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CHARACTERIZATION AND TAXONOMIC CLASSIFICATION OF SOME BASEMENT COMPLEX SOILS IN KWARA STATE

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ABSTRACT
The soils of the Oyun Local Government Area of Kwara State were studied with the aim of characterizing and classifying them to provide the needed inputs into the Agricultural Transformation Agenda of the Government. Six soil mapping units were identified and designated YN1, YN2, YN3, YN4, YN5 and YN6. The soils were all formed on basement complex rocks, had deep weathered pedons and lateritic layers at depths less than 100 cm deep. Most of the soils were imperfectly to poorly-drained with sandy loam texture while structural aggregates were still poor to weak. The soil units were low in cation exchange capacity, basic cation (Ca, Mg, K), total nitrogen, available phosphorus and organic carbon. The soil units were low in available micronutrients Cu and Zn but high in Fe and Mn. The soil mapping units are therefore, low in their inherent fertility status. The classification of the soils mapping units of the survey areas shows that nearly all the mapping units were classified as Alfisols at the order level; indicating a fairly matured soils with well developed horizonation and fairly moderate base saturation. At the suborder level, they were mostly classified as Ustalf because of their ustic moisture regime. Soils on the narrow inland valley floors (YN1) however, classified as Entisols indicating a youthful soil development. The soils were mostly Luvisols and Lixisols at the group level in WRB while the Entisols were placed as Fluvisols and Cambisols.

INTRODUCTION

Kwara State is considered as one of the States in the middle belt of the country. The zone with a well distributed temperature and rainfall which in most cases is greater than 1000 mm per annum accounts for the bulk of cereals and tuber production in Nigeria. Benue, Kogi, Nasarawa, Plateau and Niger are the other States in the zone considered by many as the most productive lands in Nigeria. The zone produces the bulk of the cassava in the country (IITA, 2004). Aside from the recent but very few large commercial farms in the zone, agriculture, generally, has not developed to any significant level beyond what is obtainable in the country. The zone like other zones in the Country is characterized by declining productivity of agricultural soils caused in most cases by lack of scientific information on soils resources, incompatible landuses, inappropriate fertilizer use, and poor soil conservation practices.

The Millennium Development Goals 1 and 7 which are reduction of poverty and hunger and environmental sustainability, the Federal Government of Nigeria introduced the Agricultural Transformation Agenda (ATA); which is to sustain an increase in production of crops such as rice, maize, cotton, cocoa, sorghum/millet, soyabean, oil palm and cassava. Aside from the rich alluvial deposits of the major rivers of Niger and Benue the zone is underlain by the Precambrian Basement Complex comprising of metamorphic and igneous rocks. The dominant rock types include granites and granodiorites, biotite granite gneisses, migmatites and foliated rocks (Kogbe 1979). Unlike the rich alluvial deposits that have benefited from numerous soil survey (Hill and Wall, 1978; Ajiboye *et al.* 2012; Adiakwu and Ali, 2013), the basement complex soils of Oyun LGA, which form parts of the "Humid Kishi-Ilorin-Kabba Plain"agro ecological zone of Nigeria lack the needed soil information for sustainable agriculture. Broadly, the zone covers most of Kwara State, west part of Kogi State and the northern strip of Oyo State (Ojanuga, 2006). This work was therefore, aimed at characterizing and classifying the soils of the Oyun Local Government Area to provide the basic soil information as input into the Agricultural Transformation Agenda of the Government.

MATERIALS AND METHODS

Study Area

Oyun LGA, one of the sixteen LGAs in Kwara State, lies approximately between Longitudes 04^0 0" E and 04^0 30" E and Latitudes 06^0 40" N and 07^0 0" N. The LGA covers an area of about 96,000 hectares of land and falls under the "Humid Kishi-Ilorin-Kabba Plain"agro ecological zone of Nigeria. Broadly, the zone covers most of Kwara State, west part of Kogi State and the northern strip of Oyo State (Ojanuga, 2006). Oyun LGA is bound on the north by the Ifelodun LGA, on the east by Asa LGA and on the south by Osun State; encloses Offa LGA. The survey area is underlain by the Precambrian Basement Complex. The Complex comprises of metamorphic and igneous rocks. The dominant rock types include granites and granodiorites, biotite granite gneisses, migmatites and foliated rocks (Kogbe 1979). Colluvial–alluvial materials are generally associated with the valley bottom land (fadama) or inland valley. Generally, the landforms of the project sites are one of a gently undulating to flat plains with only slight contrasting features. However, in the extremely southern part of Oyun LGA the topography becomes more rugged being characterized by migmatite and quartzite ridges and well exposed elliptical granitic hills. The dominant slope is <2 % on the undulating plains to > 12 % in the hilly areas.

Rainfall occurs in the area from about April to November generally with some light showers in March. The rainfall pattern is bimodal, two peaks separated by a diminution in late July to late August, usually referred to "August break", which varies annually. This in addition to the length of the growing season permits two cropping seasons to prevail in the area. The average mean annual rainfall in the area, as recorded in the nearby meteorological station at Ilorin (about 50 km away) is 1260 mm. The length of the growing season and the length of the dry season are important climatic parameters for crop growth in the area. It varies between 210 and 240 days, thereby allowing for two cropping seasons and the cultivation of long-duration annual crops with a growing season of at least 180 days, including yam, cassava and sweet potato. The temperatures of the area, although vary slightly annually and seasonally, remains high throughout the year, with a mean annual value of 27 ^{0}C, indicating the tropicality of the environment and the characterization of the climate of the area as hot. The minimum temperature during the growing season is within the range of 22 to 24 ^{0}C. Therefore, temperature during the growing season is not a limitation to the cultivation for the adapted crops of the area. In the dry season, minimum and maximum temperatures are generally lower during the harmattan months of October to January in most cases, but higher than those for the rainy season during the rest of the season. The range in the dry season is about 16 to 20 ^{0}C and 30 to 35 ^{0}C for minimum and maximum temperatures (FDALR, 1991).

The mean annual potential evapotranspiration for the area is estimated to be 1280 mm. The relative humidity is moderately high, with the average at 60 % in any month of the year. The rate of potential evapotranspiration follows the trend of the relative humidity. The climax vegetation of the area is southern Guinea savanna, naturally dominated by fire-tolerant and fire-tolerant trees such as, *Buttyrospermum paradoxii, Daniella oliveri*, *Perkin clappertomania, Afzelia Africana*, *Prosposis Africana, Anarcadium occidentale, Mangifera indica*, and an understorey of forest shrubs and grasses including *Imperata cylindrical, Andropogon tectorium and Hyparrehia spp*. However, human activities such as cultivation, burning, firewood gathering and cutting for building purposes, over the years have converted the natural vegetation to open wooded savanna. However, they are still found in the fallow lands and near the seasonal streams in the area. The dominant type of land use in the area is agriculture. The major crops grown are cassava, maize, sorghum, yam, sweet potato and rice in the low lying areas. Intercropping is commonly practiced. Crop mixtures include cassava/maize, cassava/sorghum, yam/maize, yam/cassava/maize, cassava/maize/sorghum and yam/sorghum.

Pre-field work

The digital data used in this study were mostly SPOT5 five (5) meters resolution and sometimes Landsat ETM + 15 meters resolution. The satellite imagery of LGA Administrative boundary, roads and settlements were also used. Digital data on landform used in this study followed the Landform model using the ASTER 30-meter resolution Digital Elevation Model (DEM) projected to Universal Transverse Mercator (UTM), World Geodetic System (WGS) 84; instead of the 7.5-Minute U.S. Geological Survey 30-meter resolution National Elevation Dataset (NED) data (1-arc second) to Maryland State Plane 83 meters originally used in the Landform Model document. The classes were re-classed to reflect the nature of terrain capturing soil-landscape relationship as follows; Flat or nearly flat < 20m, Plains, Hills and Undulating plains. Digital Landuse data used in this study was from the Vegetation and Landuse project of Forestry Management Evaluation and Coordinating Unit (FORMECU) of the Federal Ministry of Environment. This was reclassified depending on the area to include; Cultivated area, Forest, Grassland, Water body and Built-up area.

Digital geologic data also used in this study was derived from the geological maps of the Federal Geological Survey of Nigeria. Provisional photo-soil map was obtained when the Landform, Landuse and Geology vector GIS layers were loaded into ArcGIS 10 and the Spatial Proximity function; intersect was used to spatially merge all the three into one layer. This way every single polygon had defined the landuse, geology and landform data. A new composite class mapping units were then created with the combination of the three parameters.

These new delineations using the concept of intersects of these three factors of soil formation also encompassed other factors such as climate in vegetation while time is also embedded in geology. The resultant mapping units were therefore, mainly soil associations. The soil-photo maps were then taken to the field for field description, sampling, refinement of soil boundaries etc during the fieldwork.

Field work

Reconnaissance tour of the study area was carried out between the 1st and 4th February 2013 in the first instance to have an overview of the survey areas and to offer the opportunity to refine the provision soil mapping units. This provided information for planning the detailed field work.

The detailed field work proper was carried out between the 4th February and 24th February 2013 in selected sample areas; 20 percent of the total land areas were selected as sampling area. In most cases existing roads and footpaths were used for boundary transect checking. The Offa–Ojoku-Afon Ilorin highway served as the baselines. Traverses at right angles to the baselines were mostly the secondary roads and footpath. Auger observation points were pegged at between 500 meters and 1 km interval along the traverses depending on the variability of the soils. Soil descriptions were made at 25cm depth interval; or according to horizontal sequence to the depth of 120 cm, except where an impenetrable layer was encountered.

The most significant physical and morphological soil characteristics considered important in the assessment of the soils are, colour, texture, structure, consistence, effective soil depth, stoniness and drainage status, included materials. The surface characteristics of the soils which include topography, erosion and deposition, vegetation and land use were also recorded. Refinement of the field photo-soil map was done on the field by classifying and plotting the information gathered from soil–landscape, auger borings and site characteristics from the sample areas and the results extrapolated to the rest of the LGA. The properties employed in the process of refining the delineated soil mapping units were mainly the observed geomorphologic, morphological and physical soil characteristics mentioned above. These differentiating parameters are considered significant in the use of the soils, since they collectively influence the water and nutrient holding capacities and permeability of the soils.

A total of between six (6) major mapping units were identified in the survey area. In the entire major soil mapping units, at least two soil profile pits were dug, described and sampled. This gives a total of ten (10) profile pits. The soils were described and sampled according to their natural horizons. The description of the morphological characteristics followed the pattern of USDA (Soil Survey Staff, 2010) and FAO/UNESCO/WRB (2006). The morphological properties of each of the profile pits were then described, after which bulk soil samples were collected for laboratory analyses. Soil profile descriptions followed the patterns outlines in the Soil Survey Manual (Soil Survey Staff, 1993).

Laboratory studies

Soil samples collected from different horizons of the profiles were air-dried and ground to pass through a 2-mm sieve. Soil pH was determined in 1: 2.5 soil/water suspensions using a glass electrode pH meter. Organic carbon was determined by the wet combustion method of Walkley-Black (Nelson and Sommer, 1982). Particle-size distribution was determined by the hydrometer method using sodium hexametaphosphate (Calgon) as the dispersant (Gee and Bauder, 1986). Exchangeable bases (Ca, Mg, K, and Na) were brought into solution by repeated extraction procedure with neutral 1M NH_4OAc (pH 7) solution (IITA, 1979); Ca^{2+} and Mg^{2+} in solution were read on an atomic absorption spectrophotometer; while K^+ and Na^+ were read on the flame photometer. Cation exchange capacity was determined by the 1N NH_4OAc saturation method while the effective cation exchange capacity (ECEC) was calculated as the sum of the exchangeable bases and exchange acidity. Exchangeable acidity was by the 1N KCl method. Available phosphorus was extracted by the Bray-1 method (Bray and Kurtz, 1945) and P in solution determined colorimetrically using the ascorbic acid method (Murphy and Riley, 1962). Electrical conductivity (EC) was measured in a 1:2.5 saturation extract. The DTPA extractant was used to extract available Fe, Mn, Zn and Cu and their values read on AAS (Lindsay and Norwell, 1978).

Soil Classification

In the taxonomic classification of the soils, consideration was given to the climate, morphological, physical and chemical properties considered significant in the Soil Taxonomy (Soil Survey Staff, 1999). World Reference Base (WRB) (ISRIC/UNESCO, 2006) was also used in the classification of the soils. In all the epipedons, endopedons, the temperature and moisture regimes were all determined in the consideration of the soil taxonomic classification.

RESULTS AND DISCUSSION

Morphological Properties

Six soil mapping units (soil associations) were identified in the Oyun Local Government Area (LGA) and denoted YN 1, YN2, YN3, YN4, YN5 and YN6 (Figure 1). The description of the mapping units are presented below while Table 2 presents a summary of their properties:

The soils of the YN1 mapping unit were deep and poorly drained. The soils were developed in alluvium material over biotite granite gneiss. The surface soil ranged from 30 - 40 cm in thickness of dark gray brown to very dark gray brown (10YR 3/2, moist) colours and of sand clay loam to clay loam texture. The subsoil colours ranged from pale brown (10YR 6/3, moist) to gray (2.5Y 5/1, moist) while texture was dominantly loamy sand to clay. The soil unit occupied valley bottom positions or inland valley of the landscape with dominant gradient of 0 - 1%. The soils were either lacking structural aggregate or weakly structured. As a result of continuous cultivation the Ap horizons were puddle. There were common medium distinct yellowish red (5YR 4/6) mottles especially in the subsoils. There were few medium pores while the quartz grains in the subsoils were fine and few. In the surface horizon, the soils were slightly sticky and plastic when wet, firm when moist but hard when dried. However in the subsoil, the soils were non-sticky and non-plastic when wet, very friable when moist and loose when dried. Most of the boundaries were gradual and smooth. The representative soil profile descriptions which typify the range of morphological properties discussed above are summarized in Table 1.

The soils of the YN2 mapping unit were generally moderately deep to deep. The soils were mostly imperfectly to poorly-drained. The soils were developed in residuum of biotite granite gneiss material. The surface soil was about 25 cm thick of dark brown (10YR 3/3) to very dark gray brown (10YR 3/2, moist) colours and mostly sandy loam texture. The subsoil colours ranged from light brownish gray (2.5Y 6/2, moist) to yellowish red (5YR 4/6, moist) while texture is dominantly sandy clay loam to clay. The soil unit occupied nearly flat to lower slope positions of the landscape with dominant gradient of 0 - 2 %. The soils were weakly structured with medium subangular blocky structure. Few cracks less than 1cm wide were not encountered at depth of about 36 cm. There were few medium pores while the quartz grains in the subsoils were fine and few. In the surface horizon, the soils were mostly non-sticky and non-plastic when wet, very friable when moist and hard when dried. However in the subsoil, the soils were sticky and plastic when wet, firm when moist and very hard when dried. Most of the boundaries were gradual and smooth. The surface of the mapping unit is characterized by the presence of worm cast and termite moulds.

The soils of YN3 and YN4 mapping unit were mostly shallow to moderately deep with weathered biotite granite rocks at depths of between 50 cm and 80 cm. The soils were mostly imperfectly to poorly-drained. They developed in residuum of biotite granite gneiss material. The surface soil was about 25 cm thick of very dark brown (10YR 2/2) to very dark gray (10YR 3/1, moist) colours and were mostly loam tex-

Table 1: Summary of morphological properties of the pedons

Horizon	Depth	Colour	Mottles	Texture	Structure	Consistency	Boundary	Remark
				YN1P2				
Ap	0-25	10YR 3/2	cff	cl	wmsab	vfi	cw	many fine roots
C1	25-52	10YR 5/3	cff	sl	wfsab	vfr	gs	few medium roots
C2	52-78	10YR 6/3	cff	ls	sl	vfr	gs	few fine roots
C3	78-120	10YR 6/3	mff	ls	sl	vfr	-	few fine roots
				YN2P1				
Ap	0-24	10YR 3/3	-	ls	mmsab	vfr	cs	common fine roots
Bt1	24-68	10YR 4/4	-	scl	mmsab	fi	gs	few fine roots
Bt2	68-120	10YR 4/6	ffd	C	wmsab	fi	-	few very fine roots
				YN3P1				
Ap	0-26	10YR 3/2	fff	sl	mfmsab	vfr	cs	common fine Fe-Mn concretions
Bt1	26-60	10YR 3/2	-	C	mmsab	fi	aw	few fine roots
Bt2	60-93	10YR 5/2	-	gr C	wmsab	fi	-	many fine to medium Fe-Mn concretions
				YN4P2				
Ap	0-25	10YR 3/1	cfd	L	mmsab	vfr	cs	common fine to few medium roots
Bt	25-53	2.5Y 6/2	fff	C	mmsab	fi	ss	few medium roots
BC	53-80	2.5Y 4/3	-	C	sl	fi	aw	common stones and gravels
Cr	80-	-	-	-	-	-	-	
				YN5P1				
Ah	0-22	10YR 3/3	-	ls	mfmsab	vfr	cs	common fine to few coarse roots
Bw1	22-49	10YR 4/6	-	ls	wfsab	fi	gs	few coarse roots
Bw2	49-127	7.5YR 5/4	-	sl	wfsab	vfr	-	few fine roots
				YN6P1				
Ah	0-10	10YR 3/2	-	gr cl	wfcr	fr	-	many quartz, feldspar grains and gravels

fff = few, fine, faint.
wmsab = weak medium sub angular blocky
mmsab = moderate medium sub angular blocky
mfmsab = moderate fine to medium sub angular blocky
wfsab = weak fine sub angular blocky
wfcr = weak fine crumb
sl = sandy loam
ls = loamy sand
C = clay
gr cl = gravelly clay loam
scl = sandy clay loam
fr = friable
fi = firm
vfr = very friable
vfi = very firm
cs = clear smooth
gs = gradual smooth
cw = clear wavy
aw = abrupt wavy
ss = sharp smooth

ture. The subsoil colours ranged from brown (7.5YR 4/4, moist) to olive brown (2.5Y 4/3, moist) while texture was dominantly clay. There were common fine faint strong brown (7.5YR 4/6) mottles throughout the soil profiles. The YN4 soil mapping unit was slightly undulating and occupies middle slope positions of the landscape with dominant gradient of 0 - 2 % while YN3 mapping unit occupies the lower slope positions. The soils were moderately structured with medium subangular blocky structure especially in the surface horizon. There were few tubular fine pores while quartz grains and fine Fe-Mn concretions occurred in the subsoils. In the surface horizon, the soils were mostly non-sticky and non-plastic when wet, very friable when moist and hard when dried. However in the subsoil, the soils were very sticky and very plastic when wet, firm when moist and very hard when dried. Most of the boundaries were sharp and wavy. The surface of the mapping unit is characterized by the presence of worm cast and termite moulds.

The soils of YN5 mapping unit were mostly shallow with laterite at depths of about 40 cm to deep at about 120 cm. The soil unit occupied upper slope of the plain to the foot slope positions of the hills of the landscape with dominant gradient of 4 - 8 %. The soils were mostly well-drained. They developed in residuum of biotite granite gneiss material. The surface soil was about 15-25 cm thick of dark brown (10YR 3/3) to very dark grayish brown (10YR 3/2, moist) colours and were mostly loamy sand to loam texture. The subsoil colours ranged from brown (7.5YR 4/4, moist) to dark yellowish brown (10YR 4/6, moist) while texture was dominantly sandy clay loam. The soils were moderately structured with medium subangular blocky structure throughout the profile. There were common tubular fine pores while quartz grains and fine Fe-Mn concretions occur in the subsoils. In the surface horizon, the soils were mostly non-sticky and non-plastic when wet, very friable when moist and hard when dried. However in the subsoil, the soils were sticky and plastic when wet, firm when moist and very hard when dried. Most of the boundaries were clear and smooth. The surface of the mapping unit was characterized by the presence of worm cast and termite moulds.

Table 2: Ranges and means of the chemical properties in the surface horizon

Mapping Unit	Sand	Slit	Clay	pH (H_2O)	pH ($CaCl_2$)	OC	N	Avail.P	Ca	Mg	K	Na	H + Al	CEC
	-	g/kg	-			-	g/Kg	mg/Kg	<	-	cmol	/Kg	-	>
YN1	560-700 (630)	200-320 (250)	100-120 (110)	5.2-5.4 (5.3)	4.4-4.6 (4.5)	8.38-11.37 (9.87)	0.77-1.05 (0.91)	5.08-6.30 (5.69)	1.20-1.80 (1.50)	0.70-0.40 (0.55)	0.07-0.30 (0.19)	0.20-0.27 (0.24)	1.80-2.40 (2.10)	5.00-5.70 (5.35)
YN2	700-780 (746)	160-240 (193)	60-60 (60)	5.5-6.4 (5.95)	4.6-5.2 (5.1)	3.79-5.39 (3.06)	0.35-0.77 (0.37)	3.85-5.08 (2.98)	2.40-3.00 (1.80)	1.10-1.20 (0.77)	0.08-0.13 (0.07)	0.10-0.20 (0.10)	1.30-2.00 (1.10)	6.80-8.10 (4.97)
YN3	720-840 (766)	100-200 (100)	60-80 (73)	5.7-6.1 (6.15)	4.9-5.9 (5.4)	3.80-5.99 (3.26)	0.07-0.56 (0.21)	3.15-9.45 (4.20)	3.20-4.00 (2.40)	1.10-1.90 (1.00)	0.12-0.23 (0.12)	0.14-0.21 (0.12)	1.40-1.60 (1.00)	6.50-7.20 (4.57)
YN4	720-720 (720)	200-200 (200)	80-80 (80)	6.1-6.5 (6.3)	5.8-5.9 (5.85)	4.79-5.79 (5.29)	0.42-0.56 (0.49)	5.95-6.65 (6.30)	2.60-3.40 (3.00)	1.10-1.50 (1.30)	0.09-0.14 (0.12)	0.15-0.17 (0.16)	2.10-3.00 (2.55)	6.10-8.80 (7.45)
YN5	660-880 (115)	60-160 (126)	60-180 (106)	5.8-6.5 (6.3)	5.0-5.9 95.6)	2.00-9.18 (3.73)	0.28-0.42 (0.23)	3.15-9.45 (4.20)	3.60-4.00 (3.80)	1.50-2.00 (1.75)	0.11-0.38 (0.16)	0.15-0.16 (0.10)	0.40-2.40 (0.93)	5.80-7.40 (4.40)

Soil mapping unit YN6 consists of hills with rocky outcrops. The soils were extremely shallow. They were well drained, gravelly sandy loam.

Physical Properties

Sand is the dominant particle-size fraction in both the surface and subsurface soils of the YN1 mapping unit. The sand fraction ranged from 560 to 7000 g kg^{-1} in the surface and 460 to 800 g kg^{-1} in the subsurface soils. Clay was the least of the three fractions and was about 100 g kg^{-1} in the surface horizons and was nearly constant with soil depth. The soil was therefore, mainly sandy loam in the surface and ranged from sandy loam to loam in the subsurface hori-

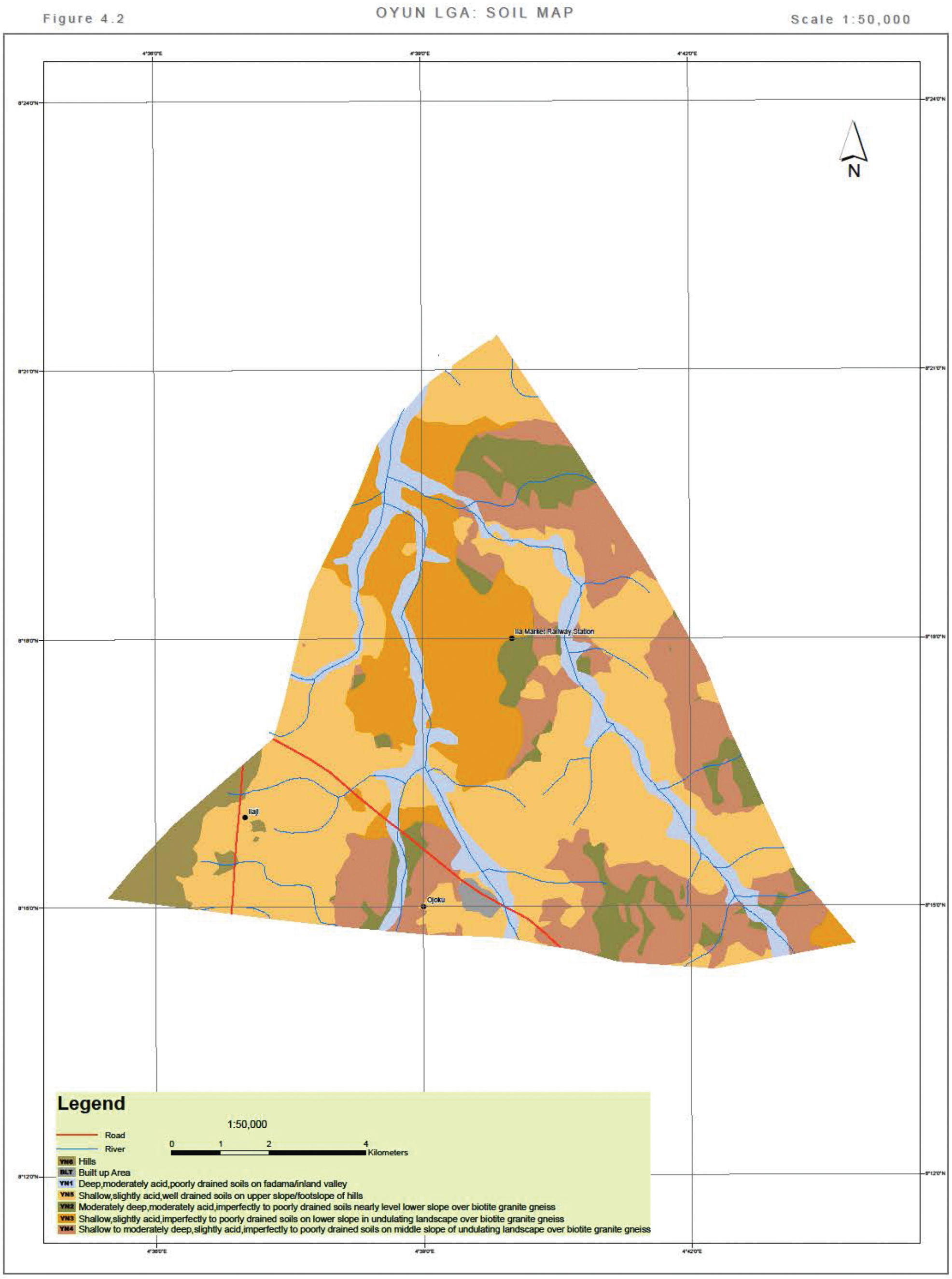

Figure 4.1: Soil map of Oyun LGA

zons. The bulk density values ranged from 1.55 to 1.58 mg m^{-3} and 1.53 to 1.59 mg m^{-3} in the surface and subsurface horizons respectively. Plants perform best in bulk densities below 1.4 mg m^{-3} for clay soils and 1.6 mg m^{-3} for sandy soils (Donahue *et al.,* 1990). Bulk density values between 1.7 and 1.8 mg m^{-3} and 1.45 and 1.65 mg m^{-3} for sandy and clayey soils have been observed to inhibit root growth. The bulk densities of the mapping unit are rated as low but adequate for plant growth. Total porosity values also ranged between 40 % and 42 % indicative of a fairly adequate pore spaces for both water and plant nutrients since most of the soils were sandy in texture.

Sand was the dominant particle-size fraction in both the surface and subsurface soils in the upland soils of YN2 through to YN5. The sand fraction ranged from 660 to 880 g kg^{-1} in the surface and 480 to 880 g kg^{-1} in the subsurface soils.

Table 3: Ranges and means of the chemical properties in the subsurface horizon

Mapping Unit	Sand	Slit	Clay	pH (H_2O)	pH ($CaCl_2$)	OC	N	Avail.P	Ca	Mg	K	Na	H + Al	CEC
	-	g/kg	-			-	g/Kg	mg/Kg	<	-	cmol	/Kg	-	>
YN1	440-800 (674)	100-420 (194)	100-240 (131)	5.3-6.1 (5.7)	4.5-5.4 (5.54)	1.80-4.99 (2.84)	0.22-0.35 (0.31)	4.90-8.05 (6.13)	1.00-3.41 (1.97)	0.30-1.30 (0.68)	0.06-0.09 (0.07)	0.18-0.50 (0.26)	0.60-2.00 (1.30)	4.70-6.90 (5.56)
YN2	420-740 (600)	120-240 (157)	100-460 (242)	5.3-6.3 (5.4)	4.4-5.4 (5.1)	3.19-5.98 (4.21)	0.28-1.40 (0.66)	2.10-3.50 (3.00)	2.20-8.40 (4.70)	0.70-3.20 (2.06)	0.09-0.29 (0.16)	0.14-0.57 (0.27)	1.20-2.10 (1.70)	6.60-15.3 (9.90)
YN3	580-720 (675)	60-160 (120)	80-360 (205)	5.4-6.8 (6.18)	5.2-5.7 (5.53)	2.99-9.58 (6.43)	0.07-0.70 (0.51)	1.93-4.38 (3.42)	2.60-4.60 (3.70)	1.30-2.70 (1.85)	0.09-0.28 (0.20)	0.10-0.43 (0.22)	1.0-1.80 (1.40)	6.20-8.8 (7.60)
YN4	540-720 (600)	120-140 (130)	160-320 (270)	6.2-7.0 (6.53)	5.5-6.2 (5.83)	2.19-11.97 (6.43)	0.35-1.05 (0.59)	3.33-4.73 (3.68)	3.20-5.60 (4.0)	1.40-2.60 (1.98)	0.17-0.29 (0.23)	0.23-0.97 (0.64)	0.60-2.80 (1.55)	7.40-11.3 (8.85)
YN5	600-880 (756)	20-160 (70)	80-300 (156)	5.4-6.4 (5.88)	4.7-5.6 (5.17)	2.40-15.76 (6.42)	0.28-1.12 (0.55)	3.15-7.35 (4.67)	1.60-5.00 (3.30)	0.60-2.30 (1.40)	0.04-0.20 (0.11)	0.09-0.63 (0.23)	0.70-2.00 (1.48)	4.20-11.3 (7.40)

Table 4: Ranges and means of the micronutrients in the surface horizon (ug/g)

Mapping Unit	Cu	Mn	Zn	Fe
YN1	1.30 (1.30)	38.3-40.7 (39.5)	0.60-1.10 (0.85)	47.06-140.6 (93.83)
YN2	0.40-2.30 (0.90)	29.52-61.17 (30.23)	1.10-3.20 (1.43)	36.70-205.10 (80.6)
YN3	0.20-0.90 (0.37)	12.70-56.46 (23.05)	0.30-0.80 (0.37)	8.19-32.82 (13.67)
YN4	0.30-1.10 90.70)	19.53-70.10 (44.81)	0.30-0.40 (0.35)	52.26-121.33 (86.79)
YN5	0.30-0.80 (0.37)	30.20-76.59 (35.59)	0.50-1.30 (0.60)	26.10-170.20 (65.43)

Clay remained the least of the three fractions and was between 60 and 100 g kg^{-1} in the surface horizons and increased gradually with soil depth to 360 g kg^{-1} in most of the profiles. The soil was therefore, mainly sandy loam in the surface and ranged from sandy loam to sandy clay loam in the subsurface horizons. The bulk density values generally ranged from 1.34 to 1.43 mg m^{-3} and 1.31 to 1.66 mg m^{-3} in the surface and subsurface horizons respectively. The porosity values also ranged from 46.70 to 49.68 percent in the surface horizons and decreased irregularly to about 37 percent in the subsurface horizons. The bulk densities of the mapping unit are rated as moderately low but adequate for plant growth.

Chemical Properties

The chemical properties of all the soil mapping units were very similar and were rated within the same range. Soil pH (water) generally ranged between 5.2 to 6.4 and 4.6 to 6.4 in the surface and in the subsurface respectively indicating strongly acid to moderately acid soil reaction except in the subsoil of one of the peons in mapping unit YN4 that had neutral soil reaction. The pH measured in $CaC1_2$ was lower than pH (water) in all the soils by 0.2 to 1.2 units, giving a negative delta pH value. The pH value measured in a soil-calcium chloride suspension gives a closer approximation to the pH of the soil solution (Schofield and Taylor, 1955). The soils had exchangeable sodium percentage (ESP) contents between 1.5 % and 4.7 % in the surface and 1.1 to 5.5 % in the subsoil except in the subsoil of YN4P2 where values as high as 13.1 was recorded. The ESP values are however, generally far lower than the critical limit of 15 % except in the YN4P2 where the value of 13.1 is close and needs to be monitored. However, while the sodium adsorption ratio values of the soils were not high, management practices that encourage leaching should be put in place to prevent salt built-up under continuous cultivation.

Among the exchangeable basic cations calcium was generally the principal saturating cation in all the soils with values that ranged from 1.20 and 4.0 cmol (+) kg^{-1} in the surface and in-

Table 5.: Ranges and means of the micronutrients in the sub-surface horizon (ug/g)

Mapping Unit	Cu	Mn	Zn	Fe
YN1	0.40-0.80 (0.56)	38.30-96.72 (63.77)	0.00-0.20 (0.21)	44.12-197.33 (34.49
YN2	0.10-1.90 (0.69)	25.28-137.13 (51.52)	0.30-8.28 (2.42)	40.20-307.37 (162.32)
YN3	0.20-0.50 (0.37)	6.66-18.16 (20.95)	0.30-0.40 (0.36)	10.20-34.19 (27.92)
YN4	0.10-0.40 (0.22)	20.30-66.60 (38.32)	0.10-0.70 (0.27)	30.20-157.37 (71.51)
YN5	0.10-0.30 (0.22)	2.27-60.20 (12.59)	0.00-0.70 (0.33)	36.65-92.76 (61.76)

creased generally with soil depth. This was followed by Mg with values that ranged from 0.40 to 2.0 cmol (+) kg^{-1} in the surface horizons but also generally increased in the subsurface horizons. This is followed by sodium and potassium was the least. All the exchangeable bases are rated low in all the soils. The values of exchange acidity (extractable) ranged from 0.40 to 3.40 com (+) kg^{-1} in the surface horizons but values decreased irregularly to between 0.60 and 2.8 com (+) kg^{-1} in the subsurface horizons. These values are rated as low in all the soils; soluble aluminium is not likely to be found in soils with a pH greater than 4.7 and likewise exchangeable aluminium is generally absent if the pH is greater than 5.0. For the purposes of interpretation, the soils in the study area are not currently under any threat of acidification.

The CEC of all the soils ranged from 5.00 to 8.80 cmol (+) kg^{-1} in the surface horizons and increased irregularly to a maximum of less than 10 cmol (+) kg^{-1} in the subsurface horizons (Table 4.2) except in the profile YN2P2 where CEC values as high as 15.3 cmol (+) kg^{-1} was obtained. The CEC of all the soil mapping units are therefore, rated as very low in both surface and subsurface soils respectively. The soils are therefore, low in their nutrient holding capacities especially for basic cations. The BS by CEC (NH_4OAc) ranged between 37.4 and 90.3 % in the surface, which generally decreased irregularly with increase in soil depth. The BS is rated moderate. The organic carbon content of all the soil mapping units was as low as 2 g kg^{-1} but as high as 11.37 g kg^{-1} in the surface horizons but generally values were lower than 5 g $gk^{-1,}$ and generally decreased with increase in depth to as low as 1.58 g kg^{-1}. These values are rated very low. Similarly, total nitrogen values were low in all the soil units. Total nitrogen content is generally less than 1.0 g kg^{-1}. Available phosphorus content was also low with values which were generally about 5 mg kg^{-1}. The low total nitrogen and available phosphorus may be tied to the low organic carbon, because it is a major source of nitrogen in soil which are reported for tropical soils (Sanchez, 1976).

Table 6: Soil Classification

	Soil Mapping Unit	USDA Soil Taxonomy	WRB
a)	Oyun LGA		
	YN1	AquicUstifluvents; AquicUstiumbrept	StagnicFluvisols; HaplicUmbrisols
	YN2	TypicHaplustepts; MollicHaplustept TypicHaplustalf	HaplicCambisols; HaplicUmbrisols;
	YN3	TypicHaplustalf; MollicHaplustept	HaplicLuvisols; HaplicUmbrisols
	YN4	TypicHaplustalf	GleyicLuvisols; GleyicLixisols
	YN5	TypicHaplustalf; TypicHaplustepts	HaplicCambisols; HaplicLuvisols

The contents of extractable micronutrient (Zn, Cu, Mn, and Fe) in all the soil mapping units were similar except for soils of mapping unit YN2 where values of Zn and Cu were generally higher. The extractable Zn in the surface horizons of all the soil units is rated moderate. The values ranged from 0.50 to generally less than 1.0 mg kg^{-1} except in YN2 where values as high 3.20 mg kg^{-1} were obtained in the surface horizons. In the subsoils, available Zn values were as low as 0.00 to 0.70 mg kg^{-1} except in YN2 where 8.28 mg kg^{-1} was recorded. Generally, values of available Zn were rated as moderately high to high in soils of mapping unit YN2 which was the only deep to very deep soils in the project area. Copper content of the soils ranged from 0.2 to less than 1.0 mg kg^{-1} in the Ap horizons and 0.20 to 0.80 mg kg^{-1} in subsoil except in soils on mapping unit YN2 where values were generally relatively higher. The values of the surface soils were considered to be high but moderate in the subsurface horizons. However, the Fe and Mn contents of all the soils were very high being more than the critical value of > 4mg kg^{-1} and >4.5 mg kg^{-1} respectively in the surface soils. This is ascribable to the high contents of the ferromagnesian minerals in soils of Nigerian basement complex and in tropical soils generally.

Soil classification

The soils had isohypothermic temperature and ustic moisture regime. All the soils had ochric epipedon because they did not have colour of 3 or less for chroma and colour value when moist, organic carbon that were less than 6 g kg^{-1} and or base saturation that was less than 50 percent except for pedons YN2P2, YN3P2 and YN3P3 which had mollic epipedons while YN1P2 had umbric epipedon.

According to the USDA Soil Taxonomy, soils of mapping units YN1 were classified in the order Entisol because they had little evidence of soil development and had no diagnostic B-horizon. The soils also had umbric and ochric epipedon and occurred on flood plains. Pedon YN1P1 was further classified as Fluvent at the suborder level; it had irregular decrease in the content of organic carbon and occurred on landscape of less than 2 % slope. At the great group level it classified as Ustifluvent and Aquic Ustifluvents at the subgroup level, since they experienced fluctuating water table condition in normal years. Pedon YN1P2 however, was classified at the suborder level as Umbrent and Ustiumbrent at the great group level. At the sub group level, it was classified as Aquic Ustiumbrent since it also witness fluctuating water table conditions.

Soil mapping units YN2 and YN3 were classified at the order level as Inceptisols except for one pedon each (YN2P3 and YN3P1) that classified as Alfisols because of the presence of Bt horizons, high base saturation that was greater than 50 percent and increased argilluviation in the subsurface horizons. Soil mapping unit YB2 are soils with an ochric epipedon, except pedon YN2P2 which had a mollic epipedon and cambic horizons with minimal soil structural development. At the suborder level they were therefore, classified as Ustepts by virtue of their ustic soil moisture regime. At the Great Groups level and subgroup they were classified as Haplustepts and Typic Haplustepts while pedon YN2P2 classified as Mollic Haplustept. Pedon YN2P3 was classified at the sub-order level as Ustalf because of its ustic moisture regime and Haplustalf at the great group level because of its simple profile morphology. At the sub group it was classified as Typic Haplustalf.

Soil mapping unit YN3, were shallow and

stony at depth except for pedon YN3P1 which was moderately deep. Except for pedon YN3P1, they were classified into the order, suborder, great group and subgroup as Inceptisols, Ustepts, Haplustept and Mollic Haplustepts. They were soils on erosion surfaces that diagnostic horizon for all other order do not occur. Pedon YN3P1 however, was classified at the order level as Alfisols because it had an ochric epipedon, an argillic horizon and high base saturation. It was classified at the suborder level as Ustalfs because of Ustic moisture regime and as Haplustalf and Typic Haplustalfs at the great group and sub-group levels respectively.

Soils of mapping units YN4 and YN5 were classified at the order level as Alfisols because they had ochric epipedon, argillic horizon and high base saturation except pedon YN5P1 which had only a cambic horizon and was classified as Inceptisol. The soils of mapping unit YN4 were however, shallow and generally less than 80 cm deep. They were classified at the suborder level as Ustalfs because of Ustic moisture regime and as Haplustalf and Typic Haplustalfs at the great group and sub-group levels. Pedon YN5P1 was however, classified as Ustept, Haplustept and Typic Haplustept at the sub-order, great group and sub-group levels respectively.

Using the criteria of the World Reference Base, the following soils; YN2P2, YN3P1, and YN3P2 had mollic diagnostic horizon while YN1P2 had an umbric diagnostic horizon. Argic diagnostic horizons were observed in the following pedons YN2P1, YN3P1, YN5P2 and P3 and soil mapping unit YN4. Cambic horizons were also observed in pedons YN2P1, YN3P2, YN3P3 and YN5P1. The soils were therefore, placed in the WRB reference group of Umbrisols for pedons YN1P2, YN2P2, YN3P1 and YN3P2 since they all had either a mollic or umbric diagnostic horizons. Because of the simple profile morphology they were further classified at the second level as Haplic Umbrisols. However, pedons YN2P1, YN3P1, YN5P2 and P3 and soil mapping unit YN4 were all classified as Luvisols because of their argic horizons and having base saturation that is greater than 50 percent except pedon YN4P2 which was classified as Lixisols because of its low BS. Except for YN4P1 and YN4P2 that were classified as Gleyic at the second level, all the Luvisols were classified as Haplic because of their simple soil profile. The Gleyic subgroup is as a result of fluctuating water conditions in the soils of mapping unit YN4.

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