

## **Geomorphologic Evaluation and Management for Soils of Shale Lithology at Okai Item in Bende, South Eastern Nigeria.**

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Received 15<sup>th</sup> August, 2018 Accepted 11<sup>th</sup> December, 2018

### **Abstract**

This study was conducted to characterize, classify and group the soils of different geomorphic units in the study area into fertility capability classes essentially highlighting their potentials, productive constraints and evolve management strategies aimed at enhancing crop productivity. The study area was stratified into summits, gentle slopes and flood plain geomorphic units. Two profile pits each per geomorphic unit were dug in the three geomorphic units at most representative points of observation in the study area. The profiles were morphologically characterized and samples from various genetic horizons collected and analysed for physical and chemical properties. The data obtained grouped the soils into two major fertility capability classes of sandy (S) and loamy (L) types. The soils of summits were characterized with sandy (S) type and clay (C) substrata type and was associated with modifier 'd', which represents an Udic moisture regime. The soils were characterized with loamy (L) type and clay (C) substrata type with modifier 'd' at the gentle slope and g, g<sup>+</sup>, v, i<sup>+</sup> at the flood plains indicating fertility problems of gleying with prolonged water logging possessing vertic properties and potential iron toxicity. The soils of the summit and gentle slope were classified as Typic Kandiodalf (USDA) and Haplic Nitosols (FAO/UNESCO). The soils of the flood plains were classified as Typic Humaquepts (USDA) and humic cambisols (FAO/UNESCO). Management strategies such as irrigation, manuring and mulching are recommended for soils of the gentle slopes and summits. However efficient water control mechanism is recommended for the flood plain soils in the study area.

**Keywords:** Geomorphology, Evaluation, Shale Lithology, Management.

### **INTRODUCTION**

Soil geomorphology refers to the characteristics of the soil in relation to the landscape. Geomorphology and soils lithology are two environmental and genetic factors that greatly influences soil characteristics. Nsor and Ibanga (2008) observed that variations in soils characteristics is usually a reflection of differences in materials from which the soil was formed and its local relief. Soil characterization in relation to its relief is the building block for understanding the soil, classifying it and getting a good understanding of how best to manage it. Ogunkunle (2005) noted that soil characterization

provides information for our understanding of the physical, chemical and microbiological properties of the soil which determines the sustenance of crops, forest, grasslands, homes, society's structures and the environments.

Land evaluation is the assessment of land performance when used for a general or specific purpose involving the execution and interpretation of soil surveys and studies of landforms, soils, vegetation, climate and other aspects of land use in terms applicable to the objectives of the evaluation (FAO, 1976). There are different kinds of land evaluation systems generally grouped into parametric and limitation procedures. The evaluation of a piece of land for

certain use can change if conditions changes. For instance, an evaluation of a piece of land under the peasant farmer's level of technology will change if an improved technology is assumed (FDALR, 1982).

Fertility Capacity Classification (FCC) is a technical system of land evaluation based on the grouping of soils according to the kinds of problems they present for agronomic management of their chemical and physical properties (Akamigbo, 2010). Sanchez *et al.*, (2003) remarked that fertility capability classification focuses attention on surface soil properties most directly related to management of field crops. Nsor and Akamigbo (2014) indicated that similar soils on different topographic or geomorphic position will respond differently to the same management strategy. They further observed that soils of valley bottom were averagely better than those of middle slope and crest in important fertility indices.

The productivity of soils in the study area is declining due to poor management practices arising from inadequate soil information. This study provides additional knowledge and information to farmers and other land users on the potential, constraint and management of soils in the study area in relation to geomorphic attributes. The specific objectives of the study were to characterized, classify and evaluate the soils in terms of fertility capability in relation to geomorphic attributes.

## MATERIALS AND METHODS

### The Study Area

This study was carried out in selected soils of diverse geomorphic or physiographic terrains in Okai Item in Bende LGA, Abia state, Nigeria. The study area lies approximately within latitude 07° 21' and 07° 30' and longitude 05° 40' and 05° 49' E. Okai Item is bordered by Akaeze in the North, Nkporo in the East, Alayi in the West, and Abriba and Igbere in the South. The soils of Okai item were derived predominantly from shale and to a minor extend from sandstones and alluvium. The study area is within the humid tropical climate characterized by bimodal rainfall

regime. The mean annual rainfall range is between 1900-2200mm, temperature is between 27°C-28°C and relative humidity is usually high (70-80%) throughout the year (NRCRI, 2016). The vegetation of the area is a tropical rainforest type which has to a large extent been degraded to a secondary forest which predominantly made of oil palm (*Eleais guinensis*), guinea grass (*Panicum maximum*), elephant grass (*Pennisetum purperum*), Bamboo (*Bambusa vulgaris*) etc. Common crops grown in the area include yam (*Discorea* spp.), cassava (*Manihot* spp), maize (*Zea mays*), and oil palm (*Eleais guinensis*) etc.

### Sampling Technique

The stratified sampling technique was adopted for the study. The study area was stratified into inland valleys, gentle slopes and summits. The basis for stratification was variation in geomorphic features of the landscape. Two (2) profile pits per strata (mapping unit) were excavated at most representative points of observation to represent the study area. A total of six (6) profiles were dug and described according to FAO (2006) guidelines. Soil samples were taken from the different horizons for routine physical and chemical analysis. Soil samples for laboratory analysis were air-dried at room temperature, ground with a wooden pestle and sieved through a 2mm mesh sized sieve.

Particle size analysis was determined by the Bouyoucos hydrometer method (Gee and Or, 2002). Soil erodibility index (SEI) was estimated by evaluating the ratio of sand and silt content to clay content (Hudson, 1995). Evidence for argillic property was obtained by evaluating the ratio of illuvial to eluvial clay.

Soil pH was determined in a 1:2.5, soil: water suspension (Thomas, 1996). Organic carbon was determined by the dichromate wet oxidation method (Nelson and Sommers, 1996). Total nitrogen was analysed according to the macro kjeldahl digestion method (Bremner, 1996). Available phosphorus was extracted by Bray II procedure and estimated by the molybdenum blue colour technique (Kuo, 1996). Cation exchange capacity was determined by the

Ammonium acetate (NH<sub>4</sub>OAc) method. Exchangeable cations in the extract were determined by flame photometry (Na<sup>+</sup> and K<sup>+</sup>) and EDTA titration method (Ca<sup>2+</sup> and Mg<sup>2+</sup>). Exchangeable acidity was determined by the KCl extraction method (Thomas, 1996).

### Fertility Capability Evaluation

The Fertility Capability Evaluation was based on quantitative soil properties directly related to the management and growth of arable crops (Sanchez *et al.*, 2003). The fertility capability classification (FCC) listed the type and substrata type in capital letters and the modifiers in lower case letters. Nutrient deficiencies, toxicities and physiological disorders specific to arable crops were highlighted and interpreted for the soils under investigation. An appropriate legend was adopted to facilitate better understanding.

## RESULTS AND DISCUSSION

### Morphological Characteristics

The morphological characteristics of three geomorphic units studied in Okai Item Bende L.G.A, Abia State is presented in Table 1. The results indicate that under moist condition, the soils at the summits were characterized by dark yellowish brown (10YR 5/4) to yellowish brown (10YR 5/6) top soils over brown (10YR 4/6) sub soils (Table 1). The summit soils were also characterized by weak medium granular top soils over moderate to strong medium sub angular blocky structures. The consistence of these soils indicated soft top soils over hard sub soils (dry); loose to very friable top soils over friable to very firm sub soils (moist) and slightly sticky-very plastic sub soils (wet). The soils of the gentle slope physiographic unit indicated a moist soil colour of dark brown (10YR 3/3) to dark yellowish brown (10YR 5/4) epipedons over greyish yellow brown (10YR 6/2) to grayish yellow brown (10YR 5/2) endopedons. These soils had weak to moderate medium granular top soils over moderate to strong coarse sub angular blocky structures. Its consistence revealed a loose to hard top soil over very hard sub soils (dry); firm over very firm sub soils (moist) and slightly

sticky, slightly plastic to sticky-plastic top soils over sticky-very plastic to very sticky-very plastic sub soils (wet) Table 1. The surface moist colour of soils at the flood plains varied from brown (7.5YR 4/6) to dark brown (7.5YR 5/6) over orange (5YR 6/8) to brownish grey (7.5YR 5/1) sub surface soils. Few fine faint to common medium prominent dark reddish brown (2.5YR 3/6) mottles were encountered in the sub soils of this mapping unit. The mottles found might be due to slow permeability and reduction-oxidation cycles taking place in these soils as also observed by (Sahu *et al.*, 2001) in their studies of some vertisols. The structures in this geomorphic unit indicated weak to moderate fine crumb and sub angular blocky aggregates over moderate to strong medium to coarse prismatic structures. The consistence revealed loose to slightly hard top soils over hard to very hard sub soil (dry); loose to friable top soils over firm to very firm sub soil (moist) and non-sticky-non plastic to slightly sticky-slightly plastic top soils over sticky-slightly plastic to very sticky-plastic endopedons. The soils in the study area are well drained at the summits and imperfectly to poorly drained at the gentle slope and flood plains respectively as equally observed by Nsor and Akamigbo (2014), for soils on similar topographic positions. Variation in grade, strength and shape of soil structure in surface horizons compared to sub surface horizons of the study area was probably caused by prolonged wet dry cycles of soils and their shale parent materials. Consistency of the study area also changed with variation in the clay content. Therefore this indicates that soil type of a particular area depends on rock mineral type and how they react to climatic elements.

**Table 1: Morphological Characteristics of Soils of Diverse Geomorphic Terrains in Okai Item, Bende L.G.A, Abia Nigeria.**

| Horizon Designation            | Horizon Thickness (cm) | Major colour  | Mottles             | Structure    | Dry | Moist | Wet   | Roots | Pores | Horizon Boundary |
|--------------------------------|------------------------|---------------|---------------------|--------------|-----|-------|-------|-------|-------|------------------|
| <b>Soils of summits</b>        |                        |               |                     |              |     |       |       |       |       |                  |
| Ap                             | 0-18                   | 10YR 5/4; Dyb |                     | 1M granular  | s   | l     | ss-sp | mf    | cf    | cw               |
| Bt <sub>1</sub>                | 18-53                  | 10YR 5/6; Yb  |                     | 1M granular  | sh  | vfr   | ss-sp | fvf   | ff    | gw               |
| Bt <sub>2</sub>                | 53-115                 | 10YR 4/6; B   |                     | 2M sbk       | h   | fr    | s-p   | fvf   | fvf   | gw               |
| Bt <sub>3</sub>                | 115-161                | 10YR 4/6; B   |                     | 3M sbk       | vh  | vf    | vs-vp | ff    | cvf   |                  |
| Ap                             | 0-15                   | 10YR 3/4; Db  |                     | 1M granular  | s   | l     | ss-sp | mf    | cf    | cw               |
| AB                             | 15-48                  | 10YR 5/4; Dyb |                     | 1M sbk       | sh  | vfr   | s-sp  | ff    | ff    | gw               |
| BC                             | 48-109                 | 10YR 5/6; Yb  |                     | 2M sbk       | h   | vfr   | s-p   | fvf   | fvf   | gw               |
| BCt                            | 109-134                | 10YR 4/6; B   |                     | 2M sbk       | h   | fr    | vs-vp | fvf   | cvf   |                  |
| <b>Soils of Gentle Slope</b>   |                        |               |                     |              |     |       |       |       |       |                  |
| Ap                             | 0-9                    | 10YR 3/3; Db  |                     | 1M granular  | l   | f     | ss-sp | cf    | cm    | cw               |
| Bt <sub>1</sub>                | 9-29                   | 10YR 5/4; Dyb |                     | 2M granular  | h   | f     | s-p   | cf    | cm    | gw               |
| Bt <sub>2</sub>                | 29-89                  | 10YR 6/2; Gyb |                     | 2C sbk       | vh  | vf    | s-vp  | fvf   | cvf   | gw               |
| Bt <sub>3</sub>                | 89-153                 | 10YR 5/2; Gyb |                     | 3C sbk       | vh  | vf    | vs-vp | fvf   | cvf   |                  |
| Ap                             | 0-11                   | 10YR 3/4; Db  |                     | 1M granular  | l   | fr    | ss-sp | mm    | mm    | cw               |
| Bt <sub>1</sub>                | 11-25                  | 10YR 6/3; Gyb |                     | 2M granular  | h   | f     | ss-p  | cm    | fm    | gw               |
| Bt <sub>2</sub>                | 25-82                  | 10YR 5/2; Gyb |                     | 2M sbk       | vh  | vf    | s-vp  | fm    | fm    | gw               |
| Bt <sub>3</sub>                | 82-144                 | 10YR 5/2; Gyb |                     | 2M sbk       | vh  | vf    | vs-vp | fm    | cf    |                  |
| <b>Soils of Inland Valleys</b> |                        |               |                     |              |     |       |       |       |       |                  |
| Ap                             | 0-10                   | 7.5YR 4/6; B  |                     | 1F crumb     | l   | l     | ns-np | cm    | cf    | cs               |
| Bh                             | 10-32                  | 7.5YR 5/6; Db |                     | 2F sbk       | sh  | fr    | ss-sp | cm    | cf    | gw               |
| Bg <sub>1</sub>                | 32-110                 | 5YR 6/8; O    | 2.5YR 3/6; fff, Drb | 2M prismatic | h   | fr    | s-sp  | cf    | mvf   | gw               |
| Bg <sub>2</sub>                | 110-155                | 7.5YR 5/1; Bg | 2.5YR 3/6; cmp, Drb | 3C prismatic | vh  | vf    | vs-p  | fvf   | fvf   |                  |
| Ap                             | 0-13                   | 10YR 3/3; Db  |                     | 1F crumb     | l   | fr    | ns-np | cm    | cm    | cs               |
| Bh                             | 13-33                  | 7.5YR 4/6; B  |                     | 2F granular  | sh  | f     | ss-sp | cf    | cm    | cw               |
| Bhg                            | 33-106                 | 7.5YR 5/1; Bg | 2.5YR 3/6; cmp, Drb | 2M prismatic | h   | f     | s-p   | cf    | fvf   | gw               |
| Bg                             | 106-139                | 7.5YR 4/1; Dg | 2.5YR 3/6; mcp, Drb | 2M prismatic | vh  | vf    | vs-vp | fvf   | ff    |                  |

**Key:**

- Colour:** Dyb = Dull yellowish brown, Yb = yellowish brown, B = Brown, Db = Dark brown, Gyb = Greyish yellow brown, O = Orange, Bg = Brownish grey, Dg = Dark grey, Drb = Dark reddish brown.
- Mottles:** fff = few fine faint, cmp = common medium prominent, mcp = many coarse prominent
- Structure:** 1 = weak, 2 = moderate, 3 = strong, F = fine, M = medium, C = coarse, sbk = sub angular blocky
- Consistent:** s = soft, sh = slightly hard, h = hard, vh = very hard, l = loose, vfr = very friable, fr = friable, f = firm, vf = very firm, ss-sp = slightly sticky-slightly plastic, s-p = sticky-plastic, vs-vp = very sticky-very plastic, s-sp = sticky-slightly plastic, s-vp = sticky-very plastic, ss-p = slightly sticky-plastic, ns-np = non sticky-non plastic, vs-p = very sticky-plastic
- Roots/Pores:** mf = many fine, fvf = few very fine, ff = few fine, cf = common fine, mm = many medium, cm = common medium, fm = few medium, cvf = common very fine, mvf = many very fine
- Boundary:** cw = clear wavy, gw = gradual wavy, cs = clear smooth

## Physical Characteristics

Physical characteristics of the soils in the study area are presented in Table 2. The particle size distribution of the soils revealed that clay, silt and sand content varied from 22-68%, 8-30% and 23-57% respectively. In general, endopedon horizons exhibited higher clay content relative to that of epipedon horizons, which might be due to illuviation process occurring during soil development as reported by Ibanga (2003).

Soils of the summit had sandy clay loam to sandy clay top soil textures over clay subsoil.

At the gentle slope the soils were found to have loamy to clayey loam epipedons over clay endopedons. Soils of the floodplains had loamy to clayey loam top soils over clayey loam to clay subsoil textures.

The result of soil erodibility index indicated that top soils had higher erodibility indexes and thus more vulnerable to erosion than the sub soils. The soils of summits and gentle slope geomorphic units had sub soil illuvial: eluvial clay ratios greater than 1.4, indicative of evidence of argillic horizons (Table 2). However, the sub soils of flood plains did not show evidence of illuviated clays.

**Table 2: Physical Properties of Soils in the Study Area**

| Horizon Designation            | Horizon Thickness (cm) | Sand (%) | Silt (%) | Clay (%) | Textural Class | Soil Erodibility Index | Illuvial: Eluvial Clay |
|--------------------------------|------------------------|----------|----------|----------|----------------|------------------------|------------------------|
| <b>Soils of Summits</b>        |                        |          |          |          |                |                        |                        |
| Ap                             | 0-18                   | 57       | 21       | 22       | SCL            | 3.5                    |                        |
| Bt <sub>1</sub>                | 18-53                  | 40       | 20       | 40       | SC             | 1.5                    | 1.8                    |
| Bt <sub>2</sub>                | 53-115                 | 23       | 23       | 54       | C              | 0.9                    | 2.5                    |
| Bt <sub>3</sub>                | 115-161                | 24       | 8        | 68       | C              | 0.5                    | 3.1                    |
| Ap                             | 0-15                   | 54       | 13       | 33       | SCL            | 2.0                    |                        |
| AB                             | 15-48                  | 50       | 11       | 39       | SCL            | 1.6                    | 1.2                    |
| BC                             | 48-109                 | 34       | 19       | 47       | C              | 1.1                    | 1.4                    |
| BCt                            | 109-134                | 27       | 12       | 61       | C              | 0.6                    | 1.8                    |
| <b>Soils of Gentle Slope</b>   |                        |          |          |          |                |                        |                        |
| Ap                             | 0-9                    | 45       | 28       | 27       | L              | 2.7                    |                        |
| Bt <sub>1</sub>                | 9-29                   | 43       | 26       | 31       | CL             | 2.2                    | 1.1                    |
| Bt <sub>2</sub>                | 29-89                  | 36       | 20       | 44       | C              | 1.3                    | 1.6                    |
| Bt <sub>3</sub>                | 89-153                 | 29       | 25       | 46       | C              | 1.2                    | 1.7                    |
| Ap                             | 0-11                   | 49       | 28       | 23       | L              | 3.3                    |                        |
| Bt <sub>1</sub>                | 11-25                  | 39       | 16       | 45       | SC             | 1.2                    | 2.0                    |
| Bt <sub>2</sub>                | 25-82                  | 27       | 16       | 57       | C              | 0.8                    | 2.5                    |
| Bt <sub>3</sub>                | 82-144                 | 21       | 16       | 63       | C              | 0.6                    | 2.7                    |
| <b>Soils of Inland Valleys</b> |                        |          |          |          |                |                        |                        |
| Ap                             | 0-10                   | 44       | 30       | 26       | L              | 2.8                    |                        |
| Bh                             | 10-32                  | 40       | 28       | 32       | CL             | 2.1                    | 1.2                    |
| Bg <sub>1</sub>                | 32-110                 | 38       | 23       | 39       | CL             | 1.6                    | 1.2                    |
| Bg <sub>2</sub>                | 110-155                | 26       | 16       | 58       | C              | 0.7                    | 1.5                    |
| Ap                             | 0-13                   | 41       | 28       | 31       | CL             | 2.2                    |                        |
| Bh                             | 13-33                  | 40       | 26       | 34       | CL             | 1.9                    | 1.1                    |
| Bhg                            | 33-106                 | 38       | 24       | 38       | CL             | 1.6                    | 1.2                    |
| Bg                             | 106-139                | 36       | 22       | 42       | C              | 1.4                    | 1.3                    |

## Chemical Characteristics

The result of chemical characteristics of soils in the study area indicate that, the pH in

water of the soils are moderately acid (pH 5.0-5.9), averaging 5.2 at the summit, 5.7 at the gentle slopes and 5.7 the flood plains. This pH is ideal for agronomic activities as most plants are known

to thrive within a pH range of 5.5 to 7.5 associated with the availability of most essential nutrients as reported by Aduayi and Ekong (1981).

Organic carbon content in the study area ranged from 4.0-24.4g/kg. Organic carbon was low (6.6-16g/kg) at the summit but medium at the gentle slope (4.0-22.1g/kg) and flood plains (5.1-24.4g/kg). The medium values at the flood plain and gentle slope might be due to high amount of litter and erosional sediments on the surface of these soils and prolonged water logging which slows down organic matter mineralization as also observed by Nsor and Akamigbo (2014).

Total nitrogen was rated medium at the summit (0.6-1.7g/kg) and gentle slope (0.8-2.1g/kg) but high in the flood plains (Table 3). Powell *et al.*, (2007) also encountered similar observations in some dairy farms in Wisconsin; U.S.A. the medium to high nitrogen level in the study area might have been enhanced by its shale parent material which gives rise to fine soil textures. Low nitrogen levels in soil had been attributed to the coarseness of soil textures. It has also been observed that organic matter and nitrogen content of the soil depends principally on soil texture as influenced by parent materials (Stevenson, 1982).

Among the exchangeable cations, sodium was low in the summits (0.5-0.6cmol/kg) and medium at the gentle slope (0.10-0.22cmol/kg) and flood plains (0.10-0.15cmol/kg). Potassium was medium (0.11-0.49cmol/kg) at the summit and high (0.26 and 0.49cmol/kg) at the gentle slopes and flood plains. Calcium was medium (2.4-5.2cmol/kg) in all the pedons studied. This might be due to the shale material of these soils which according to Best (1982) contain high oxides of calcium and magnesium.

Cation Exchange Capacity (CEC) in the study area was rated medium at the summits 8.8-13.5cmol/kg) and high at the gentle slope (10.3-14.6cmol/kg) and the flood plains (11.0-15.1cmol/kg). This implies moderate nutrient reserve at the summits and higher capacity at the gentle slopes and flood plains. The high CEC in these soils is as a result of high clay and organic matter content (high colloidal activity) of these soils. This observation corroborates Krull *et al.* (2003), who indicated that high values of exchangeable cations and CEC are due to soil clay minerals mainly high activity clays. Base saturation of top soils was in the range (38.4%-63.6%) and generally decreased down the profile (Table 3). These values were low at the summit (42.78%) but medium at the gentle slope (55.6%) and flood plains (51.18%) respectively.

**Table 3: Chemical Characteristics of Soils on Different Geomorphic Units in the Study Area**

| Horizon Designation            | Horizon Depth (cm) | pH (H <sub>2</sub> O) | pH (KCl) | Org. C<br>← gkg <sup>-1</sup> | O.M.<br>gkg <sup>-1</sup> | T.N<br>→ | Na <sup>+</sup> | K <sup>+</sup> | Ca <sup>2+</sup><br>cmolk g <sup>-1</sup> | Mg <sup>2+</sup> | CEC  | EA   | Av.P<br>mgkg <sup>-1</sup> | BS (%) |
|--------------------------------|--------------------|-----------------------|----------|-------------------------------|---------------------------|----------|-----------------|----------------|-------------------------------------------|------------------|------|------|----------------------------|--------|
| <b>Soils of Summits</b>        |                    |                       |          |                               |                           |          |                 |                |                                           |                  |      |      |                            |        |
| Ap                             | 0-18               | 5.4                   | 4.3      | 16.6                          | 28.6                      | 1.7      | 0.06            | 0.17           | 3.1                                       | 1.4              | 8.8  | 0.25 | 20.2                       | 53.8   |
| Bt <sub>1</sub>                | 18-53              | 5.2                   | 4.1      | 7.0                           | 12.1                      | 1.4      | 0.05            | 0.11           | 2.4                                       | 1.2              | 9.8  | 0.21 | 16.1                       | 38.4   |
| Bt <sub>2</sub>                | 53-115             | 5.2                   | 4.1      | 7.4                           | 12.8                      | 0.8      | 0.06            | 0.23           | 2.6                                       | 1.1              | 10.4 | 0.16 | 15.2                       | 38.4   |
| Bt <sub>3</sub>                | 115-161            | 5.0                   | 3.7      | 6.6                           | 11.4                      | 0.6      | 0.06            | 0.31           | 2.8                                       | 2.3              | 13.5 | 0.12 | 10.4                       | 40.5   |
| Ap                             | 0-15               | 5.3                   | 4.2      | 14.7                          | 25.3                      | 1.5      | 0.05            | 0.15           | 2.9                                       | 1.3              | 8.6  | 0.23 | 19.4                       | 51.2   |
| AB                             | 15-48              | 5.3                   | 4.2      | 6.3                           | 10.9                      | 1.2      | 0.05            | 0.12           | 2.1                                       | 1.1              | 9.6  | 0.20 | 14.6                       | 35.1   |
| BC                             | 48-109             | 5.1                   | 3.9      | 6.1                           | 10.5                      | 1.0      | 0.05            | 0.20           | 2.3                                       | 1.0              | 10.5 | 0.18 | 11.5                       | 33.8   |
| BCt                            | 109-134            | 5.1                   | 3.8      | 5.2                           | 9.5                       | 0.5      | 0.06            | 0.29           | 2.4                                       | 1.8              | 12.8 | 0.13 | 10.6                       | 35.5   |
| <b>Soils of Gentle Slope</b>   |                    |                       |          |                               |                           |          |                 |                |                                           |                  |      |      |                            |        |
| Ap                             | 0-9                | 5.8                   | 4.1      | 22.1                          | 38.1                      | 2.1      | 0.22            | 0.46           | 4.2                                       | 1.8              | 10.5 | 0.17 | 25.6                       | 63.6   |
| Bt <sub>1</sub>                | 9-29               | 5.6                   | 4.2      | 15.2                          | 26.2                      | 1.5      | 0.22            | 0.26           | 4.3                                       | 1.5              | 11.8 | 0.16 | 21.7                       | 53.2   |
| Bt <sub>2</sub>                | 29-89              | 5.7                   | 4.0      | 7.3                           | 12.6                      | 1.1      | 0.20            | 0.31           | 4.1                                       | 2.4              | 13.3 | 0.22 | 28.8                       | 52.7   |
| Bt <sub>3</sub>                | 89-153             | 5.5                   | 4.4      | 4.0                           | 6.9                       | 0.8      | 0.10            | 0.36           | 5.2                                       | 2.6              | 14.6 | 0.18 | 19.1                       | 56.6   |
| Ap                             | 0-11               | 5.6                   | 4.0      | 20.5                          | 35.3                      | 1.7      | 0.10            | 0.44           | 4.0                                       | 1.6              | 10.3 | 0.19 | 23.3                       | 59.6   |
| Bt <sub>1</sub>                | 11-25              | 5.5                   | 4.0      | 14.1                          | 24.3                      | 1.3      | 0.20            | 0.21           | 4.1                                       | 1.4              | 11.5 | 0.15 | 22.1                       | 51.4   |
| Bt <sub>2</sub>                | 25-82              | 5.5                   | 4.2      | 5.6                           | 9.7                       | 1.0      | 0.20            | 0.29           | 5.0                                       | 2.5              | 12.9 | 0.20 | 24.3                       | 61.9   |
| Bt <sub>3</sub>                | 82-144             | 5.4                   | 4.2      | 4.1                           | 7.1                       | 0.9      | 0.20            | 0.33           | 5.2                                       | 2.5              | 14.4 | 0.20 | 26.6                       | 57.2   |
| <b>Soils of Inland Valleys</b> |                    |                       |          |                               |                           |          |                 |                |                                           |                  |      |      |                            |        |
| Ap                             | 0-10               | 5.9                   | 4.0      | 24.4                          | 42.1                      | 2.4      | 0.15            | 0.49           | 3.6                                       | 2.5              | 11.1 | 0.32 | 20.2                       | 60.7   |
| Bh                             | 10-32              | 5.7                   | 3.7      | 12.5                          | 21.6                      | 3.1      | 0.10            | 0.32           | 3.1                                       | 1.6              | 11.2 | 0.30 | 26.1                       | 45.7   |
| Bg <sub>1</sub>                | 32-110             | 5.6                   | 3.6      | 6.5                           | 11.2                      | 2.6      | 0.10            | 0.26           | 3.6                                       | 2.2              | 12.9 | 0.24 | 28.2                       | 47.8   |
| Bg <sub>2</sub>                | 110-155            | 5.7                   | 3.6      | 5.1                           | 8.8                       | 1.6      | 0.10            | 0.38           | 4.3                                       | 2.6              | 14.6 | 0.20 | 24.2                       | 50.5   |
| Ap                             | 0-13               | 5.7                   | 3.9      | 23.2                          | 40.0                      | 2.3      | 0.15            | 0.48           | 3.5                                       | 2.4              | 11.0 | 0.33 | 21.4                       | 59.4   |
| Bh                             | 13-33              | 5.7                   | 3.8      | 10.4                          | 17.9                      | 2.4      | 0.15            | 0.30           | 3.2                                       | 1.4              | 11.4 | 0.29 | 22.4                       | 44.3   |
| Bhg                            | 33-106             | 5.6                   | 3.6      | 6.6                           | 11.4                      | 2.8      | 0.15            | 0.24           | 3.7                                       | 2.3              | 13.0 | 0.26 | 26.1                       | 49.2   |
| Bg                             | 106-139            | 5.6                   | 3.6      | 5.4                           | 9.3                       | 1.7      | 0.10            | 0.40           | 4.1                                       | 2.5              | 15.1 | 0.14 | 20.0                       | 47.0   |

### Classification of Soils in the Study Area

The soils in the study area were classified according to the USDA soil taxonomy and correlated approximately to the FAO/UNESCO legend of World Reference Base (WRB). The soils at the summit as well as the gentle slopes had moderate pH (5.0-5.8) and base saturation (38.4-63.6%) respectively, which is greater than 35% by NH<sub>4</sub>OAc method. The soils of the summits and gentle slopes also had Ochric surface, and argillic and Kandic sub surface diagnostic horizons. These properties qualify placing the soils of summit and gentle slopes under the Alfisol soil order (Soil Survey Staff, 2014). Their occurrence under Udric moisture regime qualify placing them as Udalf at the sub order level. The soils were placed as Kandiu-dalfs at the great group level due to their possession of

Kandic subsoil horizons. At the sub group level these soils were classified as Typic Kandiu-dalf. Its FAO/UNESCO equivalent is Haplic Nitosols. The soils of the flood plains were characterized with moderate pH (5.6-5.9), moderate base saturation (45.9-60.7%) which is greater than 35% by NH<sub>4</sub>OAc method. The soils also had mollic epipedons and cambic endopedons. These properties qualify the flood plain soils in the study area as Inceptisols. Their possession of mollic epipedon qualify their classification as Humaquepts at the great group level. At the sub group level, the soils of flood plains in the study area were classified Typic Humaquepts. Their FAO/UNESCO equivalent is Humic Cambisols.

## Fertility Capability Classification of Soils in the Study Area

Fertility capability classification (FCC) of soils in the study area was done to further interpret the soil taxonomy and give additional soil attributes to the soils as modified by geomorphology directly relevant to crop cultivation in the study area. Consequently, the FCC of soils in Okai Item, Bende L.G.A, South Eastern Nigeria mainly assessed the potentials of soils on different geomorphic units for crop cultivation. The FCC for the soils in the study area is presented in Tables 4 and 5. The soils of summit in the study area belonged to sandy (S) type and clay (C) substrata type. These soils were associated with modifier 'd' indicating fertility problem of udic (dry) moisture regime. The soils of this geomorphic unit can be put into arable and non-arable crops under good management practices. Such practices include manuring, fertilization and irrigation. The soils on the gentle

slope geomorphic unit belonged to loamy (L) type top soils and clay (C) sub-strata type. It also had modifier 'd' indicating that the soils have udic moisture regime. The same management practice outlined for the summits above will be useful for the soils in this unit.

The soils of flood plains in the study area belong to Loamy (L) type and clay (C) substrata type. Soils of this geomorphic unit are associated with anaerobic conditions (g-modifier) representative of aquic soil moisture regime (Table 4). Consequently, the prolonged water logging condition of this geomorphic unit pre-disposed this soil unit to potential iron toxicity ( $i^+$  modifier) showing vertic properties in dry seasons. The soils of this unit are well adapted for fish farming, swamp rice and sugarcane cultivation under efficient water control mechanisms. Furthermore, crops like vegetables, maize, yam, cassava, etc cannot be grown easily without adequate drainage.

**Table 4: Checklist showing Type, Substrata Type and Modifiers**

| Physiographic Unit/Pedon | Type | Substrata Type | Modifiers |                |   |   |   |   |   |   |                | Aggregate                         |
|--------------------------|------|----------------|-----------|----------------|---|---|---|---|---|---|----------------|-----------------------------------|
|                          |      |                | g         | g <sup>+</sup> | v | k | E | d | h | i | i <sup>+</sup> |                                   |
| Summits                  | S    | C              | -         | -              | - | - | - | + | - | - | -              | SC <sub>d</sub>                   |
| Gentle slope             | L    | C              | -         | -              | - | - | - | + | - | - | -              | LC <sub>d</sub>                   |
| Flood plains             | L    | C              | +         | +              | + | - | - | - | - | - | +              | LCgg <sup>+</sup> vi <sup>+</sup> |

**Key:**

S = Loamy sands and sands,

L = < 35% clay but not loamy sands or sands

C = > 35% clay,

g = gley, mottles, saturated with water for > 60 days in most years

d = dry udic environment

e = low CEC of plough layer

h = acidic pH in H<sub>2</sub>O between 4 and 5

i = (Fe – P fixation) or low P

k = k deficiency exchangeable K < 0.2 cmolkg<sup>-1</sup>

v = vertic properties

g<sup>+</sup> = prolonged water logging

i<sup>+</sup> = iron toxicity

**Table 5: Fertility Capability Classification (FCC) of Identified Geomorphic Units in Okai Item Bende LGA, South Eastern Nigeria.**

| FCC                               | Geomorphic unit | Description                                                                                                                                                                                                         |
|-----------------------------------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SC <sub>d</sub>                   | Summits         | Sandy (Sandy loam) top soils having < 35% clay sub soils. They have fertility problems of udic moisture regime.                                                                                                     |
| LC <sub>d</sub>                   | Gentle slopes   | Loamy (sandy clay loam) top soils having < 35% clay sub soils with fertility problems of udic moisture regime                                                                                                       |
| LCgg <sup>+</sup> vi <sup>+</sup> | Flood plains    | Loamy (sandy clay loam) top soils having < 35% clay sub soils with fertility problem of prolonged water logging with mottle sub soils (aquic moisture regime) showing vertic properties with potential Fe- toxicity |

**Key:**

S = loamy sands and sands (sandy top soils)  
 L = soils having < 35% clay but not loamy sands or sands (loamy top or sub soils)  
 C = soils having < 35% clay (clayed top or sub soils)  
 d = dry udic environment  
 g = gleying, mottles (aquic moisture regime)  
 g<sup>+</sup> = prolonged water logging  
 v = vertic properties  
 i<sup>+</sup> = potential Fe-toxicity

**CONCLUSION**

Fertility Capability Classification of soils in the study area did not indicate severe nutrient deficiencies. It however revealed fertility problems of Udic moisture regime, gleization (mottles) due to prolonged water logging and potential iron toxicity. The moderately high organic matter content and the nature of its parent material accounted for this observation.

Based on the study and field observations, it is recommended that irrigation; manuring and mulching should be applied to the soils of the Sandy (S) type and Clay (C) substrata types of the summits and Loamy (L) type top soils and Clay (C) substrata type of the gentle slopes. Efficient water control mechanisms in the loamy (L) type and clay (C) substrata type soils of flood plains would make these soils most suited for fish farming, swamp rice and sugar cane cultivation. However, vegetables and arable crops can be grown under adequate drainage scheduling.

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