Characterization and Classification of Soils in Okitipupa Local Government Area, Ondo State, Nigeria

1Department of Soil Science, Faculty of Agriculture, University of Calabar, Calabar, Nigeria
2Department of Geography and Environmental Science, Faculty of Social Science, University of Calabar, Calabar, Nigeria

Corresponding Author: I.E. Esu, Department of Soil Science, Faculty of Agriculture, University of Calabar, Calabar, Nigeria

ABSTRACT
A semi-detailed soil survey of the Okitipupa Local Government Area in Ondo State, Nigeria was carried out with the aid of Landsat-ETM satellite imagery at a scale of 1:50,000. Three soil mapping units designated as Okitipupa series, Omotosho series and Ode Erinje Fadama series were delineated and presented in a soil map. Okitipupa series occupies 41,623 ha or 52%, the Omotosho series covers 17,318 ha or 21.64% and the Ode Erinje Fadama series occupies 21,099 ha or 26.38% of the Local Government Area. All the soils have extremely to very strongly acid reaction and are nutrient impoverished. The soils also have rather sandy surface textures with sandy loam to sandy clay subsoils and are susceptible to severe surficial erosion hazard. In relative terms, the Okitipupa soil series which occur on nearly level landforms and are very deep may be considered as the prime agricultural lands, while the Omotosho series are marginal lands because they occur on strongly undulating landforms, are gravelly and shallow to bedrock or plinthic materials. The Ode Erinje Fadama series are seasonally flooded and are considered suitable for dry season vegetable farming and swamp rice production. According to the criteria of the USDA Soil Taxonomy System, the Okitipupa series is classified as Typic Paleudults, Omotosho series as Typic Plinthohumults and Ode Erinje Fadama series as Humaquentic Endoaquents at the subgroup level. These classifications correlate closely as Dystric Acrisols, Ortho-plinthic Acrisols and Arenic Gleysols for Okitipupa, Omotosho and Ode Erinje Fadama series respectively under FAO World Reference Base for Soil Resources.

Key words: Soil survey, soil characterization, soil classification, typic paleudults, typic plinthohumults, humaquentic endoaquents

INTRODUCTION
Soil is the most basic natural resource that determines the ultimate suitability and sustainability of any agricultural system. According to Raju et al. (2005), the inherent ability of soils to supply nutrients for crop growth and maintenance of soil physical conditions to optimize crop yields is the most important component of soil fertility that virtually determines the productivity of agricultural systems. Thus, a good knowledge of the soil resources of any given territory is indispensable for planning its agricultural development (Dijkerman, 1969). Soil surveys provide a scientific inventory of the soils occurring within a specified land area and involve the systematic examination, description, classification and mapping of such soils. According to Esu (2004, 2010),
during a soil survey, sufficient information is gathered in order to help the surveyor to correlate and to predict the adaptability of soils to various crops, behavior and productivity under different management systems.

Apart from the reconnaissance to near exploratory soil survey of Nigeria carried out in 1991 by the Federal Department of Agricultural Lands Resources which was published at a scale of 1:650,000, no local government area (equivalent to counties in the USA) has been systematically mapped at a semi-detailed or detailed level. However, the unprecedented agricultural productivity and development that has occurred in the USA and indeed many other developed countries have come about as a result of the semi-detailed to detailed soil surveys carried out nearly in all the counties (local government areas) of their respective nations.

Okitipupa Local Government Area is within an area that has been adjudged to have great potentials for the production of tree crops especially oil palm (*Elaeis guineensis*), cocoa (*Theobroma cacao*) and kola (*Kola nitida*). However, such assessment has been based mainly on the perceived favourable climatic and vegetal regimes prevailing within the zone (Esu, 2013). Thus, the soils within Okitipupa Local Government Area have variously been referred to as consisting of “brown and orange sandy soils, light grey sandy soils as well as swampy organic and flooded organic soils” (UNAAB-IFSERAR, 2010). Ajayi et al. (2010) also referred to them as "sandy soils, laterized soils and dark loamy soils".

According to Esu (2013), one fundamental flaw in the initial crafting of the Agricultural Transformation Agenda Policy of the Nigerian government appears to be the near absence of emphasis on the importance of the soil resource as an engine to drive the expected optimum yields of the crops in the value chains of the transformation agenda. The main objective of the present study was, therefore, to carry out a systematic semi-detailed soil survey of the Okitipupa Local Government Area at a scale of 1:50,000 so as to:

- Delineate and determine the areal extent of the soils and thus, produce a soil map for the Okitipupa local government area
- Carry out detailed characterization of the morphological, physical, chemical and fertility properties of the soil mapping units
- Carry out a taxonomic classification of the soil units according to the criteria of the USDA Soil Taxonomy system (Soil Survey Staff, 1999) and the FAO World Reference Base for Soil Resources System (FAO, 2006)

**MATERIALS AND METHODS**

**Environment of study area:** Okitipupa Local Government Area (LGA) is one of the 18 LGAs in Ondo State of Nigeria (Fig. 1). It lies between 6°25′ and 6°25′ N latitude and 4°35′ and 4°50′ E longitude within the tropical rainforest zone of Nigeria. It covers a total land area of 636 sq km and has an estimated population of 233,565 people. An udic soil moisture regime and an isohyperthermic soil temperature regime prevail in the area with total annual rainfall often exceeding 2000 mm, while the soil temperature has a narrow range of 27 to 28°C, respectively. The area has two distinct geological formations; the Precambrian Basement Complex Granitic Rocks in the northern part and the recent to tertiary sandy sediments in the central and southern parts of the local government area. Geomorphologically, the northern parts of the local government area have strongly sloping to undulating landscapes of 8 to 12% slopes, while the central and southern parts have nearly level to gently sloping landscapes of 0 to 4% slopes.
Field studies: Before the fieldwork actually started, Landsat-ETM imageries with 30 m resolution covering the entire local government area was acquired and interpreted regarding the landforms using the digital elevation modal projected to the World Geodetic System 84. The imagery was then delineated into ranges of elevation and used as the base map for the field mapping. A sample area covering about 25% of the entire survey area which reasonably represented all the delineated map
unit polygons was then selected and traversed at 500×500 m intervals using the rigid grid
procedure of soil survey (Dent and Young, 1981; Esu, 2010). At least two soil profile pits were used
to characterize each of the soil mapping units identified within the survey area and the soil
morphological descriptions followed the method in the “Field book for describing and sampling soils,
version 3.0” (Schoeneberger et al., 2012).

**Laboratory studies:** Soil samples collected from the field were air-dried, ground and sieved to
remove materials greater than 2 mm fraction. The samples were then analyzed for their physical,
chemical and fertility properties. Particle size distribution was determined by the hydrometer
method using sodium hexametaphosphate (calgon) as the dispersant (Gee and Bauder, 1986). Bulk
density was determined by the undisturbed core method of Blacke and Hartge (1986). Soil pH was
determined in a 1:1 soil/water and 1N KCl ratios with a glass electrode pH meter. Exchangeable
acidity was determined by the 1 N KCl method, while exchangeable bases (Ca, Mg, K and Na) were
determined using NH₄OAc saturation method and the Ca and Mg in solution were determined
using AAS, while K and Na were determined on a Flame Photometer (IITA, 1979). Organic carbon
was determined by the Walkley and Black dichromate wet oxidation method (Nelson and Sommers,
1982). Total nitrogen was determined by the micro-Kjeldahl technique (Bremner and Muluane,
1982). Cation Exchange Capacity (CEC) was determined by the 1N NH₄OAc pH 7.0 saturation
method and the effective CEC by summation of exchangeable bases and exchangeable Al³⁺
(Soil Survey Laboratory Staff, 2004). Percentage base saturation was calculated as the sum of all
base forming cations divided by CEC and multiplied by 100. Available forms of micronutrient
elements (Cu, Mn, Zn and Fe) were determined by the diethylene triamine penta-acetic acid
(DTPA) extraction method (Udo et al., 2009), while Boron was determined by the hot water
extraction method (Wolf, 1974).

**RESULTS AND DISCUSSION**

**Distribution, landform and parent materials of the soils:** The semi-detailed soil survey of the
Okitipupa LGA resulted in the delineation of three soil mapping units as shown in the soil map
presented in Fig. 2. The mapping units were designated as Okitipupa series, Omotosho series and
Ode Erinje Fadama series.

Okitipupa series occupy 52% or 41,623 hectares of the entire land area and are thus the most
extensive soils within the local government area. The soils are associated with nearly level plains
of 0-4% slopes at elevation of 40-60 m above mean sea level and are developed on recent to tertiary
sediments termed coastal plain sands or cretaceous Abeokuta formation (Obasi, 2013). The
prevailing crops grown on the soils include oil palm, cassava, yams and pineapple. They may be
described as the prime arable lands in the area.

The Omotosho soil series constitutes 21.64% or 17,318 hectares of the land area of the local
government and are associated with strongly undulating topography of 8-12% slopes at high
elevations of 60-105 m above mean sea level. The soils are restricted to the northern tip of the local
government area within the Omotosho area and are derived from basement complex rocks
composed mainly of granite-gneiss, mica-schist and feldspathic rocks. The common crops grown on
the soils include cocoa, kola nut, cassava and limited hectares of oil palm. Considerable amounts
of timber are still left unexploited giving the environment typical rainforest vegetation.

The Ode Erinje Fadama soil series occupy 26.36% or 21,069 hectares of the land area on nearly
level plains of 0-1% at very low elevations of 10-20 m above mean sea level. Like most fadama soils,
they are developed on alluvium but in this area, they are underlain by coastal plain sands and are seasonally waterlogged, strongly gleyed and subject to the process of ferrolysis (Brinkman, 1970). Swamp rice cultivation is the most noticeable land use, but raphia palm, cassava and pineapple farms were observed in the slightly better drained locations.

**Morphological soil properties:** The morphological properties of the soils are summarized in Table 1. A typical soil profile of the Okitipupa soil series consist of very deep, well drained, dark
Table 1: Morphology and classification of Okitupupa soil series

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>Munsell colour (moist)</th>
<th>Mottling</th>
<th>Texture</th>
<th>Structure</th>
<th>Consistence</th>
<th>Boundary</th>
<th>Other characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Okitupupa soil series-Typic Paleudults (USDA)/Orthic dystric Acrisols (FAO-WRB)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKP 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-22</td>
<td>10YR 3/3 (dark brown)</td>
<td>-</td>
<td>ls</td>
<td>Ifmogr</td>
<td>wns, mfr</td>
<td>cs</td>
<td>Many fine medium pores and roots, many ants</td>
</tr>
<tr>
<td>Bt1</td>
<td>22-75</td>
<td>10YR 5/8 (yellowish brown)</td>
<td>-</td>
<td>sc</td>
<td>Ifmsbk</td>
<td>ws, mfi</td>
<td>gs</td>
<td>Common fine and medium pores, common medium roots</td>
</tr>
<tr>
<td>Bt2</td>
<td>75-140</td>
<td>10YR 5/6 (yellowish red)</td>
<td>-</td>
<td>scl</td>
<td>Imcsbk</td>
<td>wns, mfi</td>
<td>cs</td>
<td>Common fine and coarse pores, common fine and medium roots</td>
</tr>
<tr>
<td>Bt3</td>
<td>140-187</td>
<td>2.5YR 5/8 (red)</td>
<td>-</td>
<td>scl</td>
<td>Imcsbk</td>
<td>ws, mfi</td>
<td>-</td>
<td>Common fine pores, common fine roots</td>
</tr>
<tr>
<td><strong>OKP 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-15</td>
<td>10YR 3/3 (dark brown)</td>
<td>-</td>
<td>ls</td>
<td>Ifmogr</td>
<td>wns, mfr</td>
<td>cs</td>
<td>Many fine medium roots and pores, common ants</td>
</tr>
<tr>
<td>Bt1</td>
<td>15-74</td>
<td>2.5YR 4/6 (red)</td>
<td>-</td>
<td>scl</td>
<td>Ifmsbk</td>
<td>ws, mfi</td>
<td>gs</td>
<td>Common fine medium pores and roots, clay skins on peds</td>
</tr>
<tr>
<td>Bt2</td>
<td>74-132</td>
<td>2.5YR 4/8 (red)</td>
<td>-</td>
<td>scl</td>
<td>Imcsbk</td>
<td>ws, mfi</td>
<td>ds</td>
<td>Common fine medium pores, common fine roots, clay skins on peds</td>
</tr>
<tr>
<td>Bt3</td>
<td>132-175</td>
<td>2.5YR 4/8 (red)</td>
<td>-</td>
<td>scl</td>
<td>Imcsbk</td>
<td>ws, mfi</td>
<td>-</td>
<td>Fine few roots, common fine pores</td>
</tr>
<tr>
<td><strong>Omotosho soil series-Typic Plinthicumults (USDA)/Humic Orthiplinthic Acrisols (FAO-WRB)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKP 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-11</td>
<td>10YR 2/2 (very dark brown)</td>
<td>-</td>
<td>gr ls</td>
<td>Ifgr</td>
<td>wns, ml</td>
<td>cs</td>
<td>Many medium pores, many fine medium roots, many ants and worms</td>
</tr>
<tr>
<td>Bt1</td>
<td>11-48</td>
<td>7.5YR 4/4 (brown)</td>
<td>-</td>
<td>gr scl</td>
<td>Structureless</td>
<td>ws, mfi</td>
<td>ds</td>
<td>Small and medium rounded gravels, many fine coarse pores, common fine and medium roots</td>
</tr>
<tr>
<td>Bt2</td>
<td>48-62</td>
<td>7.5 YR 4/4 (brown)</td>
<td>-</td>
<td>gr scl</td>
<td>Structureless</td>
<td>ws, mfi</td>
<td></td>
<td>Many small and medium gravel, common medium and coarse pores, few fine roots, iron concretions and iron pan</td>
</tr>
<tr>
<td><strong>OKP 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-23</td>
<td>10YR 3/1 (very dark grey)</td>
<td>-</td>
<td>ls</td>
<td>Ifmogr</td>
<td>wss, mfi</td>
<td>cw</td>
<td>Many fine medium pores and roots, common ants and millipedes</td>
</tr>
<tr>
<td>Bt</td>
<td>23-69</td>
<td>7.5YR 4/6 (strong brown)</td>
<td>-</td>
<td>gr scl</td>
<td>Ifmsbk</td>
<td>ws, mfi</td>
<td>cw</td>
<td>Common fine and coarse pores, common fine-medium roots, few ants</td>
</tr>
<tr>
<td>Btv</td>
<td>68-130</td>
<td>5YR 5/6 (yellowish red)</td>
<td>-</td>
<td>gr sc</td>
<td>Ifmsbk</td>
<td>ws, mfi</td>
<td>dw</td>
<td>Common fine and medium pores, common fine roots; common iron concretions</td>
</tr>
<tr>
<td>Cr</td>
<td>130-200</td>
<td>5YR 4/6 (yellowish red)</td>
<td>-</td>
<td>gr scl</td>
<td>Ifmsbk</td>
<td>ws, mfi</td>
<td>-</td>
<td>Common fine and medium pores, few fine roots; common iron concretions</td>
</tr>
<tr>
<td>Horizon</td>
<td>Depth (cm)</td>
<td>Munsell colour (moist)</td>
<td>Motting</td>
<td>Texture</td>
<td>Structure</td>
<td>Consistence</td>
<td>Boundary</td>
<td>Other characteristics</td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>------------------------</td>
<td>---------</td>
<td>---------</td>
<td>-----------</td>
<td>-------------</td>
<td>----------</td>
<td>------------------------</td>
</tr>
<tr>
<td>Oge</td>
<td>0-12</td>
<td>10YR 3/1 (very dark grey)</td>
<td>-</td>
<td>s</td>
<td>sg</td>
<td>wns, ml</td>
<td>cs</td>
<td>Many fine medium pores and roots; many ants and worm holes</td>
</tr>
<tr>
<td>Cg1</td>
<td>12-45</td>
<td>10YR 5/2 (greyish brown)</td>
<td>7.5YR 7/6 (reddish yellow)</td>
<td>ls</td>
<td>sg</td>
<td>wns, ml</td>
<td>cs</td>
<td>Common and medium pores, common fine roots, common fine distinct reddish yellow mottles</td>
</tr>
<tr>
<td>Cg2</td>
<td>45-60</td>
<td>10YR 6/2 (light brownish grey)</td>
<td>7.5YR 7/8 (reddish yellow)</td>
<td>al</td>
<td>sg</td>
<td>wns, ml</td>
<td>-</td>
<td>Common fine and medium pores and roots, depth of water table (60 cm), common fine-medium distinct reddish yellow mottles</td>
</tr>
<tr>
<td>OKP 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apg</td>
<td>0-13</td>
<td>10YR 3/1 (very dark grey)</td>
<td>-</td>
<td>s</td>
<td>sg</td>
<td>wns, ml</td>
<td>cs</td>
<td>Many fine and medium coarse pores, common fine and medium roots</td>
</tr>
<tr>
<td>Cg1</td>
<td>13-31</td>
<td>10YR 5/1 (grey)</td>
<td>7.5YR 5/6 (strong brown)</td>
<td>ls</td>
<td>1fmslk</td>
<td>wns, ml</td>
<td>cs</td>
<td>Common fine and medium pores and roots; few ants; common fine faint strong brown mottles</td>
</tr>
<tr>
<td>Cg2</td>
<td>31-50</td>
<td>2.5YR 5/2 (greyish brown)</td>
<td>7.5YR 7/8 (reddish yellow)</td>
<td>ls</td>
<td>1fmslk</td>
<td>wns, ml</td>
<td>-</td>
<td>Common fine and medium pores, few fine roots, common medium distinct reddish yellow mottles</td>
</tr>
</tbody>
</table>

brown (10YR 3/3), loamy sand over red (2.5YR 4/8) to yellowish red (5YR 5/8) sandy clay loam to sandy clay subsoils. Well developed illuvial clay horizons occur in the soils, an indication that eluviation-illuviation of clay and Fe-oxyhydroxides (reddish soil colour) is a dominant soil forming process in the Okitipupa soil series.

Soils of Omotosho series consist of well drained, dark brown (7.5YR 3/2) to very dark grey (10YR 3/1) gravelly loamy sand over brown (7.5YR 4/4) to yellowish red (5YR 5/3) gravelly to very gravelly sandy clay loam to sandy clay subsoils. Indeed, the soils are very gravelly and rather shallow to weathered bedrock (saprolite) or petro plinthite layer within 100-150 cm or less. The occurrence of soft and hardened iron oxide nodules and manganiferrous concretions indicates that plinthization is an active soil-forming process in the soils (Esu, 1987). Definite clay bulges (Bt horizons) also occur in the soil profiles indicating that argillic or kandic horizons abound in the soils.

A typical soil profile of the Ode Erinje Fadama soil series consists of very poorly drained, strongly gleyed, very dark grey (10YR 3/1) sand over greyish brown (2.5Y 5/2) to grey (10YR 5/1) loamy sand to sandy loam subsoils. The soils have no evidence of the development of any subsurface diagnostic horizon, but they have ochric epipedon. Most of the profiles studied, had water table at less than 60cm depth almost at the end of the dry season in April, 2013 when the field trip was undertaken.

**Physical soil properties:** Particle size distribution data for the Okitipupa series show that the sand fraction is the dominant separate with mean values ranging from 820 g kg⁻¹ in the Ap horizons to 610 g kg⁻¹ in the subsoils. Mean silt content varied only narrowly from 80 g kg⁻¹ in the surface soils to 70 g kg⁻¹ in the subsoils. However, perhaps because of the active eluviation-illuviation pedogenic process taking place in the soils, mean values of clay content varied markedly from 100 g kg⁻¹ in the surface horizons to 320 g kg⁻¹ in the subsoils (Table 2). Bulk density values ranged from 0.9-1.4 Mg m⁻³ with a mean of 1.2 Mg m⁻³ in the Ap horizons and varied from 1.2 to 1.5 mg m⁻³ with a mean of 1.4 mg m⁻³ in the subsoils. All these bulk density values are low and indicate that the soils have high macroporosity and are thus well aerated as well as non-compacted by farm machinery (Esu, 2010).

Particle size distribution data for the Omotosho series also indicates the presence of an illuvial Bt horizon in the profiles studied with the clay fraction varying from a mean of 80 g kg⁻¹ in the Ap horizons to 340 g kg⁻¹ in the subsoils. Just like was reported by Ojanuga (1975) regarding the Precambrian basement complex soils of southern Nigeria, silt content remained almost constant with a low value and narrow range of 60 to 70 g kg⁻¹ from the surface to the subsoil horizons respectively. Sand content however, varied from 850 g kg⁻¹ in the surface soil horizons to 600 g kg⁻¹ in the subsoils. The bulk density of the surface soils ranged from 0.8 to 0.9 mg m⁻³, while subsoil values ranged from 1.4 to 1.5 mg m⁻³. The very low surface soil bulk density values is an indication that the soils have not been subjected to any mechanical tillage perhaps because of the very gravelly nature of the soils.

The seasonally water logged soils of the Ode Erinje Fadama series are rather very sandy. Sand content varied on the average from 910 g kg⁻¹ in the surface horizons to 840 g kg⁻¹ in the subsoil horizons. Silt content was quite low with values varying from 30 g kg⁻¹ in the surface horizons to 85 g kg⁻¹ in the subsoil horizons. Clay content was equally quite low with values ranging on the average from 70 g kg⁻¹ in the surface to 80 g kg⁻¹ in the subsoil horizons. Bulk density was also quite low in the soil with surface soil horizon values ranging from 1.0-1.1 mg m⁻³ and the subsoil
Table 2: Particle size distribution and bulk density of the soils

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Textural class</th>
<th>Bulk density (mg m(^{-2}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Okitipupa soil series</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>OKP 1: Igbotaku</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-22</td>
<td>820</td>
<td>100</td>
<td>80</td>
<td>ls</td>
<td>0.9</td>
</tr>
<tr>
<td>Bt1</td>
<td>22-75</td>
<td>540</td>
<td>60</td>
<td>400</td>
<td>sc</td>
<td>1.5</td>
</tr>
<tr>
<td>Bt2</td>
<td>75-140</td>
<td>620</td>
<td>60</td>
<td>320</td>
<td>scl</td>
<td>1.5</td>
</tr>
<tr>
<td>Bt3</td>
<td>140-187</td>
<td>600</td>
<td>100</td>
<td>300</td>
<td>scl</td>
<td>-</td>
</tr>
<tr>
<td><strong>OKP 2: Lupete</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-15</td>
<td>820</td>
<td>60</td>
<td>120</td>
<td>ls</td>
<td>1.4</td>
</tr>
<tr>
<td>Bt1</td>
<td>15-74</td>
<td>600</td>
<td>60</td>
<td>280</td>
<td>scl</td>
<td>1.4</td>
</tr>
<tr>
<td>Bt2</td>
<td>74-132</td>
<td>640</td>
<td>60</td>
<td>300</td>
<td>scl</td>
<td>1.4</td>
</tr>
<tr>
<td>Bt3</td>
<td>132-175</td>
<td>600</td>
<td>100</td>
<td>300</td>
<td>scl</td>
<td>1.2</td>
</tr>
<tr>
<td>Surface soil range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>820-820</td>
<td>60-100</td>
<td>80-120</td>
<td></td>
<td></td>
<td>0.9-1.4</td>
<td></td>
</tr>
<tr>
<td>Surface soil mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.2</td>
</tr>
<tr>
<td>Subsurface soil range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>540-650</td>
<td>60-100</td>
<td>280-400</td>
<td></td>
<td></td>
<td>1.12-1.5</td>
<td></td>
</tr>
<tr>
<td>Subsurface soil mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>610</td>
<td>73</td>
<td>317</td>
<td></td>
<td></td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td><strong>OKP 3: Omotosho</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-11</td>
<td>860</td>
<td>60</td>
<td>80</td>
<td>giks</td>
<td>0.8</td>
</tr>
<tr>
<td>Bt1</td>
<td>11-48</td>
<td>640</td>
<td>100</td>
<td>250</td>
<td>vgrsc1</td>
<td>1.5</td>
</tr>
<tr>
<td>Bt2</td>
<td>46-62</td>
<td>600</td>
<td>60</td>
<td>340</td>
<td>gsc1</td>
<td>-</td>
</tr>
<tr>
<td><strong>OKP 4: Omotosho 2 (Akin Fisile in Omotosho-Old Benin, Lagos road)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-32</td>
<td>840</td>
<td>80</td>
<td>80</td>
<td>ls</td>
<td>0.9</td>
</tr>
<tr>
<td>Bt</td>
<td>32-69</td>
<td>600</td>
<td>60</td>
<td>340</td>
<td>gr</td>
<td>1.4</td>
</tr>
<tr>
<td>Bt2</td>
<td>69-130</td>
<td>540</td>
<td>40</td>
<td>420</td>
<td>gr</td>
<td>1.4</td>
</tr>
<tr>
<td>Cr</td>
<td>130-200</td>
<td>600</td>
<td>60</td>
<td>340</td>
<td>gr</td>
<td>1.4</td>
</tr>
<tr>
<td>Surface soil range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>840-860</td>
<td>60-80</td>
<td>80-80</td>
<td></td>
<td></td>
<td>0.8-0.9</td>
<td></td>
</tr>
<tr>
<td>Surface soil mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.85</td>
</tr>
<tr>
<td>Subsurface soil range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>540-640</td>
<td>40-100</td>
<td>250-420</td>
<td></td>
<td></td>
<td>1.4-1.5</td>
<td></td>
</tr>
<tr>
<td>Subsurface soil mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>596</td>
<td>64</td>
<td>340</td>
<td></td>
<td></td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td><strong>OKP 5: Ononde erinje</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-12</td>
<td>920</td>
<td>20</td>
<td>60</td>
<td>s</td>
<td>1.0</td>
</tr>
<tr>
<td>Cg1</td>
<td>12-45</td>
<td>860</td>
<td>60</td>
<td>80</td>
<td>ls</td>
<td>1.3</td>
</tr>
<tr>
<td>Cg2</td>
<td>45-60</td>
<td>720</td>
<td>220</td>
<td>60</td>
<td>sl</td>
<td>-</td>
</tr>
<tr>
<td><strong>OKP 6: Igbugurrin</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-13</td>
<td>900</td>
<td>40</td>
<td>60</td>
<td>s</td>
<td>1.1</td>
</tr>
<tr>
<td>Cg1</td>
<td>13-31</td>
<td>880</td>
<td>40</td>
<td>80</td>
<td>ls</td>
<td>1.3</td>
</tr>
<tr>
<td>Cg2</td>
<td>31-50</td>
<td>880</td>
<td>20</td>
<td>100</td>
<td>ls</td>
<td>-</td>
</tr>
<tr>
<td>Surface soil range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>900-920</td>
<td>20-40</td>
<td>60-80</td>
<td></td>
<td></td>
<td>1.0-1.1</td>
<td></td>
</tr>
<tr>
<td>Surface soil mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.1</td>
</tr>
<tr>
<td>Subsurface soil range</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>720-880</td>
<td>20-220</td>
<td>60-100</td>
<td></td>
<td></td>
<td>1.3-1.3</td>
<td></td>
</tr>
<tr>
<td>Subsurface soil mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>835</td>
<td>85</td>
<td>80</td>
<td></td>
<td></td>
<td>1.3</td>
<td></td>
</tr>
</tbody>
</table>

values averaging 1.3 mg m\(^{-2}\). These low values of bulk density is a clear indication that the soils have not, even minimally, been subjected to mechanical tillage.

**Chemical soil properties:** The chemical properties of the soils are shown in Table 3. Soil pH (H\(_2\)O) for the Okitipupa soil series varied from 4.3-5.0 with a mean value of 4.7 for the surface horizons and from 4.1-5.2 with a mean value of 4.7 for the subsoil horizons. All these pH values
<table>
<thead>
<tr>
<th>Horizon</th>
<th>Depth (cm)</th>
<th>H₂O (%)</th>
<th>KCl (g kg⁻¹)</th>
<th>Organic C (g kg⁻¹)</th>
<th>Total N (mg kg⁻¹)</th>
<th>Available P (mg kg⁻¹)</th>
<th>Ca (cmol kg⁻¹)</th>
<th>Mg (cmol kg⁻¹)</th>
<th>K (cmol kg⁻¹)</th>
<th>Na (cmol kg⁻¹)</th>
<th>Exch. Al (cmol kg⁻¹)</th>
<th>ECEC (cmol kg⁻¹)</th>
<th>NH₄⁺ (cmol kg⁻¹)</th>
<th>EC (dS m⁻¹)</th>
<th>NH₃⁺ (cmol kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Okitipupa soil series</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKP 1: Igbotaku</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-22</td>
<td>5.0</td>
<td>4.2</td>
<td>17.36</td>
<td>1.33</td>
<td>8.40</td>
<td>1.40</td>
<td>0.60</td>
<td>0.08</td>
<td>0.05</td>
<td>0.60</td>
<td>2.73</td>
<td>4.00</td>
<td>78.0</td>
<td>53.2</td>
</tr>
<tr>
<td>Bt1</td>
<td>22-75</td>
<td>4.8</td>
<td>4.0</td>
<td>2.59</td>
<td>0.42</td>
<td>3.85</td>
<td>0.60</td>
<td>0.20</td>
<td>0.07</td>
<td>0.25</td>
<td>2.40</td>
<td>3.52</td>
<td>4.40</td>
<td>31.9</td>
<td>25.4</td>
</tr>
<tr>
<td>Bt2</td>
<td>75-140</td>
<td>5.0</td>
<td>3.7</td>
<td>7.56</td>
<td>1.12</td>
<td>3.50</td>
<td>1.40</td>
<td>0.50</td>
<td>0.09</td>
<td>0.10</td>
<td>2.60</td>
<td>4.89</td>
<td>5.10</td>
<td>44.6</td>
<td>40.9</td>
</tr>
<tr>
<td>Bt3</td>
<td>140-167</td>
<td>4.8</td>
<td>3.7</td>
<td>1.60</td>
<td>0.14</td>
<td>17.68</td>
<td>0.60</td>
<td>0.25</td>
<td>0.11</td>
<td>0.20</td>
<td>2.60</td>
<td>3.76</td>
<td>4.30</td>
<td>30.8</td>
<td>26.9</td>
</tr>
<tr>
<td><strong>OKP 2: Lapeto</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-15</td>
<td>4.3</td>
<td>3.7</td>
<td>12.57</td>
<td>0.98</td>
<td>4.03</td>
<td>1.00</td>
<td>0.40</td>
<td>0.08</td>
<td>0.05</td>
<td>2.20</td>
<td>3.73</td>
<td>4.60</td>
<td>41.0</td>
<td>33.2</td>
</tr>
<tr>
<td>Bt1</td>
<td>15-74</td>
<td>4.1</td>
<td>3.7</td>
<td>4.99</td>
<td>0.56</td>
<td>5.43</td>
<td>0.80</td>
<td>0.30</td>
<td>0.10</td>
<td>0.10</td>
<td>4.40</td>
<td>5.70</td>
<td>7.30</td>
<td>22.8</td>
<td>17.9</td>
</tr>
<tr>
<td>Bt2</td>
<td>74-132</td>
<td>5.2</td>
<td>4.4</td>
<td>6.38</td>
<td>0.76</td>
<td>3.68</td>
<td>0.60</td>
<td>0.20</td>
<td>0.06</td>
<td>0.05</td>
<td>3.60</td>
<td>4.51</td>
<td>7.00</td>
<td>20.1</td>
<td>13.0</td>
</tr>
<tr>
<td>Bt3</td>
<td>132-175</td>
<td>4.1</td>
<td>3.7</td>
<td>3.99</td>
<td>0.42</td>
<td>2.98</td>
<td>0.80</td>
<td>0.30</td>
<td>0.07</td>
<td>0.17</td>
<td>3.40</td>
<td>4.74</td>
<td>6.20</td>
<td>28.2</td>
<td>21.7</td>
</tr>
<tr>
<td>Surface range</td>
<td>4.3-5.0</td>
<td>3.7-4.2</td>
<td>12.57-17.36</td>
<td>0.98-1.33</td>
<td>4.03-8.40</td>
<td>1.00-1.40</td>
<td>0.40-0.69</td>
<td>0.08-0.08</td>
<td>0.05-0.05</td>
<td>0.60-2.0</td>
<td>2.73-3.73</td>
<td>4.40</td>
<td>41.0-78.0</td>
<td>33.2-53.2</td>
<td>31.34</td>
</tr>
<tr>
<td>Surface mean</td>
<td>4.7</td>
<td>4.0</td>
<td>14.96</td>
<td>1.15</td>
<td>6.21</td>
<td>1.20</td>
<td>0.50</td>
<td>0.08</td>
<td>0.05</td>
<td>1.40</td>
<td>5.23</td>
<td>4.30</td>
<td>60.0</td>
<td>45.2</td>
<td>32</td>
</tr>
<tr>
<td>Subsurface range</td>
<td>4.1-5.2</td>
<td>3.7-4.4</td>
<td>2.59-7.56</td>
<td>0.14-1.12</td>
<td>2.98-17.78</td>
<td>0.60-1.40</td>
<td>0.20-0.50</td>
<td>0.05-0.11</td>
<td>0.05-0.25</td>
<td>2.40-4.40</td>
<td>3.52-5.70</td>
<td>4.30-7.30</td>
<td>20.1-44.6</td>
<td>13.0-40.6</td>
<td>9-20</td>
</tr>
<tr>
<td>Subsurface mean</td>
<td>4.7</td>
<td>3.9</td>
<td>4.52</td>
<td>0.57</td>
<td>6.19</td>
<td>0.80</td>
<td>0.29</td>
<td>0.08</td>
<td>0.14</td>
<td>3.17</td>
<td>5.44</td>
<td>5.72</td>
<td>29.7</td>
<td>24.3</td>
<td>15</td>
</tr>
<tr>
<td><strong>Onotoshio soil series</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKP 2: Onotoshio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-11</td>
<td>4.5</td>
<td>3.8</td>
<td>18.76</td>
<td>1.40</td>
<td>6.30</td>
<td>3.20</td>
<td>1.10</td>
<td>0.26</td>
<td>0.04</td>
<td>1.00</td>
<td>5.60</td>
<td>2.20</td>
<td>82.1</td>
<td>20.9</td>
</tr>
<tr>
<td>Bt1</td>
<td>11-48</td>
<td>4.2</td>
<td>3.5</td>
<td>10.37</td>
<td>1.12</td>
<td>4.88</td>
<td>1.20</td>
<td>0.40</td>
<td>0.12</td>
<td>0.05</td>
<td>1.00</td>
<td>2.77</td>
<td>2.69</td>
<td>63.8</td>
<td>68.0</td>
</tr>
<tr>
<td>Bt2</td>
<td>48-62</td>
<td>4.7</td>
<td>3.9</td>
<td>6.18</td>
<td>0.77</td>
<td>2.98</td>
<td>0.60</td>
<td>0.25</td>
<td>0.08</td>
<td>0.07</td>
<td>1.00</td>
<td>1.60</td>
<td>2.40</td>
<td>62.5</td>
<td>42.0</td>
</tr>
<tr>
<td>Horizon</td>
<td>Depth (cm)</td>
<td>H₂O</td>
<td>ECl</td>
<td>Organic C (g kg⁻¹)</td>
<td>Total N (g kg⁻¹)</td>
<td>P (mg kg⁻¹)</td>
<td>Available (mol kg⁻¹)</td>
<td>Exchangeable bases</td>
<td>CEC (mol kg⁻¹)</td>
<td>Base saturation (%)</td>
<td>CEC/Clay (mol kg⁻¹)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>------------</td>
<td>------</td>
<td>-----</td>
<td>---------------------</td>
<td>------------------</td>
<td>--------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>----------------</td>
<td>-------------------</td>
<td>---------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKP 4: Omotosho 2 (Akin Fisile in Omotosho-Old Benin, Lagos Road)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-30</td>
<td>4.9</td>
<td>4.2</td>
<td>0.84</td>
<td>2.33</td>
<td>2.40</td>
<td>1.00</td>
<td>0.11</td>
<td>0.25</td>
<td>0.80</td>
<td>4.56</td>
<td>5.10</td>
<td>82.4</td>
<td>89.2</td>
<td>57</td>
</tr>
<tr>
<td>Bt</td>
<td>32-60</td>
<td>4.9</td>
<td>3.7</td>
<td>0.66</td>
<td>3.85</td>
<td>1.00</td>
<td>0.40</td>
<td>0.12</td>
<td>0.17</td>
<td>4.80</td>
<td>6.49</td>
<td>7.20</td>
<td>26.0</td>
<td>23.5</td>
<td>19</td>
</tr>
<tr>
<td>Bv</td>
<td>60-130</td>
<td>4.9</td>
<td>3.6</td>
<td>0.21</td>
<td>4.20</td>
<td>1.60</td>
<td>0.60</td>
<td>0.12</td>
<td>0.13</td>
<td>5.00</td>
<td>7.45</td>
<td>8.60</td>
<td>32.8</td>
<td>28.5</td>
<td>18</td>
</tr>
<tr>
<td>Cr</td>
<td>130-200</td>
<td>5.0</td>
<td>4.1</td>
<td>0.14</td>
<td>3.33</td>
<td>0.40</td>
<td>0.05</td>
<td>0.19</td>
<td>0.80</td>
<td>4.59</td>
<td>7.20</td>
<td>17.2</td>
<td>11.0</td>
<td>14</td>
<td>21</td>
</tr>
<tr>
<td>Surface range</td>
<td>4.5-4.9</td>
<td>3.8-4.2</td>
<td>12.17-15.76</td>
<td>0.81-1.40</td>
<td>3.33-6.30</td>
<td>2.40-3.20</td>
<td>1.10-1.10</td>
<td>0.04-0.25</td>
<td>0.80-1.00</td>
<td>4.56-5.60</td>
<td>2.20-5.10</td>
<td>82.1-82.4</td>
<td>23.9-89.2</td>
<td>57.70</td>
<td>28.64</td>
</tr>
<tr>
<td>Surface mean</td>
<td>4.7</td>
<td>4.0</td>
<td>13.97</td>
<td>1.1</td>
<td>4.82</td>
<td>2.80</td>
<td>1.05</td>
<td>0.11-0.26</td>
<td>0.14</td>
<td>0.90</td>
<td>5.08</td>
<td>3.65</td>
<td>82.2</td>
<td>55.1</td>
<td>63.5</td>
</tr>
<tr>
<td>Subsurface range</td>
<td>4.2-5.0</td>
<td>3.5-4.1</td>
<td>2.39-10.37</td>
<td>0.14-1.12</td>
<td>2.98-4.38</td>
<td>0.40-1.60</td>
<td>0.15-0.60</td>
<td>0.05-0.12</td>
<td>0.05-0.70</td>
<td>1.00-5.00</td>
<td>1.68-7.45</td>
<td>2.40-8.69</td>
<td>17.2-63.8</td>
<td>11.0-68.0</td>
<td>5-19</td>
</tr>
<tr>
<td>Subsurface mean</td>
<td>4.7</td>
<td>3.8</td>
<td>6.10</td>
<td>0.56</td>
<td>3.74</td>
<td>0.56</td>
<td>0.09</td>
<td>0.24</td>
<td>3.12</td>
<td>4.58</td>
<td>5.60</td>
<td>40.4</td>
<td>34.5</td>
<td>13.4</td>
<td>15</td>
</tr>
<tr>
<td>Ode erinje fadama soil series</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OKP 6: Obonde Erinje</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-12</td>
<td>4.7</td>
<td>3.7</td>
<td>11.37</td>
<td>0.91</td>
<td>5.96</td>
<td>0.60</td>
<td>0.15</td>
<td>0.08</td>
<td>0.03</td>
<td>1.00</td>
<td>1.86</td>
<td>2.20</td>
<td>46.2</td>
<td>39.0</td>
</tr>
<tr>
<td>Cg1</td>
<td>12-45</td>
<td>5.2</td>
<td>4.0</td>
<td>3.59</td>
<td>0.42</td>
<td>4.03</td>
<td>0.60</td>
<td>0.20</td>
<td>0.07</td>
<td>0.23</td>
<td>1.00</td>
<td>2.11</td>
<td>2.60</td>
<td>52.6</td>
<td>42.6</td>
</tr>
<tr>
<td>Cg2</td>
<td>45-60</td>
<td>5.2</td>
<td>4.1</td>
<td>1.40</td>
<td>0.14</td>
<td>5.60</td>
<td>0.40</td>
<td>0.05</td>
<td>0.23</td>
<td>0.60</td>
<td>1.50</td>
<td>2.40</td>
<td>60.7</td>
<td>38.8</td>
<td>26</td>
</tr>
<tr>
<td>OKP 6: Igbagburrin</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ap</td>
<td>0-13</td>
<td>4.4</td>
<td>3.6</td>
<td>15.96</td>
<td>1.19</td>
<td>3.85</td>
<td>0.40</td>
<td>0.20</td>
<td>0.09</td>
<td>0.29</td>
<td>2.20</td>
<td>3.18</td>
<td>4.60</td>
<td>30.9</td>
<td>30.8</td>
</tr>
<tr>
<td>Cg1</td>
<td>13-31</td>
<td>4.6</td>
<td>4.0</td>
<td>6.98</td>
<td>0.27</td>
<td>8.25</td>
<td>0.60</td>
<td>0.20</td>
<td>0.07</td>
<td>0.16</td>
<td>1.40</td>
<td>2.43</td>
<td>3.80</td>
<td>42.3</td>
<td>42.3</td>
</tr>
<tr>
<td>Cg2</td>
<td>31-50</td>
<td>4.6</td>
<td>4.1</td>
<td>4.79</td>
<td>0.56</td>
<td>7.43</td>
<td>0.80</td>
<td>0.20</td>
<td>0.12</td>
<td>0.09</td>
<td>1.20</td>
<td>2.51</td>
<td>3.40</td>
<td>52.1</td>
<td>38.5</td>
</tr>
<tr>
<td>Surface range</td>
<td>4.4-4.7</td>
<td>3.6-3.7</td>
<td>11.37-15.96</td>
<td>0.91-1.19</td>
<td>3.85-5.95</td>
<td>0.40-0.60</td>
<td>0.15-0.20</td>
<td>0.08-0.09</td>
<td>0.03-0.29</td>
<td>1.00-2.20</td>
<td>1.86-3.18</td>
<td>2.29-4.60</td>
<td>30.9-46.2</td>
<td>30.8-39.0</td>
<td>51-118</td>
</tr>
<tr>
<td>Surface mean</td>
<td>4.5</td>
<td>3.6</td>
<td>14.7</td>
<td>1.05</td>
<td>4.90</td>
<td>0.50</td>
<td>0.17</td>
<td>0.08</td>
<td>0.16</td>
<td>1.60</td>
<td>2.52</td>
<td>3.40</td>
<td>38.5</td>
<td>34.9</td>
<td>109</td>
</tr>
<tr>
<td>Subsurface range</td>
<td>4.6-5.2</td>
<td>4.0-4.1</td>
<td>14.0-6.98</td>
<td>0.14-0.56</td>
<td>4.03-6.60</td>
<td>0.40-0.80</td>
<td>0.20-0.25</td>
<td>0.05-0.12</td>
<td>0.16-0.23</td>
<td>0.69-1.40</td>
<td>1.53-2.51</td>
<td>2.40-3.89</td>
<td>42.3-60.7</td>
<td>38.5-42.6</td>
<td>26-395</td>
</tr>
<tr>
<td>Subsurface mean</td>
<td>4.9</td>
<td>4.0</td>
<td>4.2</td>
<td>0.34</td>
<td>4.90</td>
<td>0.60</td>
<td>0.21</td>
<td>0.07</td>
<td>0.20</td>
<td>1.05</td>
<td>2.14</td>
<td>3.05</td>
<td>51.9</td>
<td>40.5</td>
<td>195</td>
</tr>
</tbody>
</table>
Table 4: Extractable micronutrient elements in the surface soils (0-30 cm) of Okitipupa LGA

<table>
<thead>
<tr>
<th>Element</th>
<th>Okitipupa series (mg kg⁻¹)</th>
<th>Omotosho series (mg kg⁻¹)</th>
<th>Ode Erinje Fadama series (mg kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>1.0-1.01</td>
<td>0.05-0.63</td>
<td>0.26-1.30</td>
</tr>
<tr>
<td>Mean</td>
<td>1.01</td>
<td>0.57</td>
<td>0.73</td>
</tr>
<tr>
<td>Manganese</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.21-3.21</td>
<td>0.10-0.13</td>
<td>0.08-0.00</td>
</tr>
<tr>
<td>Mean</td>
<td>1.71</td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.29-0.43</td>
<td>0.30-3.92</td>
<td>0.25-0.38</td>
</tr>
<tr>
<td>Mean</td>
<td>0.36</td>
<td>2.11</td>
<td>0.32</td>
</tr>
<tr>
<td>Iron</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>50.63-90.00</td>
<td>88.55-125.60</td>
<td>37.20-114.90</td>
</tr>
<tr>
<td>Mean</td>
<td>70.32</td>
<td>107.00</td>
<td>76.06</td>
</tr>
<tr>
<td>Boron</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.56-0.68</td>
<td>0.81-1.08</td>
<td>0.68-0.81</td>
</tr>
<tr>
<td>Mean</td>
<td>0.62</td>
<td>0.95</td>
<td>0.75</td>
</tr>
</tbody>
</table>

represent extremely to very strongly acid soil reaction. Similarly, the exchangeable Al³⁺ content varied on the average from 1.4 cmol(+) kg⁻¹ in the surface soils to 3.2 cmol(+) kg⁻¹ in the subsoil horizons; an indication that exch. Al³⁺ is a major contributor to the acidity in the soils. Moderate levels of organic carbon and total N are present in the soils with mean values of 15 and 1.5 g kg⁻¹, respectively (Obiogbasan, 2000). Regrettably, however, all the other parameters of soil fertility such as CEC, available P, exch. K⁺, Mg²⁺ and Ca²⁺ are low to very low (Sims, 2000; Esu et al., 2009). Also, surface soil values of micronutrient elements presented in Table 4 such as Cu, Fe and B exceed the critical limits of 1.0, 3.5 and 0.5 mg kg⁻¹, while low values of Zn (0.29-0.42 mg kg⁻¹) and Mn (0.21 to 3.21 mg kg⁻¹) with mean values of 3.36 and 1.71 mg kg⁻¹, respectively show that they are deficient in the soils (Sims and Johnson, 1991; Esu et al., 2009).

As shown in Table 3, the Omotosho soil series share the extremely to very strongly acid reaction with the soils of Okitipupa series. The pH (H₂O) range from 4.5-4.9 in the Ap horizons and 4.2-4.9 in the subsoil horizons with mean values of 4.7 in both the surface and subsoil horizons. Similarly, organic carbon content and total N values are moderate, while exchangeable cations; K⁺, Ca²⁺ and Mg²⁺ are marginal to low. However, micronutrient Cu and Mn are very low in the soils with values which are well below the critical limits, while Zn, Fe and B are adequate in the soils.

Soils of the Ode Erinje Fadama series also have very strongly acid reaction with mean pH values of 4.6 and 4.9 for the surface and subsoil horizons respectively. Organic carbon content for the soils range from 11.4-16 g kg⁻¹ in the Ap horizons, an indication of moderate levels of organic matter. Perhaps, because of the high sand content in the soils, they have very low CEC as well as low levels of exchangeable Ca²⁺, Mg²⁺ and K⁺. All the available micronutrient elements, Cu, Mn and Zn except Fe and B were all below the critical limits set for optimum soil productivity, an indication that these essential plant nutrients are deficient in the soils.

**Soil taxonomic classification:** According to the criteria of the USDA Soil Taxonomy System (Soil Survey Staff, 1999), soils of both the Okitipupa and Omotosho series have argillic horizons with a base saturation percent of less than 50% (by NH₄OAC, pH 7.0) at 50cm depth within the argillic horizon and therefore both qualify for placement in the order of Ultisols. But at the sub-order level of the classification, the Okitipupa series qualify for classification as Udults because
of the prevailing udic soil moisture regime in the area while soils of the Omotosho series qualify as Humults because the profiles contain more than 0.9% organic carbon (by weighted average) in the upper 15cm of the argillic horizon. At the great group level of the classification, the Okitipupa series have argillic horizons with a clay decrease of less than 20% from the maximum clay content within 150cm from the soil surface and therefore fit as Paleudults, while the Omotosho soil series are Humults that have one or more horizons within 150cm of the mineral soil surface in which plinthite constitutes one half or more of the volume and so fit as Plinthohumults. At the subgroup level, the Okitipupa soil series fit very closely as Typic paleudults, while the Omotosho series fit as Typic plinthohumults.

Soils of the Ode Erinje Fadama series are developed on recent water sediments and do not have any diagnostic surface or subsurface horizons except ochric epipedon and therefore fit into the order of Entisols. The soils have aquic moisture regime and qualify for placement in the suborder of Aquents. The soils experience endosaturation with water tables within 50-60cm even at the peak of the dry season, they thus fit into the great group of Endoaquents. The Ap horizons of the pedons studied have colour value moist of 3 or less and a base saturation (NH₄OAC, pH 7.0) of less than 50% in some parts within 100 cm of the mineral soil surface and therefore fit as Humaquentic endoaquents at the subgroup level.

According to the FAO-WRB system of classification (FAO, 2006), soils of the Okitipupa series are Dystric acrisols, while soils of the Omotosho series are Plinthic acrisols and Ode Erinje Fadama series are classified as Arenic gleysols, even though, would have proposed their classification as Humic arenic Gleysols, because of the moderate to high levels of organic matter within the profiles.

CONCLUSION

Three soil mapping units designated as Okitipupa soil series, Omotosho series and Ode Erinje Fadama series were delineated within the Okitipupa local government area of Ondo state, Nigeria. Okitipupa series, the most extensive of the three soils covered a total of 41.623 ha or 52% of the survey area and developed on coastal plain sands, while Omotosho series covered a total of 17,818 ha or 21.64% and are developed on granitic crystalline rocks and the Ode Erinje Fadama series occupied 21,099 ha or 26.36% of the survey area and are derived from colluvium-alluvial deposits.

All the soils are very strongly acid in reaction with a pH range of 4.3-5.0. The soils will thus require liberal doses of liming materials to ameliorate soil acidity. All the soils also have sandy textures, but the upland soils, especially the Okitipupa series have loamy sand to sandy loam Ap horizons over sandy clay loam to sandy clay subsoils and are therefore, very susceptible to surficial erosion. The Omotosho series particularly occupy strongly undulating landscapes and are subject to accelerated erosion. The soils are also particularly low in essential plant nutrients such as available P, Ca²⁺, Mg²⁺, K⁺ and micronutrient elements especially Cu, Mn and Zn but the Omotosho series are slightly richer in nutrients than the soils of Okitipupa and Ode Erinje series. However, all the soils contain medium to low levels of organic carbon and total N. Cation exchange capacity of all the soils are also low with values of less than 6 cmol(+)/kg⁻¹ in the surface horizons.

According to the criteria of the USDA Soil Taxonomy system and the FAO World Reference Base for Soil Resources system (FAO-WRB), the Okitipupa soil series have been classified as Typic Paleudults and Dystric Acrisols respectively. Similarly, the Omotosho soil series are classified as Typic Plinthohumults and Ortho-plinthic Acrisols, while the Ode Erinje Fadama series are Humaquentic Endoaquents and (Humic) Arenic Gleysols, respectively.
ACKNOWLEDGEMENT

The authors are grateful to the Director, Federal Department of Agricultural Land Resources and the Honourable Minister, Federal Ministry of Agriculture and Rural Development, Abuja, at whose instance this study was funded under the Agricultural Transformation Agenda policy of the Nigerian government.

REFERENCES


