Taxonomic information and land quality assessment of soils of Amaoba-ime South-eastern Nigeria for sustainable production of yam (D*ioscorea spp.*)

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Abstract
A field survey, morphological description and laboratory analyzes of the soil samples collected were carried out for land quality assessment of soils of Amaoba-Ime, South-Eastern Nigeria for sustainable production of yam (Dioscorea spp). Three soil mapping units were identified as 1, 2 and 3. One profile was sited in each of mapping units 1 and 2 while two profile pits were sited in mapping unit 3 due to its large area. Four representative pedons were sited in all, ranging from EA1 – 4) and described in-situ for morphological properties. Soil samples collected were analyzed for physical and chemical properties. The results revealed deep and well drained soils (moist) with friable to firm consistence. The texture of the surface soil was sandy loam overlying sandy clay loam and sandy clay. The soils were very strongly - strongly acid (4.7 to 5.2). Organic carbon (10.20 to 12.40 gkg^{-1}) and available phosphorous contents of the soils (7.1 - 10.4 mgkg^{-1}) were considered moderate. Exchangeable bases were generally low. The cations exchange capacity (CEC) was low with values ranging from 5.40 to 13.80 cmolkg-^{1}. The weathering potential, assessed by silt/clay ratio (0.57 – 2.05), indicated young soils with high degree of weathering. The soils were Typic Hapludult (USDA Soil Taxonomy) and correlated as Haplic Acrisol (World Reference Base system of soil classification). The current suitability assessment of the area ranges between moderate and marginal for yam production. Optimum performance of yam in the area can be enhanced through continuous application of organic materials to the soil, improved efficiency of use of mineral fertilizers and use of low levels of chemical inputs.

Keywords: Soil taxonomy, soil quality, yam, suitability evaluation

Introduction
Taxonomic information on soil properties and distribution is critical for making decisions with regard to sustainable crop production. Sustainable use of soil is necessary for a successful agriculture to meet the increasing demand of food from the decreasing per capital land. This is because soil is an important non-renewable land resource determining the agricultural potential of a given area (Buol *et al.,* 2003). Decisions on land use are now being based on comprehensive analysis of the production systems and the potentials of natural resources such as climate, soil, topography and hydrology.

Land evaluation interprets soil survey reports and provides information on the potentials and constraints for a defined land use type. Thus, land evaluation is very essential for land use planning as it guides decisions on land utilization for sustainable land management.

According to reports of Ogunkunle (2004), the starting point towards sustainable soil management for crop production is adequate information on the land resources followed by the suitability evaluation of the resources for specific uses, but unfortunately this trend is not followed in Nigeria in spite of several spots studied.

It is therefore important that the land that will be used for agricultural production should be used according to its carrying capacity for optimization and sustainability of soil productivity (Ande*et al.,* 2008). This becomes very vital at this time when precision farming is gaining wider acceptance and the relevance is particularly more now in the developing world where the use to which a land is put is very often not related to its capacity (Ogunkunle (2004).

Aderonke and Gbadegesin (2013) reported that poor knowledge and appraisal of suitability of parcels of land for agricultural production constitutes the current major problem of agricultural development in Nigeria as it results to poor farm management practices, low yield and an unnecessary high cost of production. The knowledge of soil limitations arising from land evaluation reports aims at ameliorating such limitations before, or during cropping period (Lin *et al.,* 2005). Therefore, soil as a main medium for cultivation needs to be surveyed and the survey reports assessed or evaluated. The performance assessment is based on matching qualities of the land in specific area with the requirements of actual or potential land utilization types. This assessment results in classification of soil to its suitability for the specific purpose or purposes (Ezeaku, 2011).

Yam (*Dioscorea spp*) is a staple tuber crop of the Nigerian and West African diet. It 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. (Aighewi *et al.,* 2015) reported that the shortfall has been consequent upon low yielding varieties and more importantly poor (low fertility) soils used for yam production among others However, ineffective and unplanned use of agricultural land is serious challenge in 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.

Materials and methods

Study area

The study was conducted at Amaoba-Ime, South-eastern Nigeria located within latitudes 5° 28' 3" and 5° 28' 15" N and longitudes 7°32' 6" and 7°32' 23" E. The study covers about 10.4 ha of land area with altitude ranging between 109 and 128 meters above sea level (masl). The area has a humid tropical climate with wet (April to October) and dry (November to March) seasons. Rainfall ranges from about 1,900 to 2,200 mm and is bimodal with peaks in July and September. Annual air temperature ranges from 23° C to 29° C and relative humidity is about 75 - 80 per cent (NRCRI, 2016).

The study area is underlain by one main geological formation, the coastal plain sands, comprising largely unconsolidated sands (Lekwa, 2002). They are dominated by low activity clays, low organic matter content and are susceptible to accelerated erosion and soil degradation (Ogban and Ibia, 2006). The native vegetation has almost completely been replaced by secondary forest of wild oil palm trees of various densities of coverage as well as woody shrubs and various grasses that form the under growth. Land use comprises mainly cultivation of arable crops with varying fallow periods.

Geo-spatial analysis and soil sampling

A perimeter survey of the land of the study area was carried out with the coordinates (latitudes and longitudes) and elevation data recorded with a hand held Global Positioning System (GPS) receiver (*Garmin-etrex*). The morphological, physical and chemical properties of the soils of the area were studied through field observation and laboratory analyses. Following the Guidelines for Field Soil Descriptions (Soil Survey Staff, 2015), auger investigations were made at various points across the study area consequent upon differences in physiographic features such as topographic features and land/soil characteristics. The auger point data were geo-referenced with a hand held Global Positioning System (GPS) receiver (*Garmin-etrex*). The spatial data of the perimeter and the auger investigations were input into the ArcMap 10.2 software in Geographic Information System (GIS) application for the production of the soil boundary delineation map (Fig. 1).Three soil mapping units were identified as 1, 2 and 3. One profile was sited in each of mapping units 1 and 2 while two profile pits were sited in mapping unit 3 because of its large area. Four representative pedons were sited in all, ranging from EA1 – 4).With reference to the Guidelines for Field Soil Descriptions (Soil Survey Staff, 2015), the pedons were described *in situ* for their morphological properties, using the Munsell chart to identify soil colors. Soil samples were collected from all identified horizons for laboratory analyses.

Based on the extent to which the soil properties (Tables 1 and 2) meet the land requirements of yam (Table 3), and with respect to the coordinates of the sample locations, the thematic layer was prepared according to the suitability class score (Table 4). All the scaled thematic layers were assigned weighted values and integrated into map algebra using Inverse Distance Weighted (IDW) interpolation provided in the Arc GIS to produce land suitability map of the area for yam cultivation (Fig. 2).

Soil analysis and data interpretation

The soil samples collected from every identified horizon and the composite samples from the different land uses were air-dried and ground to pass through 2 mm sieve. For the determinations of total N and organic carbon (OC), a 0.5 mm sieve was used. Analyses of the physicochemical properties were carried out following standard laboratory procedures described by Udo, *et al*. (2009). Particle-size distribution and bulk density were determined by Bouyocous hydrometer analysis and core methods, respectively. Soil pH was measured using a 1:2.5 soil to water ratio, whereas organic carbon (OC) was determined by wet digestion method (Walkley and Black method). Total N was determined by Kjeldahl wet digestion and distillation method, and available P by the modified Olsen method. The cation exchange capacity (CEC) and exchangeable bases were extracted by 1 *M* ammonium acetate (pH 7) method. In the extract, exchangeable Ca and Mg were determined by atomic absorption spectrophotometer

(AAS) and exchangeable K and Na by flame photometer. The cation exchange capacity (CEC) and exchangeable bases were extracted by 1 M ammonium acetate (pH 7) method (Chapman, 1965). In the extract, exchangeable Ca and Mg were determined by atomic absorption spectrophotometer (AAS) and exchangeable K and Na by flame photometer. Percent base saturation was by calculation. The exchangeable acidity, that is, hydrogen (H^+) and aluminum (Al^{3+}) was determined by titrimetric method. Data were interpreted based on Chude, *et al*. (2011) and Hezelton and Murphy (2011).

Soil classification

Based on the morphological (field data), physical and chemical (laboratory data) properties obtained, the soils were classified using the USDA Soil Taxonomy System (Soil Survey Staff, 2014) and correlated with World Reference Base for soil resources (WRB, 2014).

Land evaluation procedure

Limitation method

Tables 1 and 2 give the land qualities/characteristics (ranges) of the four pedons at the study location. The pedons were first placed in suitability classes by matching their characteristics (Tables 1 and 2) with the land requirements of yam in Table 3. The suitability class of a pedon (aggregate suitability) in Table 4 is that indicated by its most limiting characteristic.

Parametric method

Each limiting characteristic was rated as in Table 4. The index of productivity (IP) for each pedon was then calculated.

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

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). In this study, five land quality groups (Table 4) were used; climate (c), topography (t), soil physical characteristics (s) wetness (w) and chemical fertility (f). Only one member in each group was used because there are usually strong correlations among members of the same group (e.g. texture and structure in group's').

Results and discussion

Taxonomic information of soils of the study area

The positions of the soils on the landscape range between nearly flat (1 - 2 % slope gradient) and gently sloping terrain (4 - 5 %). They have udic moisture regime; soil moisture control section not dry for more than 90 cumulative days during the year. The soils are very deep (> 170 cm) and well drained with dark brown surface (7.5YR 4/2) colour notation which graded to various degrees of brown in the subsurface (Table 1). The horizons (surface and subsurface) of all the pedons were bright and mottle-free. This is an indication of good surface drainage as evidenced by the chroma value colour notation greater than 2. This may be attributed to perhaps, presence of sesquioxides in hydrated form, especially the goethite. (Idoga and Azagaku, 2005).

The surface soil was weak and crumb-structured over moderate and sub-angular structured subsurface. Consistence (moist) varied from friable to firm in the subsurface and in wet condition, it was non-sticky and non-plastic. Roots concentrated in the upper 30 cm of the soil surface. The friable consistence of the epipedons was an indication of good tillage operation and easy penetration of plant roots. Ojeniyi (2002) reported that a friable soil often has the optimum conditions for tillage operations, resulting in better seedbed preparation with good drainage.

Particle-size distribution (Table 1) showed that the surface horizons show high in sand fraction but with a decreasing trend with profile depth (760 – 460 gkg^1). Conversely, there was a progressive increase in clay content down the pedal depth (80 - 350 gkg^1). Silt fraction did not show any definite pattern of distribution down the profile depth. The high sand fraction of the soil indicates that the soils of the study area were characterized by high infiltration rate. This will have good water transmittance but the soil can easily be depleted of essential nutrients and moisture through leaching (Chude *et al*., 2011). Therefore, good management practices such as the incorporation of organic manure would increase the colloidal properties of the soil for adequate nutrient and water retention and consequently improve the capacity and sustainability of the soil for crop production. The increased clay content observed down the pedal depth especially pedon EA3 could be attributed to a marked pedogenic process of eluviation-illuviation consequent upon high and intense rainfall experienced in the area, leading to clay migration via the network of pores of the coarse texture of the upper horizons (Malagwi *et al*., 2000). The bulk density values (1.10 – 1.34 gcm^{-3}) were lower than the critical limit values (1.75 – 1.80 gcm^{-3}) for root penetration implying that there is no excessive compaction inhibiting root development. The weathering potential of the soils was assessed by silt/clay ratio. This was used to evaluate clay migration, stage of weathering of the soils. The silt/clay ratio ranged from 0.57 – 2.05, indicating that the soils are relatively young with high degree of weathering potentials. Yakubu and Ojanuga (2009), and Ayolagha and Opene, (2012) reported that those soils with silt/clay ratio less than 0.20 indicate low degree of weathering. The decrease in silt/clay ratio with depth is an indication that the endopedons are more weathered than the epipedons.

The chemical properties of the soils (Table 2) showed that pH (H_2O) values ranged from 4.7 to 5.4. This pH range falls within the very strongly to strongly acid class (Chude *et al*., 2011), The acid nature of the soil could be attributed to high sand fractions resulting to high rate of leaching of bases which is prevalent in the humid tropics. Chude *et al*. (2011) had established pH range of 5.5 - 7.0 (slightly acid to neutral reaction) as optimal for overall satisfactory availability of plant nutrients. This implies that the soils of the study site were 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 plants in these strongly acid soils (Osodeke and Osondu, 2006). Organic carbon content of the surface horizons of EAs 1 and 3 ranged from 10.20 to 12.40 gkg^{-1} which is considered moderate based on soil nutrient interpretation of Chude *et al*., (2011) that soil organic carbon between 15 and 20 gkg^{-1} is moderate for crop production. However, the low surface organic carbon values of EAs 2 and 4 (5.50 – 6.34 gkg^{-1}) compared to other pedons in the area could be consequent upon less vegetal cover attributable to continuous cultivation practiced in the segment of the land area. The subsurface horizons were generally lower in organic carbon than the surface horizons. The reasons for this may be attributed to higher litter falls on the surface horizons and are the points where decomposition of organic materials takes place. Available phosphorous content of the soils varied from 7.1 to 10.4 mgkg^{-1} in the surface horizons with decrease in values down the depths. The available P values in the location are considered moderate as they are within the range recommended for most commonly cultivated crops (Enwezor., *et al*., 1989). The observed low level of bases in the soils could suggest leaching as a marked pedogenic process, resulting from the high sand fraction in the area (Amusan, *et al*., 2006). The cations exchange capacity (CEC) was relatively low with values ranging from 5.40 to 13.80 cmolkg-^{1}. Nnaji, *et al*. (2002) observed that, low CEC of a soil could be because of clay type content, high rainfall intensity as well as previous land use. Base saturation was low and a reflection of the characteristic of an ultisol (Lekwa, 2002).

3.2. Soil classification

The soils on the three mapping units were classified (Soil Survey Staff, 2014 and correlated (World Reference Base, 2014). The evidence of argillic/argic horizons coupled with low base saturation (< 50% by NH_4OAc at pH 7.0) classified the soils of the mapping units at order level as Ultisols. The udic soil moisture regime qualified the units as Udults at suborder level and absence of other diagnostic properties placed them as Hapludults at Great group level and Typic Hapludults at Sub-group level in the USDA Soil Taxonomy. The strongly acid nature of the soils with low activity argic horizons, weakly developed structure, particularly in the surface and their low base saturation have classified the soils as Haplic Acrisols under WRB classification system.

3.3. Land quality and suitability classes

The study area is highly suitable (S1) for yam production with reference to temperature, soil drainage condition (well drained), slope (< 4 %) and effective soil depth (> 100 cm). However, the heavy rainfall aspect of climate (> 2000 mm), makes the area moderately suitable. The suitability classes of the soil-mapping units are shown in Table 4. The textural class of the soils in the area (sandy loam and sandy clay loam) could not place the area at optimum performance for yam production but only on moderate suitability class (S2). This is because the soil texture for optimum yam performance is clay loam or loam according toSys *et al*., (1991) and Mongkosalwat *et al*., (1997).

Considering the fertility status of the soils (CEC, Base saturation, pH, exchangeable K, total N and available P), the soils across the mapping units are moderately suitable for yam production except mapping units 1 (EA 1) and 2 (EA 2 and 4) which are low in total N thus, classify as marginally suitable (S3). Also, mapping unit 2 (EA 2 and 4) is low in exchangeable K and then classifies as marginally suitable (S3) for yam production.

From the above result, it is clear that in the study area, topography and drainage are optimum for yam production while soil characteristics (texture), climate (rainfall) and fertility (N, P, K, CEC) are sub-optimal and are major constraints to yam production in Amaoba-Ime.

Generally, the suitability assessment showed that although certain qualities or characteristics such as mean annual temperature, relative humidity, topography, and base saturation were optimum for yam cultivation. However, there was no highly suitable (S1) mapping unit for yam cultivation in the area. The area is currently moderately (S2) and marginally suitable (S3) for yam production (Fig. 2).

Conclusion and recommendation

The soils are strongly acid in reaction with relatively low values of cation exchange capacity and low base saturation. The high sand fraction of the soil indicates that the soils of the study area are characterized by high infiltration rate. This will have good water transmittance but the soil can easily be depleted of essential nutrients and moisture through leaching. Therefore, good management practices such as the incorporation of organic manure would increase the colloidal properties of the soil for adequate nutrient and water retention and consequently improve the capacity and sustainability of the soil for crop production.

The suitability assessment result showed that although certain qualities or characteristics such as mean annual temperature, relative humidity, topography, and base saturation were optimum for yam cultivation. However, there was no highly suitable (S1) mapping unit for yam cultivation in the area. The area is currently moderately (S2) and marginally suitable (S3) for yam production. For optimum performance of yam in the area, soil management techniques should enhance the nutrient and moisture holding capacity of the soil. Such techniques should such as continuous application of organic fertilizers/materials to the soil, improved efficiency of use of mineral fertilizers and use of low levels of chemical inputs should be adopted.

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Table 1: Morphological and physical properties of the soils of the study area

Pedon	Horizon	Depth (cm)	Colour (Moist)	Drainage	Slope %)	Structure	Consistence Moist	Consistence Wet	Sand (gkg^{-1})	Silt (gkg^{-1})	Clay (gkg^{-1})	Texture	Silt/ Clay	Bulk density (gcm^{-3})
	Ap	0-25	7.5YR 4/2;Db	WD	2	2CCr	vfr	ns-np	762.0	160.00	78.00	SL	2.05	1.20
EA1	AB	25-60	10YR 4/6;DYb	WD		2MSb	fr	ns-np	705.0	167.00	128.00	SL	1.30	1.28
	B	60-110	10YR 4/6;DYb	WD		2MSb	fm	ss-np	644.0	170.00	186.00	SL	0.91	1.39
	Bt	110-	10YR 7/6;Yb	WD		2MSb	fm	ss-np	600.0	145.00	255.00	SCL	0.57	1.42
	Ap	0-19	10YR 4/3;Db	WD	4	2FCr	fr	ns-np	652.0	189.00	159.00	SL	1.19	1.20
EA2	Bt1	19-68	7.5YR 5/4;B	WD		2MSb	fm	ss-np	535.0	222.00	253.00	SCL	0.88	1.26
	Bt2	68-180	7.5YR 5/6;Sb	WD		2MSb	fm	s-sp	493.0	229.00	278.00	SCL	0.82	1.31
	Ap	0-22	10YR 3/2;Db	WD	2	1MCr	fr	ns-np	750.0	147.00	103.00	SL	1.43	1.24
EA3	AB	22-52	7.5YR 6/6;Ry	WD		2MSb	fm	ns-np	689.0	141.00	170.00	SL	0.83	1.27
	Bt	52-175	7.5YR 6/8;Ry	WD		2MSb	fm	s-p	460.0	189.00	351.00	SC	0.54	1.29
	Ap	0-21	10YR 4/3;Db	WD	3	2MCr	fr	ns-np	659.0	182.00	159.00	SL	1.14	1.21
EA4	Bt1	21-68	7.5YR 5/4;B	WD		2MSb	fm	ss-np	535.0	212.00	263.00	SCL	0.81	1.24
	Btc	68-180	7.5YR 5/6;Sb	WD		2MSb	fm	s-sp	493.0	221.00	286.00	SCL	0.77	1.36

Key: Colour: Db=Dark brown, DYb= Dark Yellowish brown, Yb=Yellowish brown, B=Brown, Sb=Strong brown, Ry= Reddish yellow.
Structure: 1=Weak, 2=Moderate, 3=Strong. M=Medium, C=Coarse. Cr=Crumb, Bk=Blocky, Sbk=Sub-angular blocky. **Root:** ff=fine few, fvf=fine very few, fc=fine common, cf=coarse few, mf=medium few, a=absent. **Texture**: SL=Sandy Loam, SCL = Sandy Clay Loam, SC = Sandy Clay. **Boundary:** a=abrupt c=clear, g=gradual, w=wavy, s=smooth. **Consistence:** fr = friable, fm=firm, firm, ns-np=non sticky-non plastic, ss-sp=slightly sticky-slightly plastic, s-p=sticky-plastic.

Table 2: Some chemical properties of the soils

Pedon	Horizon	Depth (cm)	pH (H_2O)	OC (gkg^{-1})	Total N (gkg^{-1})	Av.P ($mgkg^{-1}$)	Exchangeable bases Ca^{2+}	Mg^{2+}	K^+ (cmolkg^{-1})	Na^+	Exch. Acid H^+	Al^{3+}	CEC	BS (%)
	Ap	0-25	5.20	10.22	0.84	9.94	2.0	1.40	0.38	0.05	1.44	0.76	10.80	34.83
EA 1	AB	25-60	5.00	5.18	0.50	6.80	1.2	1.10	0.20	0.06	1.14	0.65	8.50	30.11
	B	60-110	4.70	4.10	0.13	5.23	2.1	2.00	0.21	0.04	1.22	0.43	13.80	31.52
	Bt	110-185	4.70	2.25	0.10	4.20	2.1	1.60	0.26	0.06	1.11	0.61	12.50	32.20
	Ap	0-19	5.20	5.50	0.52	9.62	0.8	0.15	0.20	0.80	1.50	0.90	6.50	30.81
EA 2	Bt1	19-68	4.90	2.17	0.50	7.75	1.6	1.20	0.13	0.09	0.91	0.30	8.70	34.73
	Bt2	68-180	4.80	1.65	0.24	5.57	1.4	1.10	0.03	0.01	1.22	0.88	7.40	34.30
	Ap	0-22	5.40	12.40	1.35	10.40	1.2	0.80	0.35	0.06	1.18	0.99	8.00	28.60
EA 3	AB	22-52	5.20	6.04	1.00	9.65	1.1	0.40	0.18	0.04	1.20	0.75	5.70	30.22
	BC	52-175	4.80	2.43	0.61	8.40	1.1	0.40	0.19	0.11	1.10	0.35	5.40	33.33
	Ap	0-21	5.30	5.01	0.45	9.05	0.7	0.17	0.18	0.70	1.50	0.90	6.50	28.00
EA 4	Bt1	21-68	4.80	1.92	0.33	6.75	1.3	1.13	0.03	0.03	1.22	0.88	7.40	34.19
	Btc	68-180	4.70	1.40	0.25	5.72	1.5	1.22	0.15	0.07	0.91	0.30	8.70	34.60

Key: OC = organic carbon; N = nitrogen; Av. P = available phosphorus; CEC = cation exchange capacity; BS = base saturation

Table 3: Soil and climatic requirement for yam production

Land Quality	100 – 95 (S1)	94 - 85 (S2)	84 – 40 (S3)	39 – 20 (N1)	0 – 19 (N2)
Climate (c)					
Annual rainfall (mm)	1500 - 1200	1200 – 1000/ >15000	1000 - 800	< 800	< 300
Annual temperature (^0C)	18 – 30	16 – 18/30 – 35	< 12 or > 35	any	Any
Topography (t) *Slope (%)*	0 -2	3 – 6	7 - 15	15 - 20	> 20
Wetness (w) Drainage	Well drained	Imperfectly drained	Poorly drained	Very poorly drained	Very poorly drained
Soil physical characteristics (s)					
Texture	L, CL,	SL, SCL	LS	C	Any
Soil depth (cm)	> 100	100 – 75	75 – 50	< 50	< 20
Fertility (f)					
CEC (cmolkg^{-1} clay)	>16	16 – 3	< 3	any	-
Base saturation (%)	>35	35 – 20	< 20	any	-
pH	6.1 – 7.3	7.4-7.8/ 5.1-6.0	>8.4 or <5	any	-
Total nitrogen ((gkg^{-1}))	>2	2 – 1	< 1	any	-
Available P (mgkg^{-1})	>25	25 - 6	< 6	any	-
Exchangeable K (cmolkg^{-1})	>0.6	0.6 – 0.3	< 0.3	any	-

Key: C-Clay, CL=Clay Loam, L=Loam, SL= Sandy Loam, SCL = Sand Clay Loam, LS=Loamy Sand
Sources: Sys *et al*., (1991); Mongkosalwat *et al*., (1997).

Table 4: Suitability class scores of the soils of the study area for yam

Land Quality		EA 1	EA 2	EA 3	EA 4
Climate (c)	Mean Annual Rain (mm)	S2(85)	S2(85)	S2(85)	S2(85)
	Mean Annual Temp.(^{0}C)	S1(100)	S1(100)	S1(100)	S1(100)
Topography (t)	Slope (%)	S1(100)	S1(100)	S1(100)	S1(100)
Wetness (w)	Drainage	S1(100)	S1(100)	S1(100)	S1(100)
Soil Physical Characteristics(s)	Texture	S2(85)	S2(85)	S2(85)	S2(85)
(s)	Soil depth (cm)	S1(100)	S1(100)	S1(100)	S1(100)
Fertility (f)	CEC (cmolkg^{-1} clay)	S2(85)	S2(85)	S2(85)	S2(85)
	Base saturation (%)	S2(85)	S2(85)	S2(85)	S2(85)
	pH	S2(85)	S2(85)	S2(85)	S2(55)
	Total nitrogen (%)	S3(60)	S3(40)	S2(85)	S3(40)
	Available P (mgkg^{-1})	S2(85)	S2(85)	S2(85)	S2(85)
	Exchangeable K (cmolkg^{-1})	S2(85)	S3(60)	S2(85)	S3(60)
Aggregate suitability	**Potential**	S2(72)	S2(72)	S2(72)	S2(72)
	Limiting factors	*S2sf*	*S2sf*	*S2sf*	*S2sf*
Suitability	**Actual (Current)**	S2(51)	S3(34)	S2(72)	S3(34)
	Limiting factors	*S2csf*	*S3f*	*S2csf*	*S3f*

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

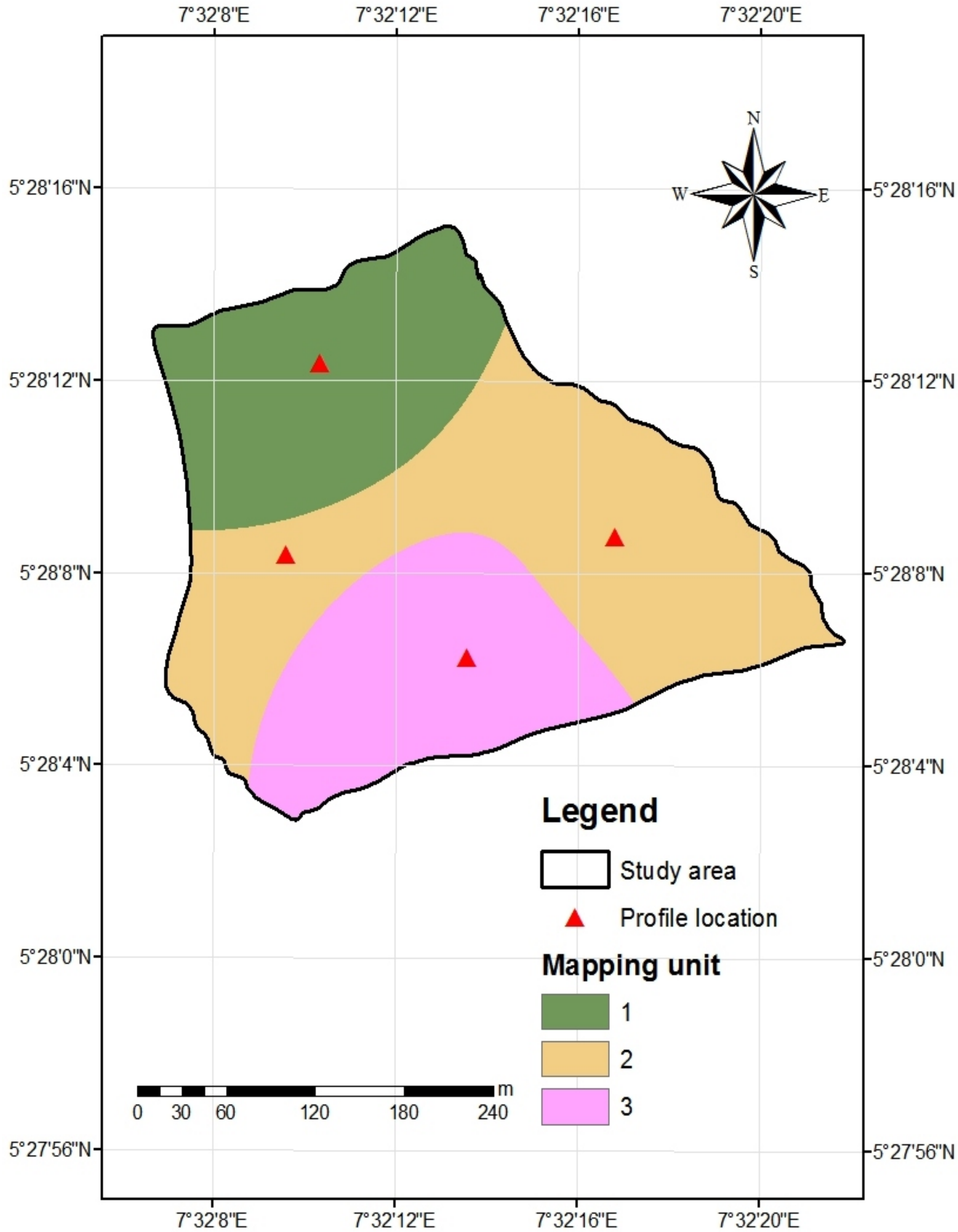

Fig. 1: Map of the study area showing soil mapping unit and soil profile

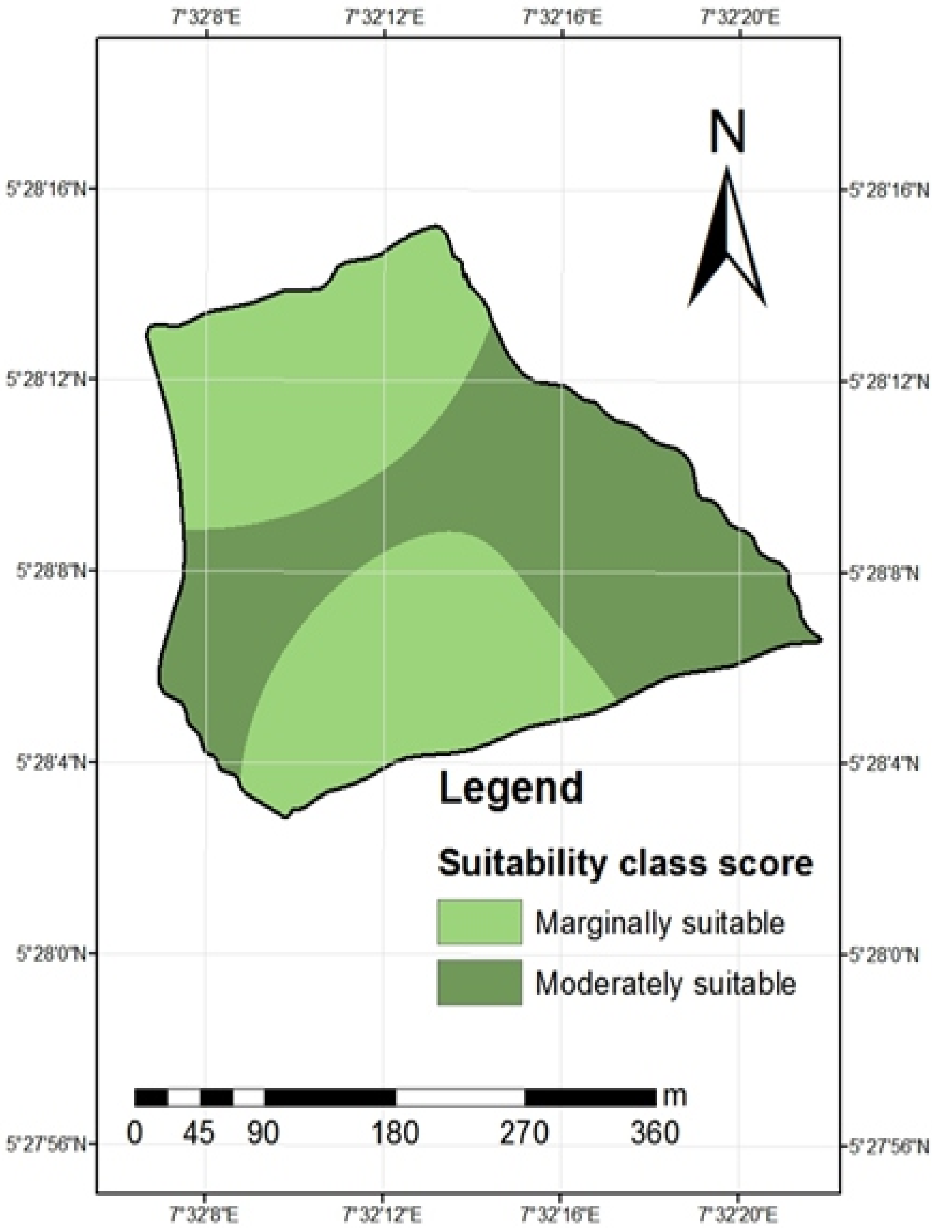

Fig. 2: Suitability map of the study area for yam cultivation