
Pedon 5	Ap	0-16	2.5YR 3/2	Good	5	2CCr	Fr	ns-np	740.00	170.00	100.00	SL	1.52	43.00
	Bt	16-48	5YR 3/2			1msbk	Fm	ss-np	580.00	190.00	240.00	SCL	1.46	45.00
	B	48-92	5YR 5/2			2msbk	Fm	ss-np	660.00	250.00	100.00	SL	1.64	38.00
	BC	92-186	10YR 6/6			2CCr	Fr	ns-np	920.00	30.00	60.00	S	1.81	32.00

Key: *Texture* (T): SL=sandy loam, SCL=sandy clay loam, SC=sandy clay, C=clay, S=sand; ***Structure***: 1=Weak, 2=Moderate, 3=Strong. M=Medium, C=Coarse. Cr=Crumb, Sbk=Sub-angular blocky.***Consistence***: Fr = friable, Fm = firm, vfr = very friable, ns=non sticky, np=non plastic, ss=slightly sticky, s=sticky, sp=slightly plastic.

Generally, the Ap horizons of all the soils showed a lower bulk density than the B horizons. This increase down the pedal depth could be attributed to a decrease in organic matter down the depth (Sakin *et al.*, 2011; Uzoho *et al*., 2007; Onweremadu *et al*., 2008).

3.2 Chemical properties of the soil units

The soils are generally strongly acid (pH5.1 -5.5) (Table 3). The strongly acid nature of the soil could be adduced to nature of the parent material (Nnaji *et* al, 2002; Nkwopara*et al.*, 2019). The low pH values observed, as reported by Chude *et al* (2011) that pH < 5.6 is not ideal for most crops to thrive well as most nutrient elements especially; phosphorus will be fixed and thus, will not be readily available for absorption by plant roots. Therefore, the sustainable productivity of the soils is anchored on adequate liming to reduce the acid effects and ensure adequate availability of soil nutrients to crops.

Organic carbon was high (>1.50 %) in all the mapping units but decreased sharply down the depth. The higher organic carbon observed in the surface compared to the subsurface horizons may be attributed to higher litter falls on the surface horizons and are the points where decomposition of organic materials takes place (Akinrinde and Obigbesan, 2000).

Continuous tillage operation for cassava cultivation may have accounted for the relatively lower organic carbon in some sections of ANU II (pedon 2) and ANU III (pedon 4). Riezebos and Loerts, (1998) reported in their findings that continuously cultivated land increased decomposition and mineralization of organic materials. The area was relatively under the influence of nitrogen deficits especially, pedons 2 and 3. The low values may be attributed tothe continuous cropping of the sections of the land which in turn may result in volatilization of the nutrient especially, under high temperature regimes and denitrification processes. The exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) were generally low except the exchangeable Mg^{+} which was moderate.Available phosphorus was also moderate (> 7.00 < 20.00 mg/kg).The low level of exchangeable bases generally observed could be attributed to strongly acid nature of the soil in the area.This observation corroborates the findings of Chikezie *et al.* (2009) and Udoh and Ogunkunle (2012) that most Nigerian soils are moderately low in phosphorus partly due to the existence of parent rocks low in phosphorus but complicated by high phosphate fixing capacity of the soil.

Therefore, there is need to adopt cultural practices such as minimum tillage operation, mulching, organic manuring, etc that will encourage the return and incorporation of plant/crop residues into the soil to sustain/increase the level of soil organic matter in the area.

3.3 Land Suitability Evaluation for yam and oil palm cultivation

Land suitability evaluation of the study site for the cultivation of yam and oil palm using the parametric method was determined. Results of matching agronomic requirements (Tables 1 and 2) for production of the test crops with land characteristics (Tables3 and 4) are shown in aggregate suitability class score (Table 5). Climate was not a constraint to the production of yam and oil palm in the farmland and environs because there are more than five months of steady rainfall. Consequently, the crops would do best when planting and developmental stages are programmed to fall within the rainy months in the year. Topography (slope gradient) of the entire mapping units, < 5 % was highly suitable for optimal production of the selected crops (Sys *et al.*, 1993) and therefore, would not pose any limitation to optimal performance of the crops on the farmland and its environs. Similarly, soil depth in the study area was greater than 100 cm and is considered adequate for sustainable production of any crop (Sys *et al.*, 1991).

In terms of soil wetness (drainage), ANUII and III had good drainage, while ANUI had imperfect drainage. Therefore, imperfect drainage in ANUIwas considered a limiting factor to the optimal performance of the farmland for yam and oil palm. The entire farmland was strongly acid and deficient of basic nutrients such as nitrogen, available phosphorus and exchangeable potassium. These are limitations to the optimal performance of the soils for production of the crops.

The aggregate assessment of study site has shown that the optimal performance of ANUI was constrained by imperfectly drained condition (w) of the unit and thus, currently puts the unit as marginally suitable (S3w) for the cultivation of yam. Contrarily, ANU II and III were well drained however, the productivity of these units is constrained by fertility (f) thus, currently puts the units in moderate suitability class (S2f) for the cultivation of yam (Fig. 2).

In similar development, the imperfectly drained condition (w) of ANU I and fertility deficits (f) of ANU IIIhave limited the sustainable productivity of the unit for oil palm cultivation thus, puts the units into moderate suitability class (S3). Although ANU II was low in fertility, the deficiency is not as high as that of ANU I and III thus, classifying ANU II moderately suitable (S2f) for oil palm cultivation (Fig. 3).

Soil fertility status especially; available phosphorus and exchangeable potassium, and the imperfect drainage condition of the study site have been found out to currently limit the potentials of the soils for optimal production of yam and oil palm.

4.0. Conclusion

The study site has is characterized by imperfectly and well drained moisture conditions. The soils are strongly acid in reaction with moderately low values of total nitrogen and exchangeable bases. The suitability assessment confirmed that climate, topography and base saturation are optimum for the cultivation of yam and oil palm.

The optimal performance of mapping unit ANU I is limited by imperfectly drained condition (w) and thus, currently marginally suitable (S3) for the cultivation of yam and oil palm. The productivity of mapping unit ANU II is constrained by fertility (f)

Table 4: Chemical properties of the soils at different slope positions

Mapping Unit	**Horizon**	**Depth (cm)**	**pH (H_2O)**	**OC %**	**TN %**	**Av. P mgkg^{-1}**	**OM**	**Ca^{2+}**	**$^{+}$ Mg^{+}**	**K^{+}**	**Na^{+}**	**ECEC**	**EA**	**Al^{3+}**	**BS (%)**
								← (cmolkg^{-1}) →							
ANU I	Ap	0-12	5.70	2.96	0.21	16.80	5.10	6.00	3.10	0.35	0.32	11.25	1.48	0.46	86.84
Pedon 1	Bt1	12-35	4.90	0.93	0.07	12.10	1.60	2.80	0.80	0.08	0.06	5.40	1.66	0.54	69.25
	Bt2	35-68	5.30	0.93	0.07	9.60	1.60	2.80	0.80	0.07	0.04	5.43	1.72	0.10	68.32
	BC	68-114	5.50	0.46	0.04	9.60	0.79	2.00	0.60	0.04	0.02	4.34	1.68	0.10	61.29
ANU II	Ap	0-24	5.90	1.57	0.13	18.30	2.71	4.6	1.80	0.37	0.31	8.62	1.54	0.58	80.97
Pedon 2	AB	24-75	5.40	0.64	0.06	10.80	1.10	2.8	1.00	0.22	0.10	5.80	1.68	0.54	69.31
	Bt	75-112	5.30	0.61	0.04	10.10	1.05	2.9	0.80	0.05	0.03	5.59	1.80	0.32	64.22
	BC	112-158	5.30	0.51	0.02	9.40	0.88	2.0	0.80	0.04	0.03	4.67	1.80	0.26	57.17
Pedon 3	Ap	0–18	5.00	2.28	0.19	18.40	3.93	5.40	2.40	0.36	0.31	10.36	3.93	0.64	81.66
	B	18-66	5.20	0.68	0.06	11.80	1.17	3.00	1.00	0.09	0.06	5.99	1.17	0.52	69.28
	BC	66-177	5.00	0.61	0.04	10.30	1.05	1.80	0.80	0.03	0.02	4.49	1.05	0.46	59.02
ANU III	Ap	0-13	5.30	1.50	0.12	17.00	2.59	4.40	1.80	0.37	0.29	8.54	2.59	0.60	79.15
Pedon 4	Bt	13-40	5.30	0.93	0.08	9.80	1.60	4.60	1.20	0.17	0.08	7.68	1.60	0.52	77.34
	B	40-120	5.50	0.79	0.06	8.20	1.36	3.00	0.60	0.05	0.06	5.36	1.36	0.28	67.53
	BC	120-200	5.00	0.11	0.01	7.60	0.19	0.80	0.40	0.05	0.04	2.99	0.19	0.28	39.79
Pedon 5	Ap	0-16	4.90	3.18	0.22	16.60	5.48	6.40	2.80	0.40	0.36	11.40	1.44	0.44	87.01
	Bt	16-48	5.00	0.89	0.07	9.00	1.53	5.10	2.00	0.28	0.10	9.20	1.72	0.22	80.86
	B	48-92	5.50	0.57	0.04	7.20	0.98	2.20	0.70	0.03	0.02	4.79	1.84	0.52	61.58
	BC	92-186	5.80	0.57	0.05	7.40	0.98	2.00	0.80	0.01	0.06	4.63	1.76	0.21	62.42

Key: OC=Organic carbon; TN=Total nitrogen; Av. P=Available phosphorus; ECEC=Effective cation exchange capacity; BS=base saturation thus, currently moderately suitable (S2) for the cultivation of yam and oil palm.However, ANU III is deficient in fertility (f) thus currently suitable (S2f) for yam but marginal (S3) for oil palm.

Adequate and proper drainage of ANU I is necessary through construction of drainage channels to control the inflow and outflow of water into the field. Otherwise, the unit could be devoted to cultivation of lowland rice.Consequent upon the fragility of the soils, heavy equipment such as bulldozer should not be used to carry out any farm operation like stumping rather, manual stumping should be encouraged.The strongly acid nature of the soils will require proper liming for adequate availability of nutrients to crops.

Table 5: Aggregate Suitability Scores of the study site for the Cultivation of the Test Crops

	ANU 1	**ANU 2**		**ANU 3**	
Test crop	**Pedon 1**	**Pedon 2**	**Pedon 3**	**Pedon 4**	**Pedon 5**
Yam					
Potential	S2	S1	S1	S1	S1
Actual	S3	S2	S2	S2	S2
Limitation	*w*	*f*	*f*	*f*	*F*
Oil palm					
Potential	S2	S1	S1	S2	S2
Actual	S3	S2	S2	S3	S3
Limitation	*w*	*f*	*f*	*f*	*F*

Aggregate suitability class scores: S1 =75-100; S2=50-74; S3=25-49; N1=15-24; N2=0-14

Note: f = fertility, w = wetness (drainage).

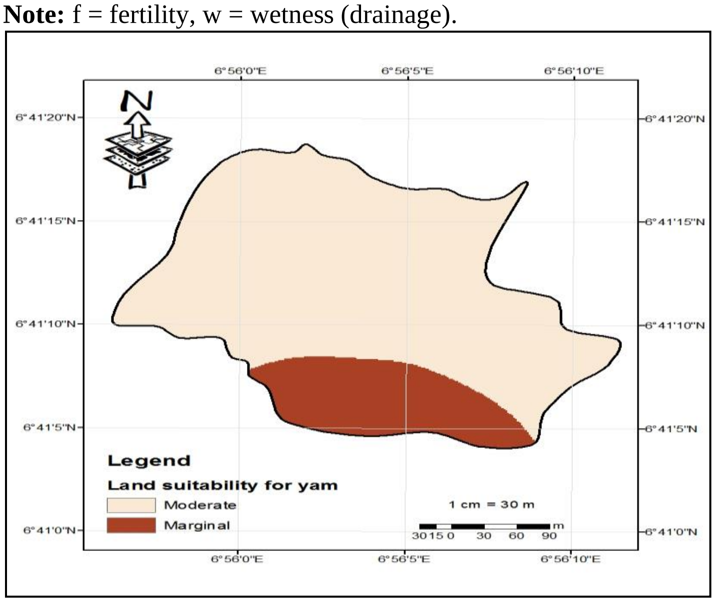

Fig. 2: Land suitability evaluation for yam cultivation

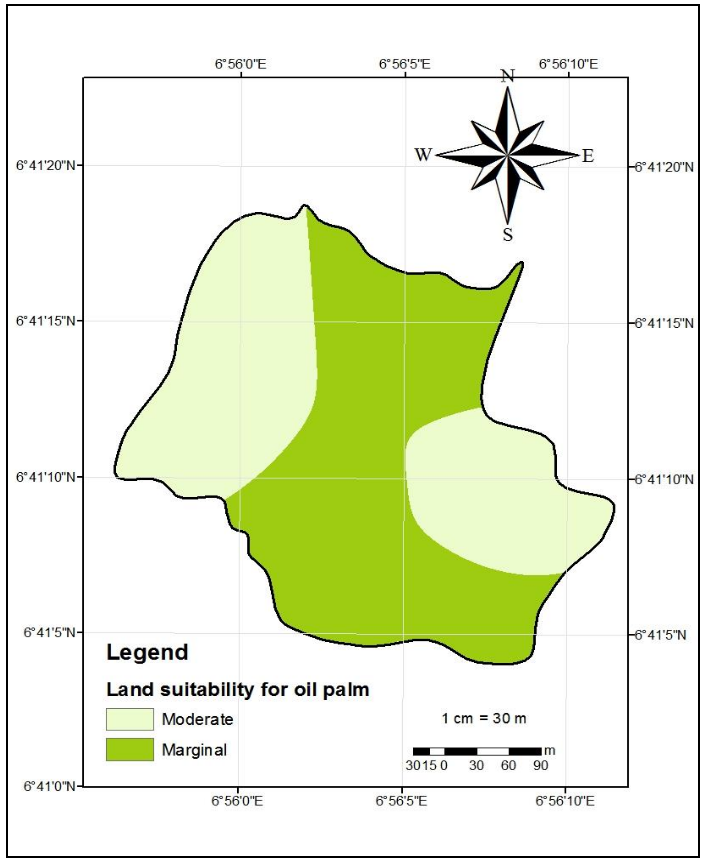

Fig. 3: Land suitability evaluation for oil palm cultivation

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