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Soil mapping and *in-situ* soil description of selected land area of Funtua, Nigeria

Shobayo A.B., Ya'u, S. L. and Tarfa, B.D.

Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University, PMB 1044, Zaria, Nigeria.

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Corresponding Author's E-mail Address:
abshobayo@yahoo.com +2348036439717

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ABSTRACT

The study was done to delineate soil mapping units and produce the soil map of a selected 10 000 ha land. Landsat imagery of the study area was acquired and used for land cover and land use identification. Digital Elevation Models (DEM) of 10 m resolution was also obtained to produce landforms and contour maps. A 10 000 ha land was delineated from the landform map and divided with grids at 400 m interval from which a base map was produced at a scale of 1:20,000. The maps were digitized and geo-referenced. The base map with grids was uploaded into a geographical positioning system (GPS) for detailed fieldwork. The detailed fieldwork identified six major soil mapping units, namely FT1, FT2, FT3, FT4, FT5, and FT6. In each soil mapping unit (excluding FT6), two soil profile pits were dug, described and sampled. Evaluation of the soil mapping units indicates FT1 covered 1755.17 ha (17.55 %) and occupied level (0 – 2 %) lower slope position and was very deep (> 150 cm) and well-drained. The FT2 occupied 6407.90 ha (64.08 %), was imperfectly drained and deep (100 – 150 cm) and was situated on nearly level (0 – 2 %) to gently sloping ground on mid-slope to lower slope position. The FT3 was deep (100 – 150 cm), very poorly to poorly drained, covered 636.60 ha (6.37 %) situated on gently sloping (2 – 4 %) ground on lower slope. The FT4 soils span through the crest to lower slope positions, shallow (25 - 50 cm), well -drained and occupied 708.70 ha (7.09 %) and FT5 occupied 175.60 ha (1.76 %) located on a nearly level to gently sloping crest to mid-slope positions. The FT5 soils were well-drained and had moderate depth of soil materials (50 - 100 cm). The FT6 was very shallow soils to rock outcrops, occupied 316.03 ha (3.16), and no profile pit was sunk to characterize the map unit.

1. Introduction

Dynamic processes affecting geology and landforms as influenced by climate and other factors of soil formation have contributed to soil heterogeneity (references). The different soil distribution creates challenges to meet societal needs for ecosystem services that agricultural and non-agricultural lands provide. To make sound decisions regarding land use, knowledge of specific properties related to soils are necessary. In Funtua, the current information on soils is based on the reconnaissance soil survey, pedological information about its soils that formed and developed within the basement complex, the Northern Guinea Savanna is scanty. Interpretations based on properties of the soil in place are only applicable if characteristics of the land area are similar to what they were when soil mapping was done (Dobos *et al., 2017)*.

Soil map units are designed to efficiently deliver soil information to meet user needs for management and land use decision (references)s. A map unit is a collection of areas defined and named the same in terms of their soil components, miscellaneous areas, or both (references). Each map unit differs in some respect from all others in a survey area and is uniquely identified on a soil map. A map unit description is a written characterization of the component within a map unit and the relationship of one map unit to another (Scheffe and McVey, 2017). Soil descriptions give the properties of pedons and polypedons plus the extent of the components in each map unit, the variations in properties and in extent of components from one delineation to another throughout the survey area, and the geographic relationships of components within each map unit and of map units to each other (Soil Science Division Staff, 2017).

Set of soil descriptions is essential to the purpose of the soil survey and can be used by those who need the information. However, available data which have newly appreciated scientific importance for pedological studies are not being used for research because they are not georeferenced and available in digitized formats. Information from this study will be digitized and geo-referenced and will provide baseline information for appropriate land use intervention. It is expected to benefit the government, planners, and other soil users understand soils of the study area better, as well as enrich the Nigeria Soil Information System. It was on this view that the study was conceived to delineate soil mapping units and assess their geographic distribution within the study area and ultimately produce the soil map of the selected 10 000 ha land.

2.0 Materials and Methods:

The study area

The study area lies between 11°25'N to 11°34'N and 7°16'E to 7°22'E, located in Funtua, Funtua Local Government Area (LGA) of Katsina State, Nigeria. It is bordered by Faskari LGA to the north, Bakori and Danja LGAs to the east and Dandume LGA to the west (Fig.1). The area has land coverage of 10 000 ha.

Geology

Katsina State has two dominant geological formations. The south (study area) and the central parts are underlain by crystalline rocks of basement complex (from Funtua to Dutsin-Ma), but in the northern parts, cretaceous sediments overlap the crystalline rock (Buchanan and Pugh, 1955; Katsina Diary, 1989). The selected study area has three geological formation types, namely; the migmatite, granite gneiss, and undifferentiated schist. The undifferentiated schist has limited occurrence (Fig. 2).

Landform

The State is composed of undulating plains which generally rise gently from 360 m in the north-east around Daura to 600 m around Funtua in the South-west. The State forms part of the extensive plains known as the "High Plains of Hausaland." The Katsina-Daura Plain lies at a lower base level than other parts of the State. Southwards of Katsina-Daura plain, is flat to gently undulating surface, which is the result of years of erosion action on the surface rock. In areas around Funtua, there are numerous quartzitic and granitic hills, which rise 60 - 200 m above the surrounding plains (Katsina Diary, 1989; Sani, 2014).

Climate

The State can be classified into two zones climatically - tropical continental and semi-arid continental. South of the State from (Funtua [study area] to Dutsin-Ma) has total an-

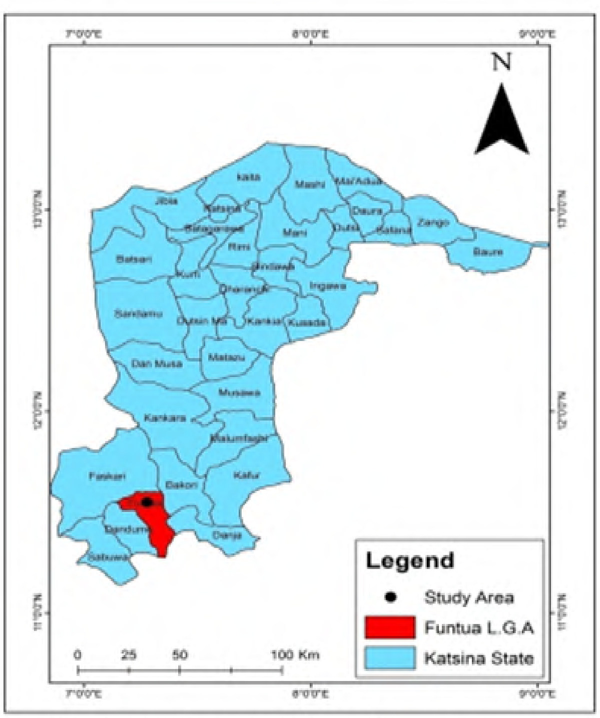


Fig. 1: Location map of the study area

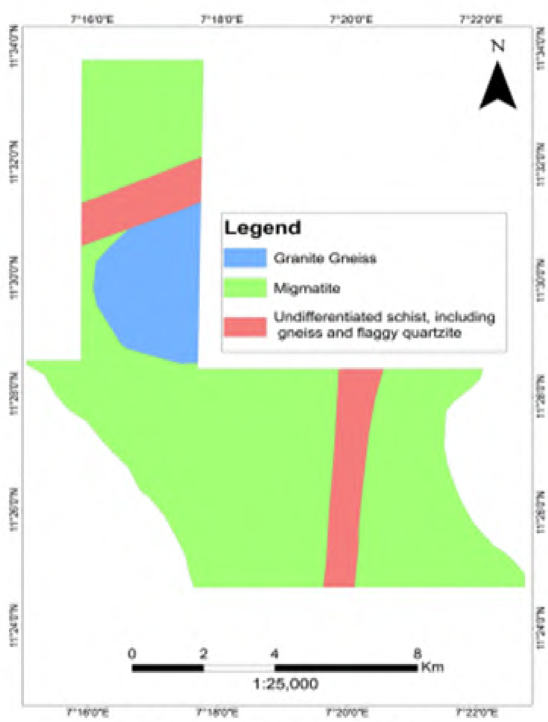


Fig. 2: Geological map of study area

nual rainfall figures ranging from 1000 mm around Funtua to over 800 mm around Dutsim-Ma (Abaje *et al*., 2014; Abaje *et al*., 2016). The north of Katsina State (from around Kankia to the extreme north-east) has total rainfall figures ranging from 600 - 700 mm annually (Abaje *et al*., 2012).

Figures 3 and 4 contain a long-term (1964-2013) rainfall and temperature data of the study area.

Vegetation and land use
The southern half (study area) of the State belongs to northern guinea savanna zone, while the north belongs to the Sudan savanna zone. Vegetation in the south consists of broad-leaved species with tall tussocky grasses of guinea affinities, mixed with fine-leaved species of thorny trees with continuous short and feathery grass cover. The northern districts consist of trees that grow long taproots and thick barks that make it possible for them to withstand the long dry season and bush fires (Katsina Diary, 1989). The grass cover has durable roots which remain underground after stalks are burnt away or wilted in the dry season, only to germinate with the first rains. The existing vegetation in Funtua is a function of many years of human interference and degradation. The exploitation of the vegetation has largely influenced the soil types (Sani, 2014).

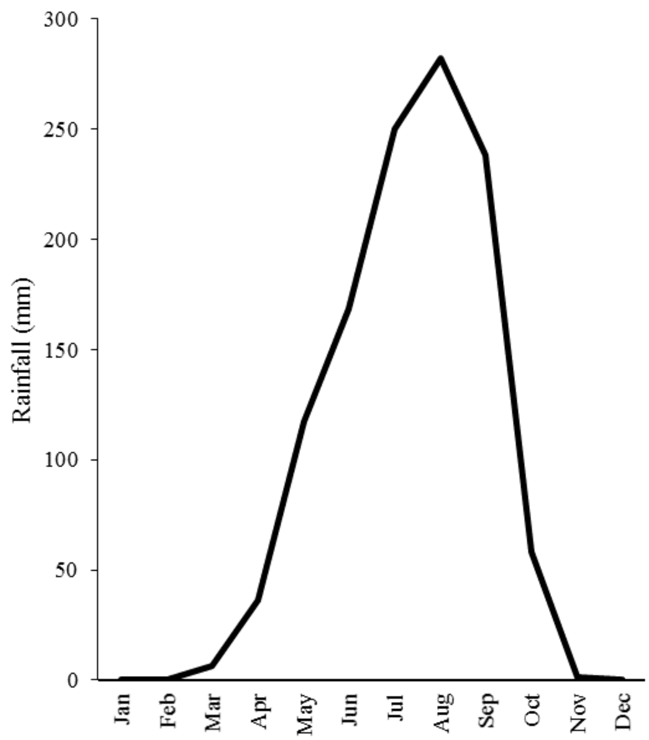


Figure 3: Long-term (1964-2013) rainfall data of the study area

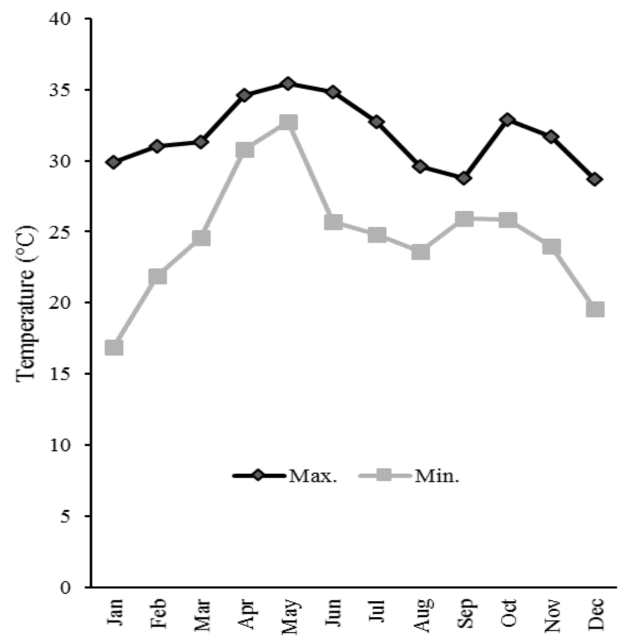


Figure 4: Long-term (1964-2013) temperature data of the study area

Acquisition of ancillary data covering the study area
Landsat imagery (Quick Bird) covering the study area (Figure 5) was acquired and used for land cover and land use identification. Digital Elevation Models (DEM) of 10 m resolution was acquired and used as an input data in ArcGIS software to generate landforms and contour maps. The materials used for the fieldwork were work-map, secondary data, survey tools/kit, motorcycle, vehicle, and Global Positioning System (GPS) for collecting geographic coordinates. For working map (base map), the topographic map scale 1:50.000 was used. The working map was supported with the geology map, landform and landuse map. Secondary data used was the climatological data collected on precipitation (rainfall), temperature, relative humidity, sunshine, and evapotranspiration. These data were used as tentative reference for interpreting the condition of the study area.

Pre-field work
These include collation and study of existing data of the study area, i.e., maps, reports, topo-sheets and analytical data, general field reconnaissance, Landsat imageries and interpretation and design and planning of fieldwork.

Processing of satellite imagery

The approach adopted involved the following activities:

Landform and contour

Using the DEM in a Geographical Information System (GIS) environment, landform boundaries were identified and drawn to primary units of hills, high plains, low plains, and flood plains. Geological map (Fig. 2) covering the study area was superimposed on the area, and four major landforms (Fig. 6) were identified as follows.

Irregular plains with low relief.

Smooth plains with some local relief.

Flat or nearly flat plains.

Wetland (Floodplain)

The map (Fig. 6) was digitized and geo-referenced at a scale of 1: 25,000. Contour map (Fig. 7) was also derived from the DEM, which shows that the study area is dominated by plains. The map was also digitized and geo-referenced.

Vegetation and land use

Vegetation and land use map of the study area was produced from Landsat satellite image. The map was digitized and geo-referenced and is presented in Fig. 8. Figure 8 shows that cultivation is very intensive in the upland and lowland flood plain.

Preparation of Base Map

From the landform map (Fig. 6) that was produced from DEM, a 10,000 ha land was delineated. The selected 10,000 ha of land was divided with grids at 400 m interval. The base map was produced at a scale of 1:25,000 (Fig. 9). The map was digitized and geo-referenced. The base map with grids was uploaded into a geographical positioning system (GPS) for detailed fieldwork.

Reconnaissance Survey

A reconnaissance survey was carried out in the study area. This was undertaken to obtain preliminary information as well as the actual land area that will be studied; thus, to enable for preparation of comprehensive fieldwork. Interpretation of the satellite imagery (Fig. 5) was ground troth during this visit. Soil mapping legend for the detailed field works was developed. This was done by augering and describing the different soil appearance in the study area and landforms. A soil mapping legend was finally prepared. The visit was also used to sensitize the communities within the study area about the research study. Village heads of the communities were adequately informed about the study.

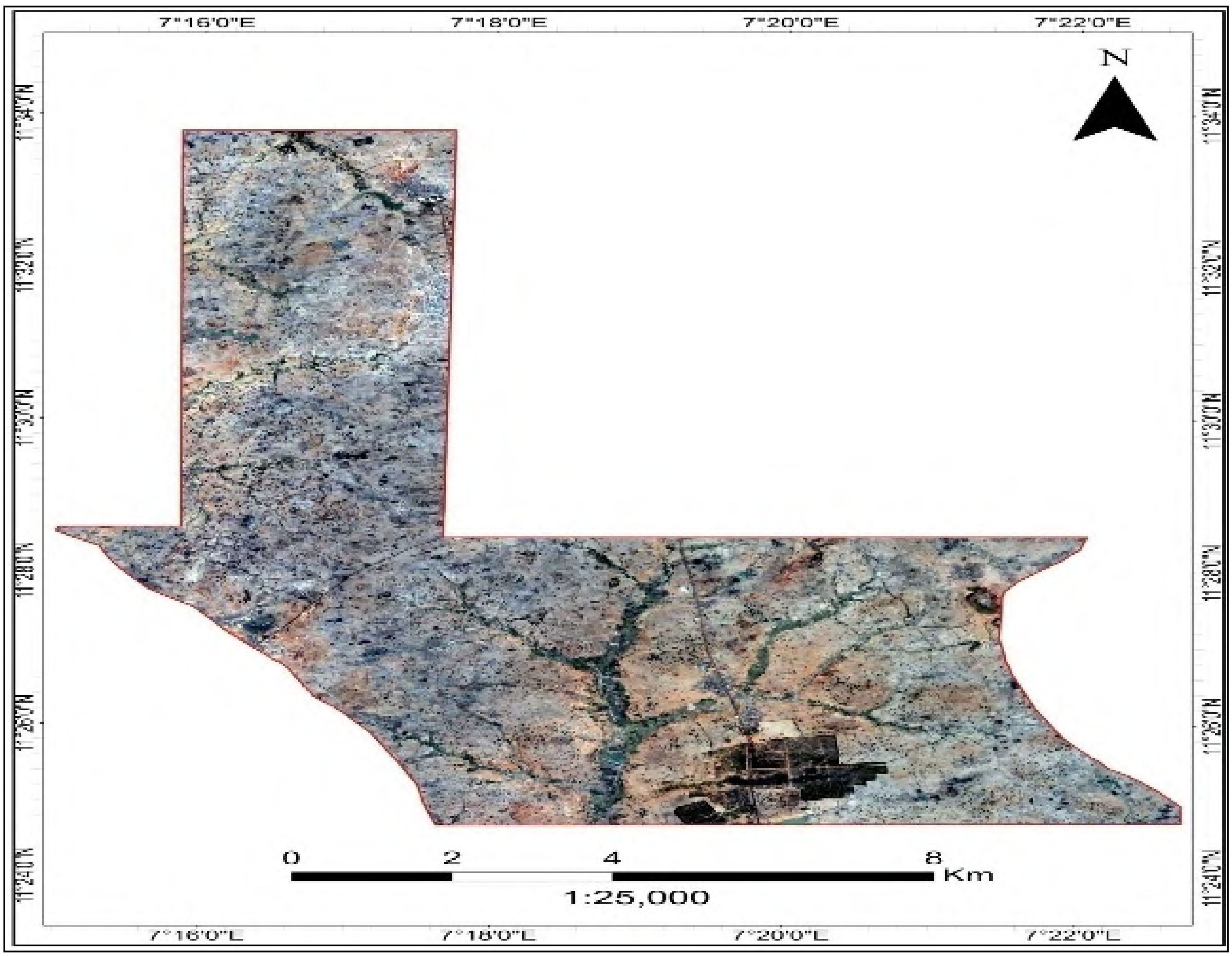


Figure 5: Landsat imagery of the study area

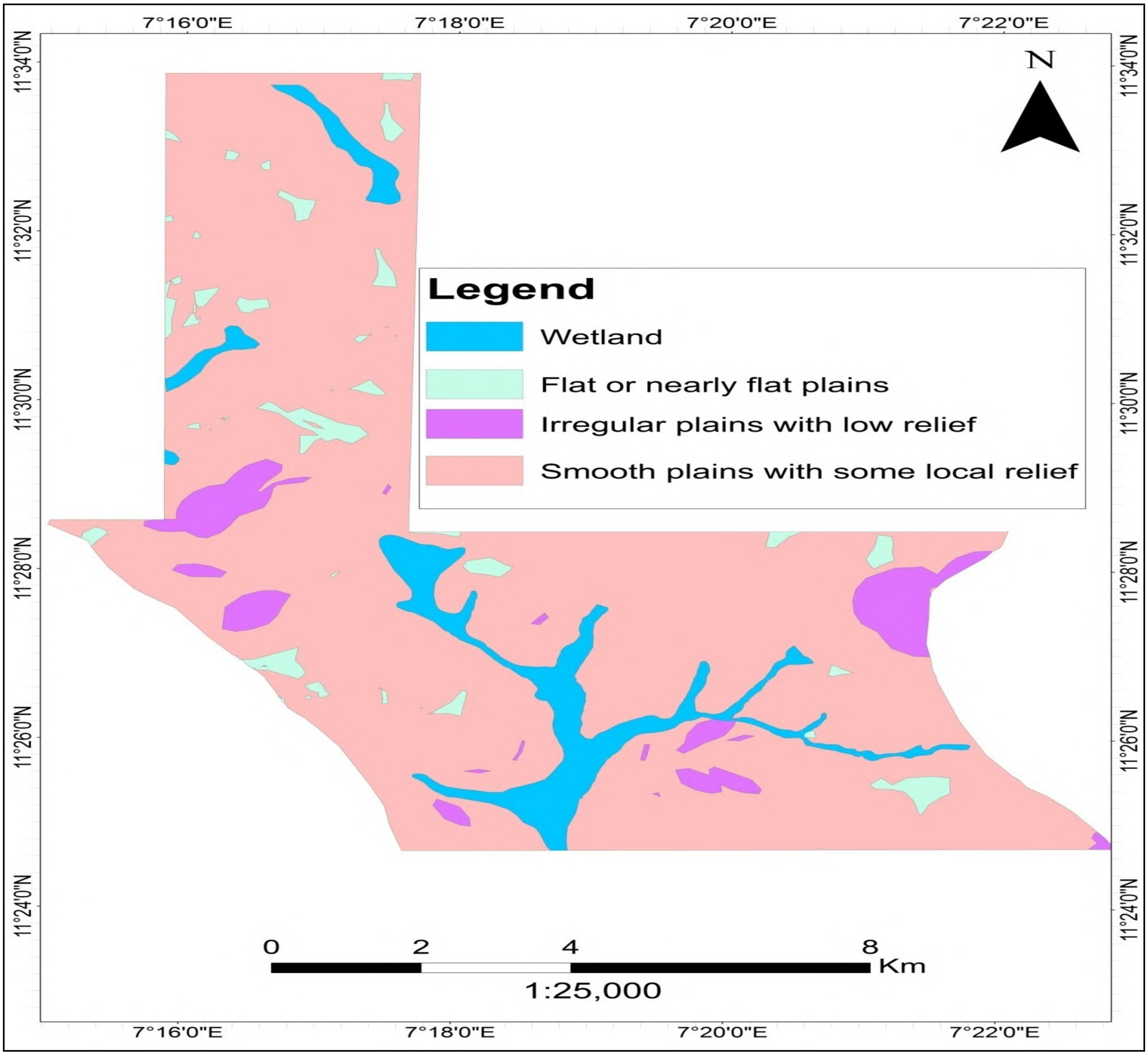


Figure 6 Landform map of the study area

Detailed fieldwork

The conventional method of a survey involving non-rigid grid procedure was adopted for the study in which observations were made at points where changes were expected along traverses noting changes with slope, vegetation and soil surface characteristics within the study area.

Traversing and auger hole description

Auger observation points were provisionally fixed at 400 m interval along baselines and traverses. The grid map was uploaded into Global Positioning Systems (GPS). At each of the observation point, auger borings were made to a depth of 130 cm or an impenetrable layer. Soil descriptions were made at 25 cm depth interval or according to a horizontal sequence where possible. At each observation point, full range of environmental characteristics and selected soil morphological characteristics were recorded. These include locality, local relief in terms of slope position and slope class, risk of soil erosion or deposition, rock and rock outcrops, drainage status, iron pan, surface characteristics, vegetation, and present land use.

Soil morphological characteristics that were evaluated include horizon identified, soil depth, the colour of matrix and mottles (if any), texture, stoniness, consistence, nature, and abundance of included materials, such as concretions and stones, roots, surface, and internal drainage conditions. The auger descriptions were classified and plotted along the traverse on a base map. Soil boundary lines were then drawn to fit soil mapping unit polygons.

Soil mapping and *in-situ* soil description of selected land area

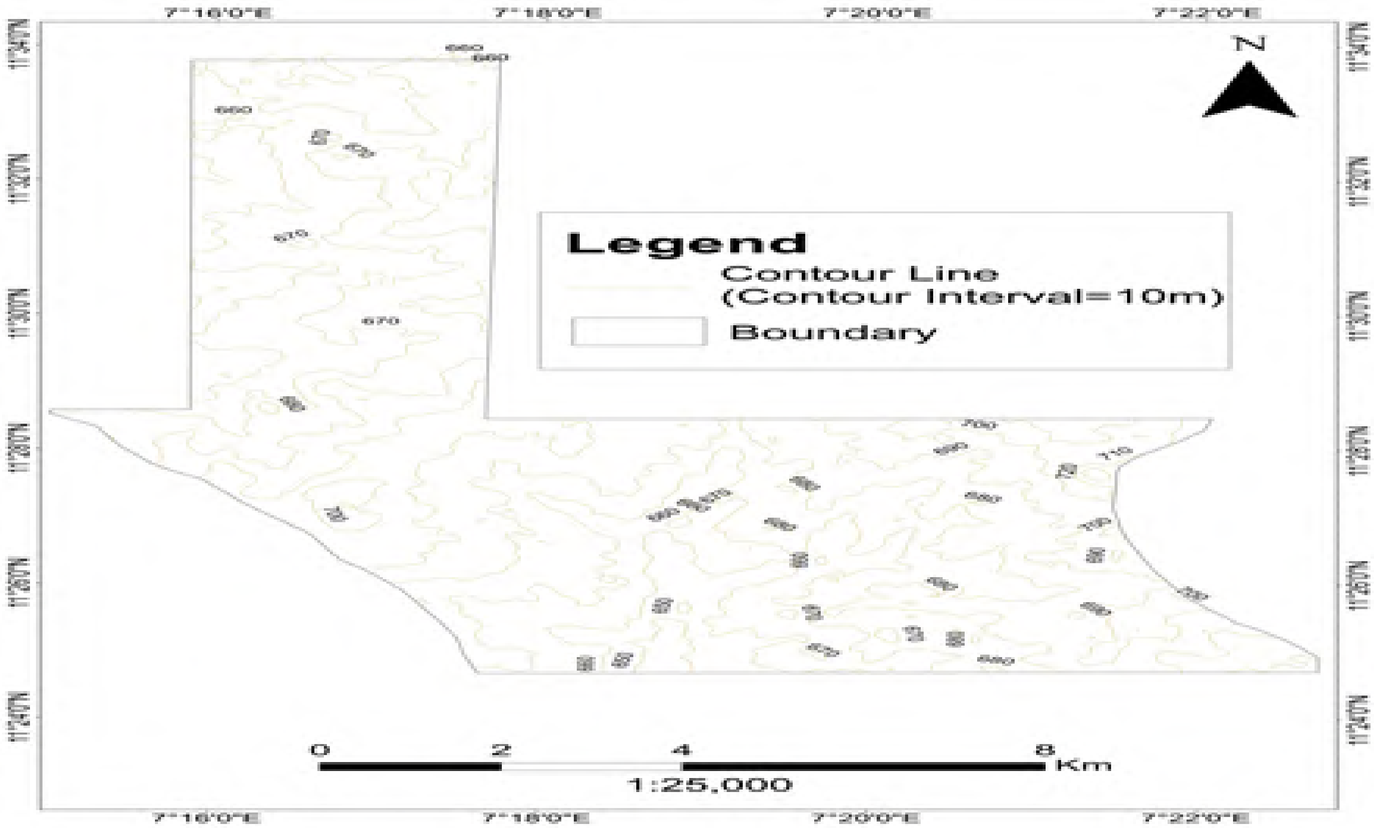


Figure 7: Contour map of the study area

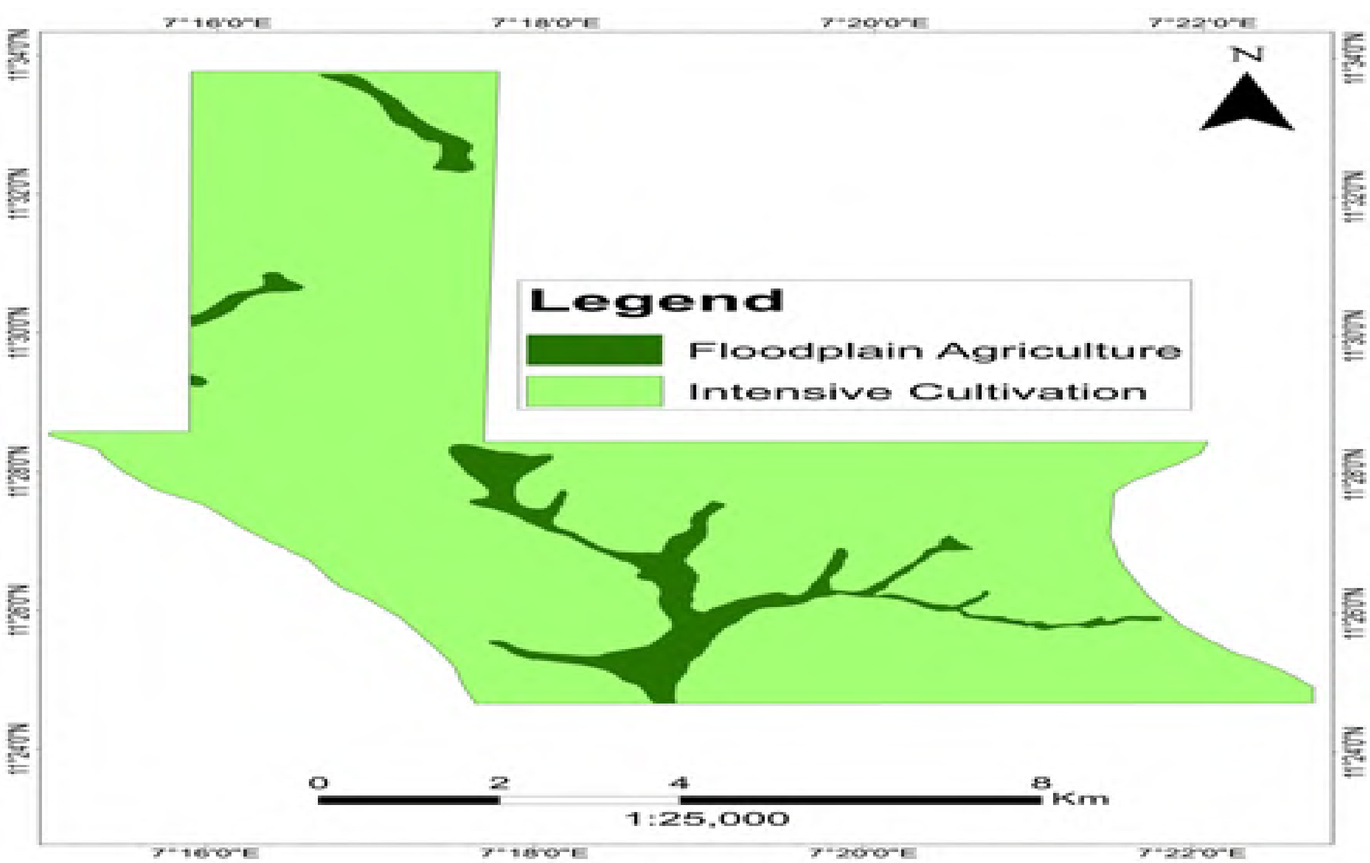


Figure 8: Land use map of the study area

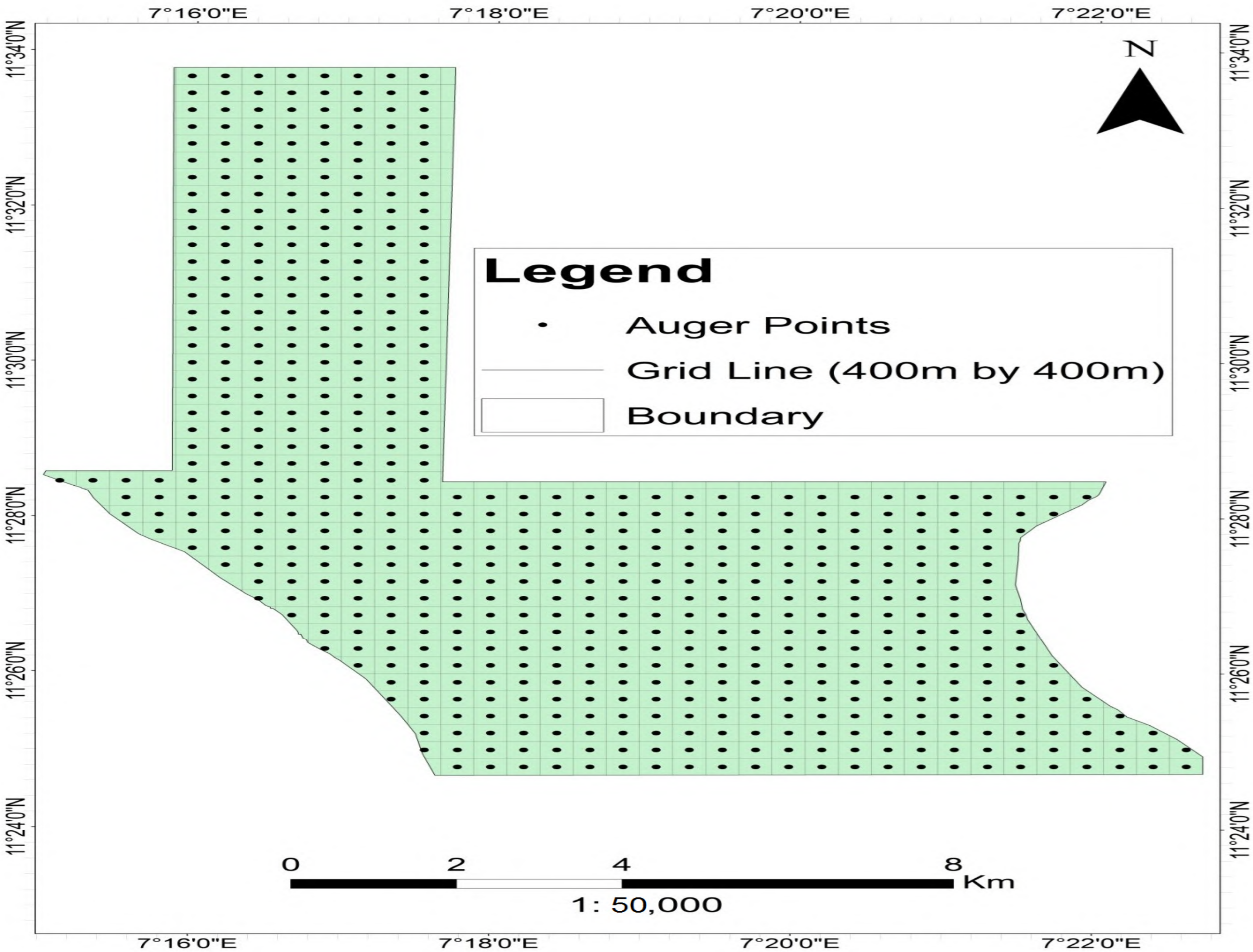


Figure 9 Base map of the study area

Soil profile pit description

In each soil mapping unit that was identified in the study area, two soil profile pits were dug, described and sampled from bottom-up, to minimize contamination by falling debris across a horizon's full depth and breadth (to avoid atypical pockets or lenses) according to the occurrence of genetic (natural) horizon for soil characterization. Each soil profile pit was dug to a standard size (200 cm long, 100 cm wide and maximum depth of 200 cm or until an impenetrable layer or water table was encountered). Each pit was described regarding its full range of morphological characteristics according to international standards of USDA/FAO (2014). These include soil depth, horizon thickness, colour of matrix and mottles, texture, structure, consistency, porosity, added materials, roots and horizon boundary, records of vegetation/land use, topography, slope, depth to water table and internal drainage status (Table 2); and finally, digital pictures (Plates I - VI) of the soil profile pits were taken.

Results and discussion

Soil mapping units :

The descriptions of the soil mapping unit considered a soil mapping unit as a group of closely interrelated soils with similar horizon arrangement in their profiles. The concept of the soil mapping unit was based on soils which shared similar morphological, topographical, and physical characteristics of depth, drainage, colour of soil matrix and mottles, texture, and structure identified. The soil mapping units were not completely homogenous but showed some variation concerning depth, textures, horizon arrangement.

Mapping units identified within the study area

Identified in the study area were six major soil mapping units namely FT1 (Plate I), FT2 (Plate II), FT3 (Plate III), FT4 (Plate IV), FT5 (Plate V) and FT6 (Plate VI). The area and percentage proportion covered by each mapping unit are presented in Table 1. The distribution of soil mapping units in the area is shown in the soil map (Fig. 10) produced at a scale of 1: 25,000.

Soil mapping and *in-situ* soil description of selected land area

Table 4.1 Extent of soil mapping units

Soil Unit	Area (ha)	Area (%)
FT1	1755.17	17.55
FT2	6407.90	64.08
FT3	636.60	6.37
FT4	708.70	7.09
FT5	175.60	1.76
FT6	316.03	3.15
Total	**10000**	**100.00**

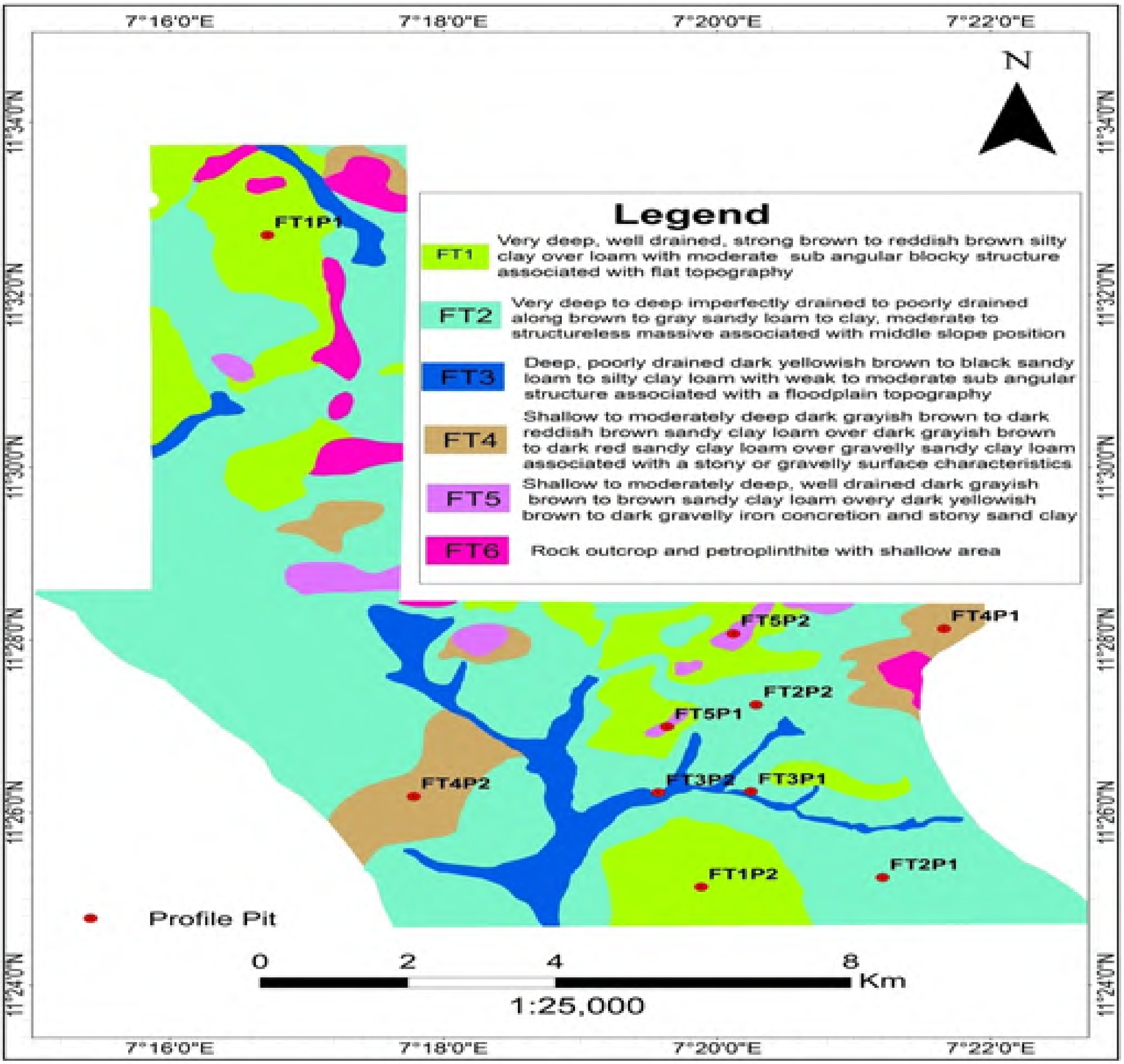


Figure 10 Soil map of the study area

Morphological Properties

Soil morphological properties considered include soil depth, colour, texture, structure, consistency, concretions, roots, pores, and horizonation. Summary of these morphological properties is presented in Table 2, while the detail morphological features are discussed below.

Soil extent, slope, drainage, and depth characteristics

The soil drainage and depth characteristics of the representative soil profiles typifying the soil mapping units are shown in Plates I - V. Soil mapping unit FT1 covered 1755.17 ha (17.55 %) and occupied level (0 – 2 %) lower slope position in the landscape. This is not beyond the critical slope limit of 3 % for the use of machinery and cannot crop production. The soil was very deep (>150 cm) and well-drained. The extent of root development is highly controlled by the effective soil depth, which is the depth beyond which roots will not readily penetrate the soil (Shobayo, 2010; Aliyu *et al*., 2016). The soils were deep, hence will provide ample root zone and support higher capacities to store plant nutrients and water. Ogunkunle (2009) reported a different slope position and submitted that soils on upper to mid-slope position developed on basement complex rocks were found to be deep. Soil mapping unit FT2 covered an extensive part of the study area occupying 6407.90 ha (64.08 %). The soils were imperfectly drained and deep (124 – 151 cm) situated on nearly level (0 – 2 %) to gently sloping ground on mid-slope to lower slope of the study area. This suggests that waterlogging conditions are expected in this area especially during peak period of rainfall. It is therefore essential that surface drainage channels are constructed on this field to convey excess water out of the field as soon as possible.

Soils of mapping unit FT3 were deep (142 – 147 cm), situated on gently sloping (2 – 4 %) terrain on the lower slope and covered 636.60 ha (6.37 %) within the study area. The mapping unit soils were very poorly to poorly drained. Supply of certain plant nutrients is controlled by the degree of aeration, which in turn is determined by the amount of water held in the soil at any given time. Waterlogging is known to affect the growth of most crops because most crops do not tolerate prolonged waterlogging period. Excess moisture will be detrimental for germination of many cereal crops grown within the study area. Oxygen is expelled from the soil system under poor drainage conditions which restrict roots respiration and nutrient uptake by plants. Poor drainage also encourages the deterioration of soil structure which subsequently affects the degree of aeration as evident in the soil colour matrix (Aliyu *et al*., 2016).

The soils of mapping unit FT4 occurred randomly within the study area and occupied 708.70 ha (7.09 %). The soils' surface was characterized by scattered quartz stones, hardened laterites. The soils span through crestal to lower slope positions. The soils were shallow (25 - 50 cm) and were well-drained, with stony quartz line, petroplinthite and parent rocks restricting soil depth. Okusami (1981) associated stone-line only to those soils that are formed partially or wholly in situ in basement complex rocks and have quartz gravels in the subsoil horizons. Soils mapping unit FT5 was the least extensive in area, occupying 175.60 ha, and proportion of 1.76 % (Table 1). The soils were located on a near level to gently sloping crest to mid-slope positions. The surface was characterized by presence of scattered stones and pebbles. The soils were well-drained and had moderate depth of soil materials (71 - 80 cm) with underlying stone line and coarse quartz restricting depth followed by saprolitic layer. The scattered stones and pebbles will be a constraint to mechanized agricultural production for this mapping unit. Soil mapping unit FT6 (second to FT5 in the ascending order of coverage) occupied a hectarage of 316.03 and percentage proportion of 3.16 (Table 4.1) and consisted of very shallow soils to rock outcrops. No profile pit was sunk. The use of this study area would be influenced by topography and surface characteristics. The nature of the surface characteristics/ topography specifies the use of sophisticated farm machinery and special conservation measures such as contour farming and terracing. Soil mapping unit FT6 has slopes of 2 – 4 % coupled with its rugged landscape (Plate VI) and therefore would limit usual cultivation practice.

Soil colour

All soils that occupied upland positions on the landscape expressed colours that were usually associated with well-drained environments. However, the soil colours were associated to inheritance from the mineral parent materials, but more generally, the soil colours were generated by soil-forming processes; as variant colours were observed on soils formed on each soil mapping unit. The most prominent feature of the soils or soil layers is probably its colours (Brady and Weil, 2013). Soils of mapping unit FT1 was dominated by strong brown to reddish-brown (7.5YR 4/6 – 2.5YR4/6 moist) to red (2.5YR 4/6) colours (Table 2, Plate I). Soils of mapping unit FT2 varied from brown (10YR 4/3, moist) to dark yellowish-brown (10YR 4/6, moist) colour in the surface horizon and gray (2.5YR 6/1) in the subsoil (Plate II). Soils mapping unit FT1 was well-drained as evidenced by the absence of mottles within 100 cm depth in the entire soil profile; however, FT2 showed some limitation to drainage. Soils of mapping unit FT3 had varying brown (10YR 4/6, 10YR 4/4, 2.5Y 4/4, 2.5Y 5/3) colours to black (2.5Y 2.5/2, wet – Table 2, Plate III). The subsoils were characterized by varying degree of mottles in the soil pedons. Soils of mapping unit FT4 had brown (7.5YR 4/4, moist) to dark reddish brown (2.5YR 3/4, moist) colour with dark red (2.5YR 3/6) colours in the parent materials (Cv) horizons (Plate IV). Soils of mapping unit FT5 had varying brown soil matrix (Plate V).

Table 2a Morphological properties of FT1 & FT2 soils of the study area

Horizon	Depth (cm)	Munsell colour (moist)	Mottling	Texture	Structure	Consistency Wet	Consistency Moist	Consistency Dry	Boundary	Other Features
Soil Unit FT1 (Pedon P1) Location: Latitude:11°32'40.9" Longitude: 7°16'41.6" Altitude: 699m (Typic Haplustalfs, fine-loamy, mixed, semiactive, isohyperthermic)										
Ap	0-9	7.5YR4/6	-	SCL	Mmsb	ss, sp	fr	-	cs	Common fine roots, common macro and micro pores, low excavation difficulty.
BA	9-50	5YR5/6	-	L	Mfsb	ss, sp	fr	-	gs	Few tubular very fine pores, few fine roots.
B_1	50-84	2.5YR4/4	-	L	Mfsb	s, p	fm	sh	gs	Many tubular very fine-medium-coarse pores, very few very fine (1mm) roots.
B_2	84-200	2.5YR4/6	-	SCL	Sfsb	vs, vp	vf	h	-	Moderately few tubular very fine pores, very few, very fine (1mm) roots, few medium Mn concretions
Soil Unit FT1 (Pedon P2) Location: Latitude:11°25'8.3" Longitude: 7° 19'54.4" Altitude: 693m (Typic Haplustalfs, fine-loamy, mixed, semiactive, isohyperthermic)										
Ap	0-29	7.5YR4/6	-	L	Mmsb	ss, sp	fr	sh	cs	Many tubular very fine-medium-coarse pores, common medium to fine roots.
B	29-65	7.5YR5/6	-	L	Mmsb	ss, sp	fr	sh	gs	Common fine roots, common macro and micropores, low excavation difficulty.
Bt	65-110	2.5YR4/4	-	CL	Mfsb	vs, vp	fm	h	gs	Few tubular very fine pores, few fine roots.
BCt	110-165	2.5YR4/6	-	CL	Mcsb	s, p	fr	h	-	Few tubular very fine pores, few fine roots.
Soil Unit FT2 (Pedon P1) Location: Latitude:11°25'15.3" Longitude: 7°21'11.6" Altitude: 680m (Ultic Haplustalfs fine-loamy, mixed, subactive, isohyperthermic)										
Ap	0-22	10YR4/6	-	CL	Wfmsb	ss, sp	fm	sh	cw	Few fine pores, many fine (1-2mm) roots, low-moderate excavation difficulty.
Bg	22-60	2.5Y5/2	-	L	Massive	ss, sp	fm	vh	cs	Few tubular fine pores, few fine Fe-Mn concretion.
Btg	60-109	2.5Y5/1 (wet)	fffm	CL	Smcab	vs, vp	vfm	vh	ds	Very few tubular fine pores, common fine Fe-Mn concretion.
BCtg	109-151	2.5Y6/1 (wet)	fffm	CL	Smcab	vs, vp	vfm	vh	-	Fine Fe-Mn concretions, medium - coarse decomposed parent material
Soil Unit FT2 (Pedon P2) Location: Latitude:11°27'15.9" Longitude: 7°20'16.8" Altitude: 692m (Ultic Haplustalfs fine-loamy, mixed, subactive, isohyperthermic)										
Ap	0-26	7.5YR4/4	-	L	Wfmsb	ss, sp	fr	s	cw	Few tubular fine pores, many fine-medium (1-5mm) roots.
Bt_1	26-74	7.5YR5/8	-	CL	Mmsb	s, p	fm	vh	ds	Few vesicular coarse pores, very few fine (1-2mm) roots.
Bt_2	74-100	5YR5/8	-	L	Mmsb	ss, sp	fm	vh	-	Excavation difficulty was high.

Table 2b Morphological properties of FT3 & FT4 soils of the study area

Depth (cm)	Munsell colour (moist)	Mottling	Texture	Structure	Consistency Wet	Consistency Moist	Consistency Dry	Boundary	Other Features
3 (Pedon P1) Location: Latitude:11°26'14.7" Longitude: 7°20'13.0" Altitude: 680m (Aeric Endoaqualfs coarse-silty, mixed, active, isohyperthermic)									
0-17	10YR4/6	-	SiCL	Wmsb	ss, sp	fr	-	cw	Few tubular very fine pores, few very fine (1mm) roots, low excavation difficulty
17 – 40	5Y2.5/2	fffm	L	Wfsb	s, p	vfr	-	ds	Few irregular very fine pores, very few very fine (1mm) roots
40 – 142	5Y2.5/2	cfdm	L	Wmcsb	s, p	vfr	-	-	Common tubular medium pores, few very fine (1mm) roots, common medium black Mn concretion ≤2 in value & chroma.
3 (Pedon P2) Location: Latitude: 11°26'10.8" Longitude: 7°19'26.3" Altitude: 673m (Aeric Endoaqualfs coarse-silty, mixed, active, isohyperthermic)									
0-29	10YR4/4	-	SiL	Mcsb	ss, sp	vfr	-	cs	Common tubular medium pores, few very fine (1mm) roots.
29-66	2.5Y4/4	-	SiL	Mmsb	ss, sp	fr	-	as	Common tubular medium pores, few very fine (1mm) roots.
66- 98	2.5Y5/3	fdm	SiL	Smsb	ss, sp	vfr	-	cs	Few tubular medium pores, moderate excavation difficulty.
98-147	10YR4/4	cfm	SiL	Mmsb	ss, sp	vfr	-	-	Common tubular medium pores, moderate excavation difficulty.
4 (Pedon P1) Location: Latitude:11°28'8.3" Longitude: 7°21'38.5" Altitude: 704m (Lithic Haplustepts loamy, mixed, semi-active, isohyperthermic)									
0-25	7.5YR4/4	-	SL	Mmsb	ss, sp	vfr	-	cs	Common tubular medium pores, few very fine (1mm) roots, presence of Fe-Mn concretions.
25-43	-	-	-	-	-	-	-	-	Stony
4 (Pedon P2) Location: Latitude:11°26'10.8" Longitude: 7°17'45.5" Altitude: 700m (Lithic Haplustepts loamy, mixed, semi-active, isohyperthermic)									
0-31	2.5YR3/4	-	SCL	Structureless	ns, np	fr	s	cs	Few-common tubular medium-coarse pores, many medium (2-5mm) roots, many medium quartz and Fe-Mn concretions.
31-50	2.5YR3/6	-	Ma	-	-		vh	-	Moderately few-common tubular medium-coarse pores, common ant activities.

Table 2c Morphological properties of FT5 & FT6 soils of the study area

Horizon	Depth (cm)	Munsell colour	Mottling	Texture	Structure	Consistency			Boundary	Other Features
		(moist)				Wet	Moist	Dry		
Soil Unit FT5 (Pedon P1) Location: Latitude:11°26’10.8” Longitude: 7°17’45.5” Altitude: 700m (Lithic Haplustalfs loamy, mixed, active, isohyperthermic)										
Ap	0-13	10YR3/3	-	SL	Structureless	ns, np	vfr	s	Cw	Common vesicular fine pores, common fine (1-2mm) roots.
B	13-54	10YR3/6	-	SL	Wfmsb	ss, sp	ls	h	As	Fine (5-25%) thin cutans located in pores, moderately few tubular fine medium pores, moderately few fine (1-2mm) roots, presence of Fe-Mn concretions.
Cv	54-71	-	-	-	-	-	-	-	-	Petroplinthite encountered at 54m and excavation difficulty was very high.
Soil Unit FT5 (Pedon P2) Location: Latitude:11°27’59.9” Longitude: 7°20’6.5” Altitude: 701m (Lithic Haplustalfs loamy, mixed, active, isohyperthermic)										
A	0-25	10YR4/2	-	SL	Wmsbk	ss, sp	fr	s	Di	Few tubular fine pore, many fine (1-2mm) roots.
Bt	25-56	10YR4/4	2%	SCL	Scsbk	vs, vp	fm	vh	Cw	Very few vesicular fine pores, common very fine (1mm) roots.
CRv	56-80	10YR5/1	-	SL	Structureless	-	-	-	-	Stony, gravelly, single grained, petroplinthite quartz and black reddish Fe-Mn concretions, high excavation difficulty.
Soil Unit FT6 The unit consisted of very shallow soils to rock outcrops. No profile pit was sited (Lithic Ustorthents fragmental isohyperthermic)										

Foot note:

Texture: SiC = Silty clay, SiCL = silty clay loam, LS = Loamy Sand, L = Loam, SL = Sandy loam, S= sand and C = Clay

Structure: Wfcsb = Week, fine, crumb, sub angular blocky and Sm = Structureless, massive,

Consistence Dry: L = Loose, Moist: fr = friable, vfr = Very friable and fi= Firm

Consistence Wet: vs = very sticky, Ss = Slightly sticky, s= sticky, and ns = nonsticky

Plasticity: vp= very plastic, sp= slightly plastic, p= slightly plastic, np= nonplastic.

Boundary Distinctiveness: a = abrupt, c = clear, g = gradual and d= diffuse,

Boundary Topography: s = smooth, w = wavy and i = irregular

Soil texture

Soil mapping unit FT1 varied from clay loam to loam. Soil mapping unit FT2 had the varying texture of loam overlying clay loam. The loamy nature of soils will allow for easy mechanical workability of the soil with less damage to soil structure. Moisture retention in these soils was moderate. The loamy texture of the soil also suggests that leaching of fertilizer nutrients from these soils will be low. Soil mapping unit FT3 was dominantly loam to silt loam textured materials while soil mapping unit FT4 was dominantly sandy loam. Soil mapping unit FT5 was textured by sandy clay loam over gravely sandy clay loam in the subsoil.

Soil structure

All soils studied had moderate structure grade usually of the subangular blocky type indicating structural development that is typical of matured soils on relatively stable landscapes. Soil mapping unit FT1 had moderately developed subangular blocky structure in the surface horizon overlying moderately-strong structured subsoil horizons associated with nearly flat topography. Proper structural development improves root development, permeability, and aeration (Brady and Weil, 2013). The soils of this mapping unit had some crusted surfaces, moderate sheet erosion with gully cuts along the rivers in the area exposing granitic rocks. This will typically result in lower permeability and infiltration, which could induce more runoff and subsequent erosion. With moderate structural development, this soil mapping unit could withstand more intensive cultivation than the others. Soil mapping unit FT2 had weakly developed subangular blocky structure over moderately developed subangular blocky structure.

Soil mapping unit FT3 had weak (structural deterioration is expected under continuous cultivation) to moderately developed subangular blocky structure attributed to its poor drainage that encourages the degradation of soil structure which subsequently affects the degree of aeration as evident in the soil structure. Mapping units FT4 and FT5 had structureless aggregation that was massive and weak to a moderately developed subangular blocky structure. The reduced structural development seems to be related in part to the low organic matter content of the soils. Improvement of structure of soils of these mapping units are therefore necessary, and incorporation of crops residues and other organic matter sources besides with crop rotation should be adopted.

Soil consistency

Soil consistency would determine when and what type of mechanization would be suitable for land preparation at the study area without destruction of the soil structure. Consistency and structure are very closely related, and destruction of one lead to the destruction of the other (Singer and Munns, 1999). Consistencies of surface horizons of the soils were generally slightly sticky and slightly plastic (wet) except for FT4 P2 and FT5 P1 that were non-sticky and non-plastic (wet). In the subsoils, they varied from slightly sticky and slightly plastic (wet) to very sticky and very plastic (wet) consistency. The increase in cohesion and adhesion, consistency feature of these soils down the profiles were related to increases in illuviation, as was observed with sticky and plastic (wet) consistency in the argillic horizons having clay or clay loam texture. All the soils were found to vary between friable and firm (moist) consistence. Under the dry condition, most of the soils had slightly hard to hard consistency. The very friable consistency of the horizons (FT3) implies that the weak structural aggregates can easily be destroyed especially under intensive cultivation. Such a situation often leads to reduced pore space or aeration and increased bulk density, a significant limitation to easy root development especially as it was under poor drainage. It also suggests that these soils do have many problems with the soil moisture content of the fields before land preparation.

Miscellaneous observations

The examined soil profiles gave valuable insight into the soils' fertility. The light coloured horizons in the subsurface soils (Plates I, II and IV) were indicative of a highly weathered, infertile soil from which nutrients have leached away. As the soil weathers and organic matter decomposes, the profiles (FT4 and FT5) of the soil changed with attendant shallow surface layers that contain low amounts of organic matter. With clues provided by the soil profiles, it suggests that the soils will perform under enhanced nutrient management conditions. Tubular pores dominated the soils with very few occurrences of vesicular pores within horizons; however, surface (Ap) horizons had common medium pores to common fine pores. The upper portions of subsurface horizons of FT1 and FT2 had common fine pores, and the pores decreased in density and size with an increase in pedal depth. This may be attributed to argilluviation into the pores. There were many media to common fine roots observed in the Ap horizons of the soils. The immediate horizons underlying Ap horizons were observed to have common medium roots to many fine roots. Generally, the density and size of roots decreased with increase in soil depth. Excavation difficulty was low to moderate at Ap horizons for most of the soils; except soil units FT4 and FT5, that had their surfaces characterized by presence of scattered stones and pebbles. Excavation difficulty increased with increase in clay content down the profiles. Soil units FT4 and FT5 exhibited high to very high excavation difficulty as the lower subsoils were underlain with petroplinthite and or concretionary iron pan (Plates IV and V). The presence of iron and manganese concretions (FT5) along with mottles (FT2 P1, FT3) in B horizons of some of the pedons indicated accumulation and aggregations of iron and manganese oxides resulting in plinthization and might be attributed to parent material with the period of pedogenic exposure resulting in increased Fe illuviation. Generally, horizonation was more pronounced between the surface horizons (Ap) and subsurface soil than within the subsurface soil horizons and may be ascribed to melanization from the humification of organic matter in the Ap horizons.

Soil colour was the primary index used to detect horizon discontinuity. However, texture and consistency were used (especially in the subsoils) where applicable. Surface horizons of all the soil mapping units were mostly clear smooth. However, clear wavy was also observed in some pedons (FT2, FT3P1, and FT5P1), and this was attributed to tillage effect. Horizon differentiation in the subsurface soils varied from gradually smooth to smooth to abruptly smooth in the soils (Table 2).

Profile pits on soil mapping units/Morphological properties

Plate 1: Pedon FT1 P2 showing a very deep, well drained red soil formed on a nearly level slope.

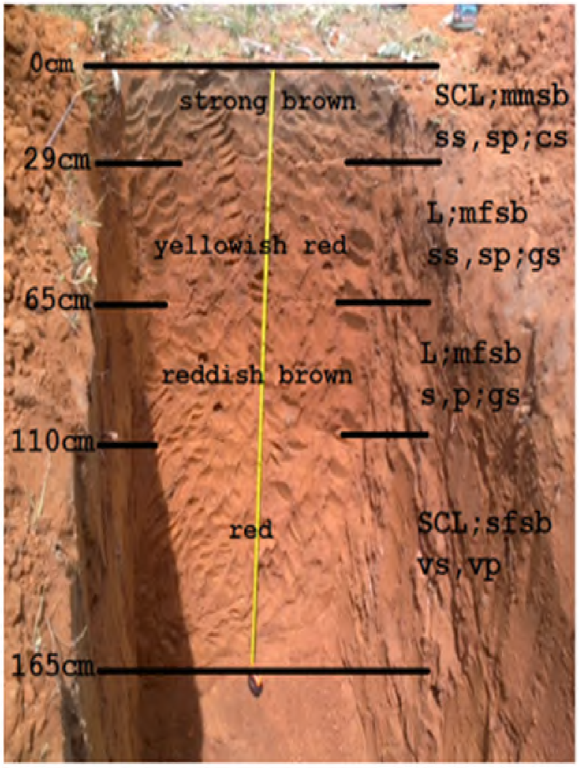
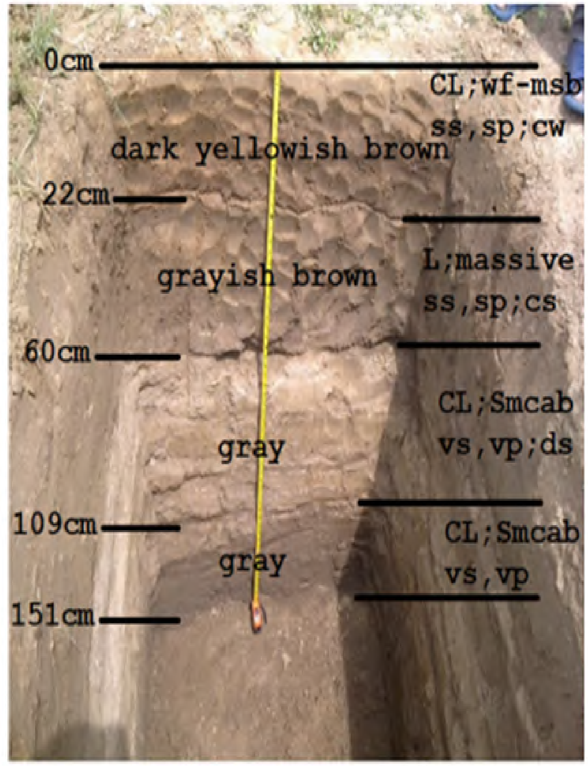


Plate 2: Pedon FT2 P1 showing a very deep, imperfectly drained soil formed on a nearly level slope.



Profile pits on soil mapping units/Morphological properties contd.

Plate 3: Pedon FT3 P1 showing a deep, poorly drained soil formed on a gently sloping ground on a lower slope.

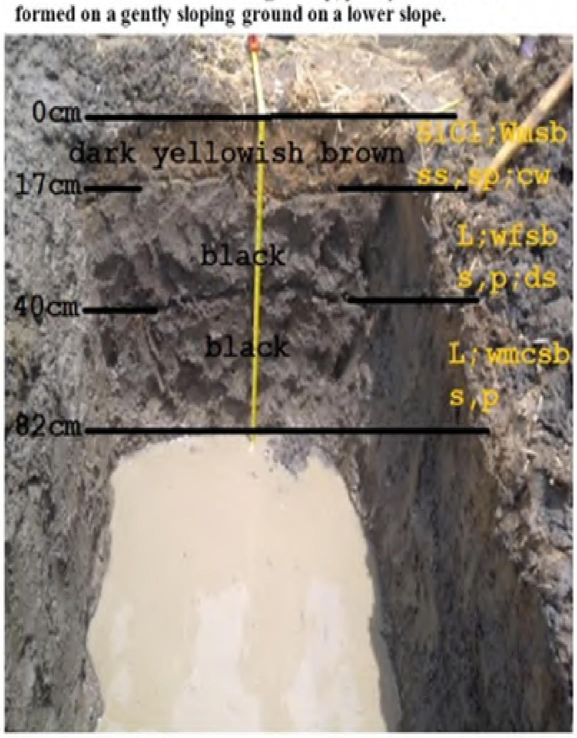
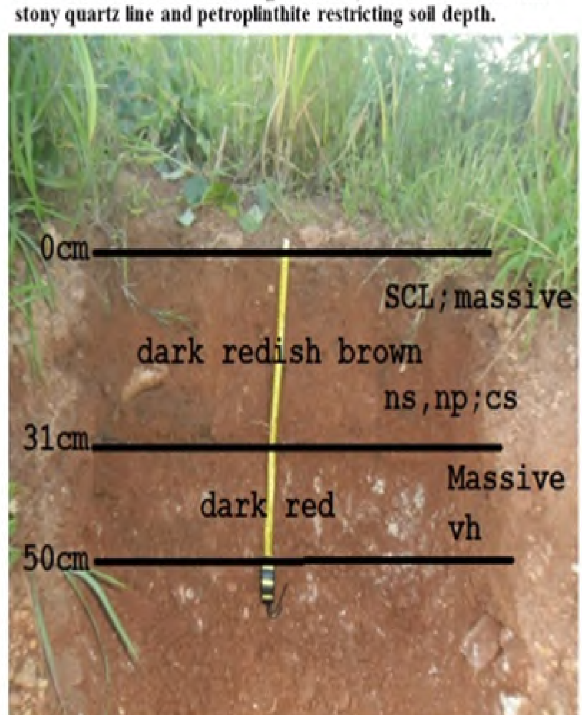


Plate 4: Pedon FT4 P1 showing a shallow, well drained soil with stony quartz line and petroplinthite restricting soil depth.



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Profile pits on soil mapping units/Morphological properties contd.

Plate 5: Pedon FT5 P1 showing a moderately deep, well drained soil formed on a nearly level to gently sloping crest to mid-slope positions with underlying saprolitic layer.

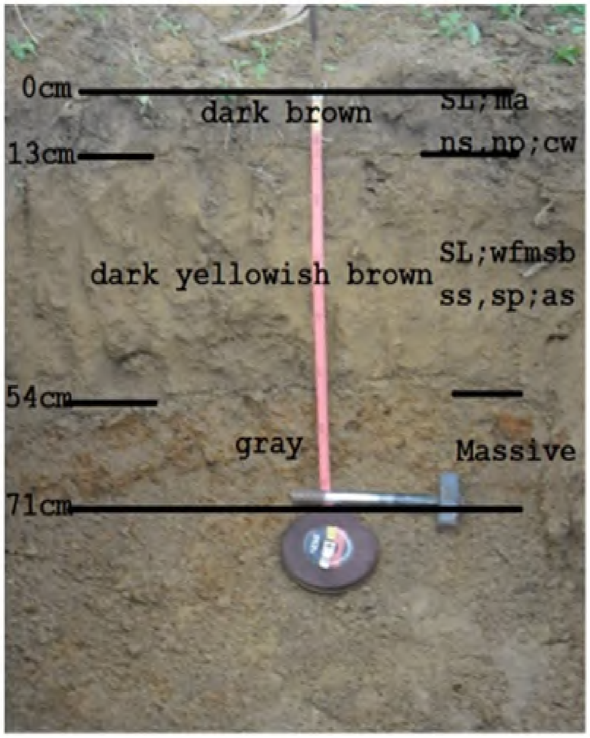

Plate 6: Soil mapping unit FT6 showing a very shallow soils and exposed rock outcrop.

Conclusion

The study was done to delineate soil map units of the selected 10 000 ha land area. Soil mapping units were delineated, and their geographic distribution within the study area was assessed. Identified in the study area were six major soil mapping units namely FT1, FT2, FT3, FT4, FT5, and FT6; whose distributions are shown in the soil map (Fig. 4.1) produced. All soils that occupied upland positions on the landscape expressed colours that were typically associated with well-drained environments. Soil colours were associated with an inheritance from the mineral parent material; but more generally, the soil colours were generated by soil-forming processes as variant colours were observed on soils formed across mapping units. All soils studied had moderate structure grade usually of the subangular blocky type indicating structural development that is typical of mature soils on relatively stable landscapes. Texturally, all soils had loam property, a characteristic that will allow for easy mechanical workability of the soils with less damage to soil structure.

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