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# Fertility Evaluation of Selected Top Soils for Crop Production in Ondo State, Nigeria

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***Authors' contributions***

*This work was carried out in collaboration between the two authors. Author EAA designed the study, performed the geo-spatial analysis, wrote the protocol and wrote the first draft of the manuscript. Author MON managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.*

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## ABSTRACT

The soil resource of a nation is finite and its natural quality cannot be exchanged. However, maintenance of the good quality soil resource at a high level to support agricultural production is a key to poverty eradication and environmental sustainability. The study assesses the fertility status of selected surface soils in Ondo State of Nigeria with a view to making recommendations for sustainable crop production. Examination of the attributes of soils of the area was carried out and their potentials assessed for crop production in twelve selected locations (Ose, Ago-Ajayi, Ikun 1, Ikun 2, Iwaro, Oka. Akungba, Oyinmo, Agbanimu, Aiyegunle, Araromi and Ago-Fulani. Composite soil samples were collected at the depth of 0 - 20 cm across the selected locations in the area and analysed. Results of the analyses showed that surface soil textures ranged between sandy loam and sandy clay loam. Soil reaction varied from slightly acidic to neutral (6.66 - 7.09). Percent organic carbon was low to moderate (0.43 – 1.61%). Total nitrogen was generally moderately low to medium while available phosphorus ranged from low to medium. Exchangeable bases were

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generally low except the potassium content that was high in soils of Ose and Oka. The cation exchange capacity (CEC) and percent base saturation were generally low across the locations. The results generally revealed low nutrient status of the soils.

*Keywords: Assessment; soil potential; sustainable crop production.*

## 1. INTRODUCTION

Soil provides ecosystem services critical for life. The Global Food Security (GFS) reported that, the soil provides the basic medium for plant growth, underpinning the production of crops and fodder and facilitates a range of ecosystem services such as nutrient cycling, water regulation while supporting biodiversity. One major but often overlooked factor of crop production is the soil condition. The failure of previous efforts to achieve self-sufficiency in food production in Nigeria has been partly due to the neglect of the soil factor. The Soils Organic Matter (SOM) originated from living things which has subsequently been broken down by decomposition by micro-organisms with attendant release of nutrients and carbon dioxide ($CO_2$) to the atmosphere. The soil is the non-renewable natural resource from which over 90% of our food comes from. This therefore underscores the importance of soil within the context of attainment of food and nutritional security.

Different soils have varying nutrient supplying power, depending on the amount of total reserves, on mobilization and accessibility of the chemically available nutrients to plant roots. The process of determining the nutrient status of soils or their capacity for providing nutrients in order to guide effective fertilizer application can be referred to as 'Soil Fertility Evaluation' [1]. Therefore, understanding the fertility status of soils in an area is very important and crucial for productive and sustainable management of such soils without diminishing the potential for their future use [2].

The low fertility status of soils of the tropics has led to a decline in per capita food production as well as environmental degradation. The spatial variability in the morphological, physical and chemical properties of soils determines their varying response to management options. The indiscriminate deforestation and continuous cultivation are attributed as the main source of decline in per capita productivity of soils and fertility [3]. Among the basic tools and methods identified for the diagnosis of soil fertility problems (visual diagnosis, biological tests, plant analysis, soil analysis and fertilizer experiments), soil analysis is most important. This is because it allows for the grouping of soils into their various classes (low, medium and high) for the purpose of fertilization as well as amendments to the problem soils, evaluation of soil fertility status vis-à-vis soil productivity to help monitor both soil fertility and yield sustainability over time and specific soil condition. The interest of any farmer is geared towards how profitable it is to grow crops in a given plot of land and the amendments required to optimize the productivity of the soil for the specified crops thus, a periodic fertility evaluation of soils is necessary [4]. In addition, there is inadequate soil information in most areas in Nigeria. It is of the view that evaluation of soils of Akoko Southwest Local Government Area of Ondo State will add to the existing soil information in Nigeria.

Keeping these considerations in view, an investigation was undertaken in the study area to assess the fertility status of the soils and prepare nutrient-wise maps for identification of nutrient constraints.

## 2. MATERIALS AND METHODS

### 2.1 The Study Area

The study was conducted in Akoko Southwest Local Government Area of Ondo State, located between latitudes 7° 18' and 7° 28' N and longitudes 5° 30' and 5° 50' E, with altitudes ranging between 228 m and 431 meters above sea level. Soils of the area were formed predominantly from Precambrian Basement Complex, which forms parts of the African crystalline shield [5]. The area occurred on nearly level plain to gently undulating terrain.

### 2.2 Climate and Vegetation

The climate of the area is humid tropical. It is marked by alternating wet and dry seasons. The rainfall which is heavy and bimodal lasts for about seven months. Temperatures are relatively high all the year round. Annual rainfall totals range from 1200 – 1500 mm and air

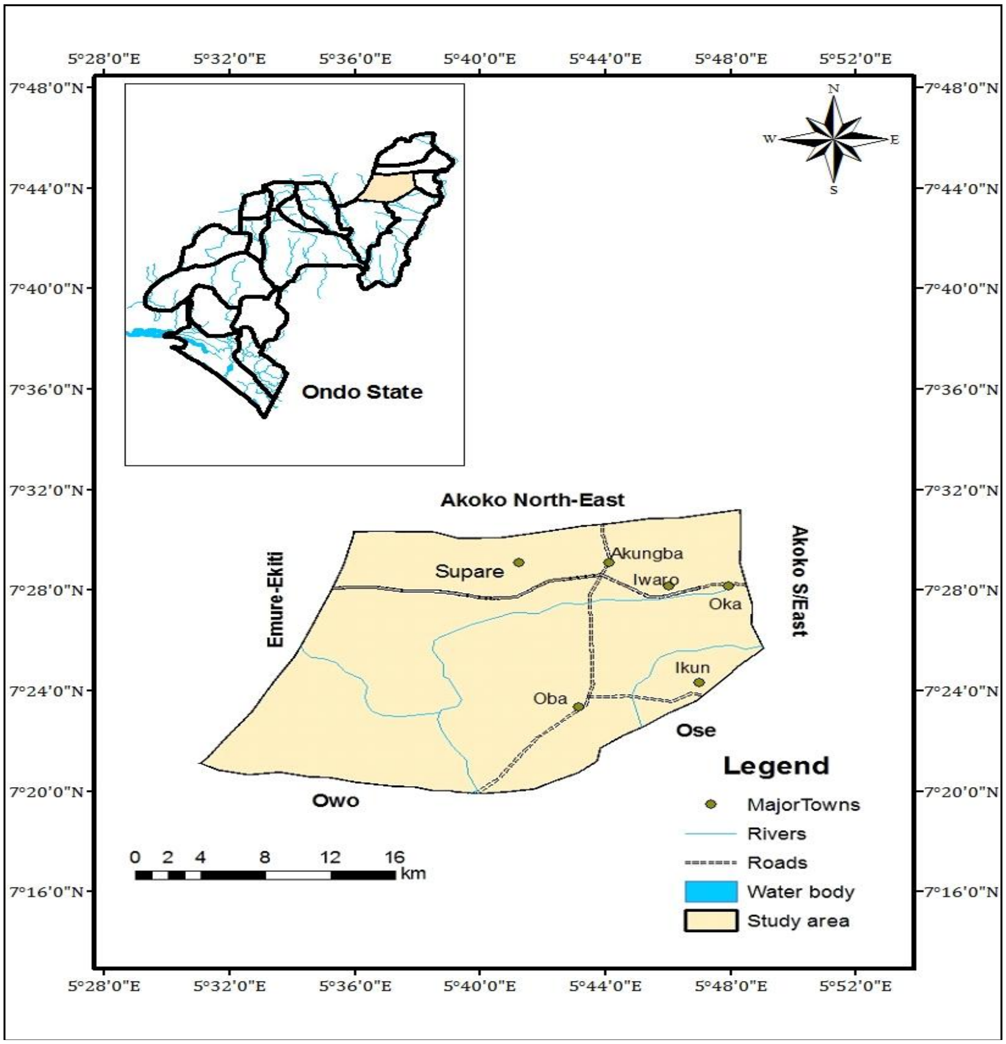


**Fig. 1. Map of the study area**

temperatures range between 21 and 32°C, implying a mean of 26.5°C annually. Mean relative humidity is generally high (about 80%), reaching the peak between May and October [6]. The natural rainforest vegetation of the study area is gradually receding to derived savannah due to human activities. The major crops cultivated in the area include *Theobroma cacao, Cola spp* and *Elaeis guinensis*. Traditional subsistence arable like *Zea mays*, *Dioscorea* spp. and *Manihot spp* are cultivated in the area.

## 2.3 Field Sampling

Based on landform and other physiographic unit observations in the study area, twelve locations were identified: Ose, Ago-Ajayi, Ikun 1, Ikun 2, Iwaro, Oka, Akungba, Oyinmo, Agbanimu, Aiyegunle, Araromi and Ago-Fulani. Seven top soils (0 – 20 cm) were sampled each from the twelve locations in a random pattern. Each sampling point was geo-referenced with Global Positioning System receiver (*Garmin Etrex*). Soil samples collected from each location were analysed for nutrient availability using standard analytical techniques.

## 2.4 Laboratory Analyses

The soil samples were air-dried and passed through a 2 mm sieve. Some portions of the fine earth fractions were further passed through 0.5 mm-mesh sieve for organic carbon and N determination. Particle size distribution was determined by hydrometer method [7]. Soil pH was determined using a glass electrode in 1:2

soil:water ratio [8]. Soil organic carbon (O.C) was determined using Walkley and Black method [9]. Total Nitrogen was determined by Kjeldahl digestion procedure [10]. Available phosphorus was determined using the Bray 1 Method and exchangeable acidity by KCl extraction method [9]. Exchangeable Bases ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$) were leached with 1.0 *N* $NH_4$ OAc (pH 7.0). $Ca^{+}$ and $Mg^{+}$ were determined by atomic absorption spectrophotometer and $Na^{+}$ and $K^{+}$ by flame emission spectrophotometer. Cation exchange capacity (CEC) was determined by ammonium saturation method. Percent base saturation and cation exchange capacity (CEC) were calculated. The mean values of the soil properties for each location were also calculated.

## 2.5 Generation of Fertility Maps

Following the Framework for land evaluation, multi-criteria evaluation technique in GIS was used to model fertility indices of the study area [11]. Based on the extent to which the soil properties meet the nutrient rating index (Table 1), and with respect to the coordinates of the sample locations, the thematic layer was prepared according to the rating scale as very low, low, medium, and high. All the scaled thematic layers were assigned weighted values and integrated into map algebra using Inverse Distance Weighted (IDW) interpolation provided in Arc GIS 9.2 software to produce soil fertility maps of the area (Figs. 3 - 6).

**Table 1. Nutrient rating for soil data interpretation**

| | Very low | Low | Moderate | High | Very high |
|---|---|---|---|---|---|
| Organic carbon (%) | < 0.4 | 0.4 – 1.0 | 1.0 - 1.5 | 1.5 – 2.0 | > 2.0 |
| Total N (%) | < 0.05 | 0.05 – 0.15 | 0.15 – 0.25 | 0.25 – 0.30 | > 0.30 |
| Available P (mg/kg) | < 3.0 | 3.0 – 7.0 | 7.0 – 20.0 | > 20.0 | - |
| Exch. K (cmol/kg) | < 0.2 | 0.2 – 0.3 | 0.3 – 0.6 | 0.6 – 1.2 | > 1.2 |
| Exch. Na (cmol/kg) | < 0.1 | 0.1 – 0.3 | 0.3 – 0.7 | 0.7 – 2.0 | > 2.0 |
| Exch. Ca (cmol/kg) | < 2.0 | 2.0 – 5.0 | 5.0 – 10.0 | 10.0 – 20.0 | > 20.0 |
| Exch.Mg (cmol/kg) | < 0.3 | 0.3 – 1.0 | 1.0 – 3.0 | 3.0 – 8. 0 | > 8.0 |
| CEC (cmol/kg) | <6.0 | 6.0 – 12.0 | 12.0 – 25.0 | 25.0 - 40 | > 40 |
| Base Saturation (%) | 0 - 20 | 20 - 40 | 40 - 60 | 60 - 80 | 90 – 100 |
| **Soil Depth (cm)** | **pH (*Acid*)** | | **pH (*Alkaline*)** | | |
| Very shallow: < 30 | Extremely acid: < 4.5 | | Neutral (6.6 – 7.2) | | |
| Shallow: 30-50 | Very strongly acid: 4.5 - 5.0 | | Very strongly alkaline (> 9.0) | | |
| Moderate: 50 - 100 | Strongly acid: 5.1 - 5.5 | | Strongly alkaline (8.5 – 9.0) | | |
| Deep: > 100 | Moderately acid: 5.6 - 6.0 | | Moderately alkaline (7.9 – 8.4) | | |
| | Slightly acid: 6.1 - 6.5 | | Slightly alkaline (7.3 - 7.8) | | |

*Sources: [1;12;13]*

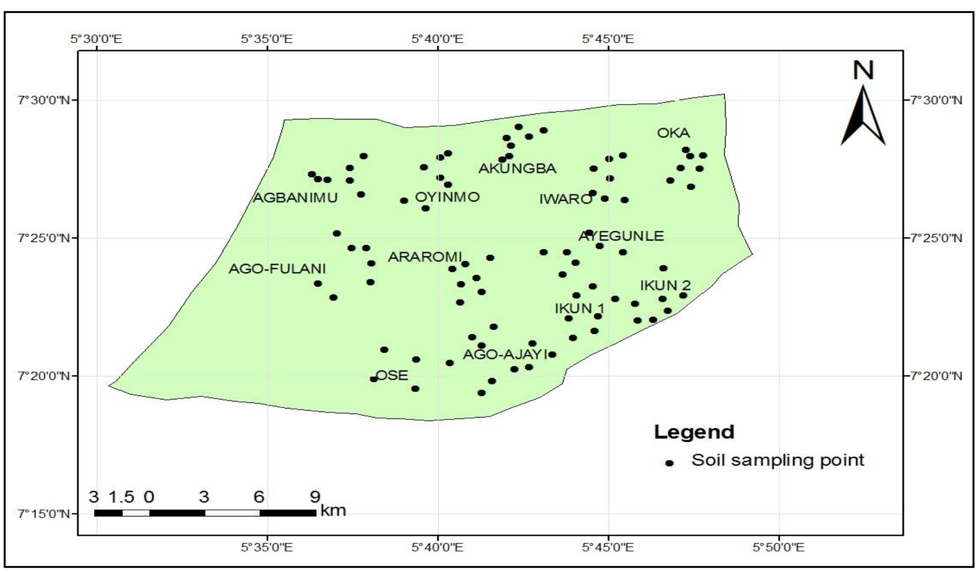


**Fig. 2. Sampling locations for fertility evaluation in the study area**

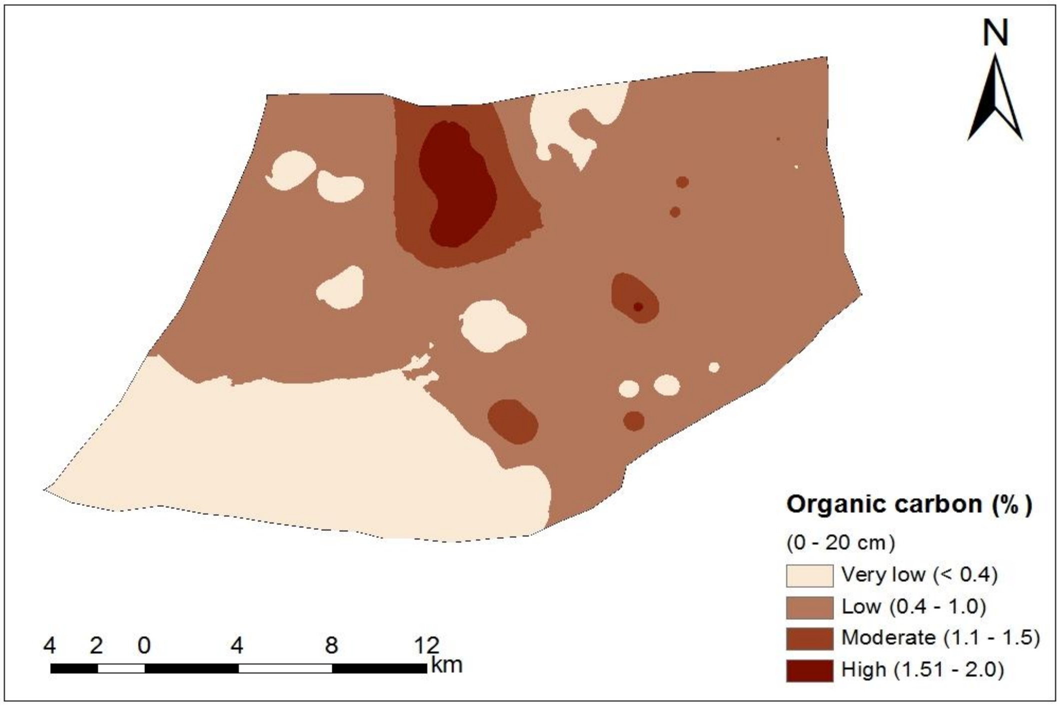


**Fig. 3. Organic carbon distribution across the study area**

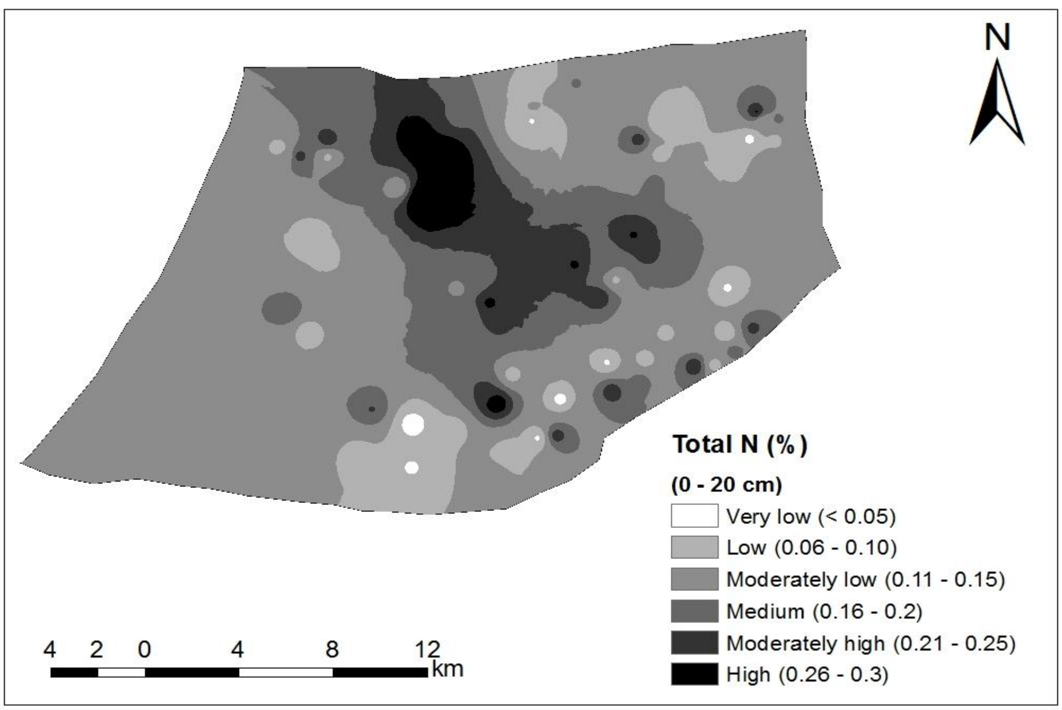


**Fig. 4. Nitrogen distribution in the study area**

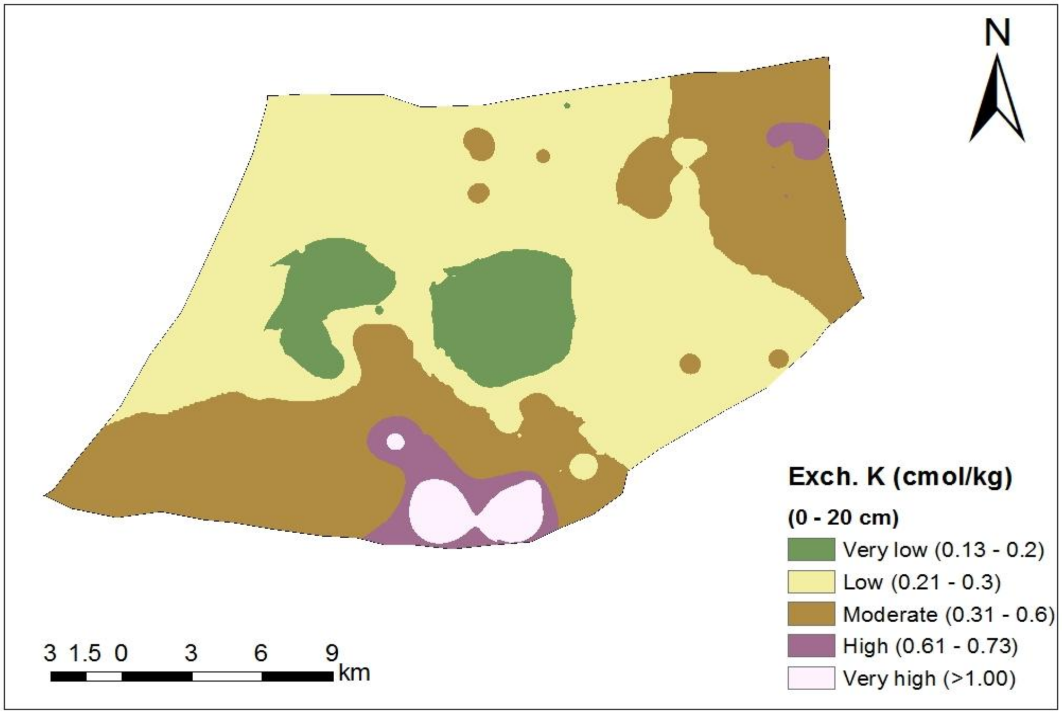


**Fig. 5. Distribution of exchangeable K in the study area**

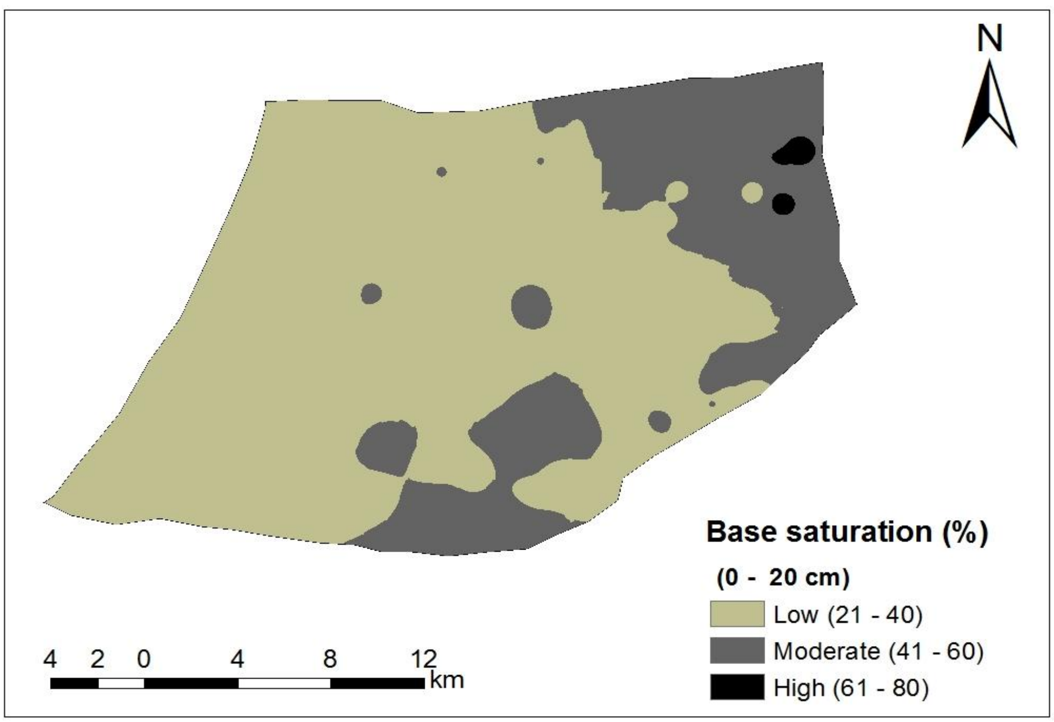


**Fig. 6. The study area showing distribution of base saturation**

## 3. RESULTS AND DISCUSSION

### 3.1 Soil Physical Properties

The particle-size distribution (Table 2) showed that sand particle size fraction accounted for over 65% by weight of the soil particle sizes in the area. Soils of Ose, Ikun 1, Iwaro, Akungba, Oyinmo, Agbanimu, Aiyegunle, Araromi and Ago-Fulani were sandy loam while Ago-Ajayi, Ikun 2 and Oka were sandy clay loam. The high sand particle size fraction in the area may be indicative of its less chemical and physical activeness. Sands have a smaller surface area and tend to be less chemically and physically active [14]. Therefore, good management practices such as the incorporation of organic manure into the soil (especially, farmyard manure) will help bind the soil particles together and thus, improve the aggregate stability of the soils. More so, cultivation of cover crops and minimum tillage will reduce the effects of splash erosion and leaching in the area.

**Table 2. Particle size distribution of soils of the study area**

| S/ point | Sand % | Silt % | Clay % | Texture | S/point | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|---|---|---|---|---|
| | | **OSE** | | | | | **AKUNGBA** | | |
| 1 | 69.50 | 11.50 | 19.00 | SL | 43 | 70.00 | 12.70 | 17.30 | SL |
| 2 | 70.00 | 12.20 | 17.80 | SL | 44 | 66.80 | 17.00 | 16.20 | SL |
| 3 | 71.20 | 15.80 | 13.00 | SL | 45 | 70.80 | 14.20 | 15.00 | SL |
| 4 | 71.50 | 12.50 | 16.00 | SL | 46 | 66.20 | 20.80 | 13.00 | SL |
| 5 | 67.00 | 16.50 | 16.50 | SL | 47 | 66.00 | 18.80 | 15.00 | SL |
| 6 | 70.80 | 17.20 | 12.00 | SL | 48 | 67.50 | 16.50 | 16.00 | SL |
| 7 | 67.20 | 17.80 | 15.00 | SL | 49 | 67.00 | 15.20 | 17.80 | SL |
| **Mean** | **67.20** | **17.80** | **15.00** | **SL** | **Mean** | **67.75** | **16.50** | **17.75** | **SL** |
| | | **AGO-AJAYI** | | | | | **OYINMO** | | |
| 8 | 68.40 | 8.00 | 23.60 | SCL | 50 | 65.70 | 24.30 | 10.00 | SL |
| 9 | 66.00 | 18.80 | 15.00 | SL | 51 | 68.00 | 19.20 | 12.80 | SL |
| 10 | 64.00 | 15.00 | 21.00 | SCL | 52 | 66.20 | 20.80 | 13.00 | SL |
| 11 | 67.20 | 10.00 | 22.80 | SCL | 53 | 70.20 | 18.00 | 11.80 | SL |
| 12 | 64.50 | 11.50 | 24.00 | SCL | 54 | 67.20 | 22.00 | 10.80 | SL |
| 13 | 70.00 | 12.70 | 17.30 | SL | 55 | 66.00 | 18.80 | 15.00 | SL |
| 14 | 65.70 | 10.30 | 24.00 | SCL | 56 | 66.00 | 22.50 | 11.50 | SL |
| **Mean** | **66.50** | **12.30** | **21.10** | **SCL** | **Mean** | **67.00** | **20.80** | **12.20** | **SL** |
| | | **IKUN 1** | | | | | **AGBANIMU** | | |
| 15 | 71.00 | 16.00 | 13.00 | SL | 57 | 69.20 | 17.80 | 13.00 | SL |
| 16 | 70.00 | 16.00 | 14.00 | SL | 58 | 70.00 | 14.40 | 15.60 | SL |
| 17 | 66.00 | 18.80 | 15.00 | SL | 59 | 71.30 | 16.70 | 12.00 | SL |
| 18 | 67.50 | 16.50 | 16.00 | SL | 60 | 68.40 | 18.00 | 13.60 | SL |
| 19 | 66.20 | 20.80 | 13.00 | SL | 61 | 67.20 | 22.00 | 10.80 | SL |
| 20 | 70.20 | 18.00 | 11.80 | SL | 62 | 70.80 | 17.20 | 12.00 | SL |
| 21 | 67.30 | 21.70 | 11.00 | SL | 63 | 67.20 | 17.80 | 15.00 | SL |
| **Mean** | **68.30** | **18.25** | **13.40** | **SL** | **Mean** | **69.15** | **17.70** | **13.15** | **SL** |
| | | **IKUN 2** | | | | | **AIYEGUNLE** | | |
| 22 | 64.00 | 14.00 | 22.00 | SCL | 64 | 66.80 | 15.00 | 18.20 | SL |
| 23 | 69.00 | 13.20 | 17.80 | SL | 65 | 71.00 | 16.00 | 13.00 | SL |
| 24 | 68.40 | 8.00 | 23.60 | SCL | 66 | 70.00 | 16.00 | 14.00 | SL |
| 25 | 65.00 | 13.20 | 21.80 | SCL | 67 | 68.40 | 18.00 | 13.60 | SL |
| 26 | 66.80 | 15.00 | 18.20 | SL | 68 | 64.00 | 19.20 | 16.80 | SL |
| 27 | 67.00 | 10.00 | 23.00 | SCL | 60 | 66.00 | 18.80 | 14.20 | SL |
| 28 | 64.50 | 11.50 | 24.00 | SCL | 70 | 70.00 | 14.40 | 15.60 | SL |
| **Mean** | **66.38** | **12.12** | **21.50** | **SCL** | **Mean** | **68.00** | **16.77** | **15.02** | **SL** |
| | | **IWARO** | | | | | **ARAROMI** | | |
| 29 | 70.00 | 16.00 | 14.00 | SL | 71 | 70.50 | 13.00 | 16.50 | SL |
| 30 | 69.70 | 18.30 | 12.00 | SL | 72 | 69.70 | 14.30 | 16.00 | SL |
| 31 | 71.00 | 16.00 | 13.00 | SL | 73 | 69.00 | 16.00 | 15.00 | SL |
| 32 | 69.70 | 14.30 | 16.00 | SL | 74 | 70.20 | 15.00 | 14.80 | SL |

| S/ point | Sand % | Silt % | Clay % | Texture | S/point | Sand % | Silt % | Clay % | Texture |
|---|---|---|---|---|---|---|---|---|---|
| 33 | 70.00 | 16.00 | 14.00 | SL | 75 | 68.80 | 14.00 | 17.20 | SL |
| 34 | 71.50 | 15.00 | 13.50 | SL | 76 | 68.20 | 10.80 | 21.00 | SCL |
| 35 | 66.00 | 18.80 | 15.00 | SL | 77 | 70.00 | 15.00 | 15.00 | SL |
| **Mean** | **69.70** | **16.34** | **13.93** | **SL** | **Mean** | **69.49** | **14.01** | **16.50** | **SL** |
| | | **OKA** | | | | | **AGO-FULANI** | | |
| 36 | 67.00 | 11.00 | 22.00 | SCL | 78 | 65.50 | 11.50 | 23.00 | SCL |
| 37 | 64.70 | 11.00 | 24.30 | SCL | 79 | 71.00 | 13.00 | 16.00 | SL |
| 38 | 67.20 | 10.00 | 22.80 | SCL | 80 | 66.80 | 15.00 | 18.20 | SL |
| 39 | 58.80 | 13.00 | 28.20 | SCL | 81 | 67.00 | 13.00 | 20.00 | SCL |
| 40 | 58.50 | 16.50 | 25.00 | SCL | 82 | 66.00 | 18.80 | 14.20 | SL |
| 41 | 67.20 | 10.00 | 22.80 | SCL | 83 | 66.00 | 15.80 | 18.20 | SL |
| 42 | 64.00 | 12.00 | 24.00 | SCL | 84 | 70.00 | 14.40 | 15.60 | SL |
| **Mean** | **63.91** | **11.92** | **24.16** | **SCL** | **Mean** | **67.47** | **14.50** | **17.89** | **SL** |

*Key: SL – Sandy loam; SCL – Sandy clay loam;*

### 3.2 Soil Fertility Status

Organic carbon contents (Fig. 3 were relatively low; varying from 0.43 to 0.95 across the study area except a small portion (Oyinmo) that recorded relatively high content (1.61) possibly because of higher accumulation of organic matter content consequent upon higher vegetal cover on the soil surface. The generally low value of organic carbon contents in the soils could be attributed to high rate of decomposition and mineralization of organic matter consequent upon the prevalent high temperature, low vegetal cover, and poor soil management sometimes by burning of crop residues, intense cultivation and seasonal bush burning, which is a common practice in the area. Therefore, there is need for the farmers in the area to adopt cultural practices such as minimum tillage operation, mulching, organic manuring, etc that will encourage the return and incorporation of plant/crop residues into the soil to increase the level of soil organic matter.

The percentage total nitrogen values (Fig. 4) were low (0.09 – 0.13%), covering about 66% of the study area while 24% of the area was medium (0.15 – 0.25). The larger portion of the study area under the influence of nitrogen deficits may be attributed to volatilization especially, under high temperature regimes, denitrification processes and massive crop removal without replenishment common in the area.

The exchangeable bases ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$) were generally low in all the locations. However, the exchangeable $K^{+}$ values in Ose (0.73 cmol/kg) and Oka (0.58 cmol/kg) were high (Fig. 5). The low values of exchangeable bases in the study area may be connected to the poor colloidal behaviour of the soils. The low content of available phosphorus in the soils may be adduced to the low cation exchange capacity of the soil biological fixation.

Base saturation provides indication of how closely nutrient status approaches potential fertility in soil. Clays have higher base saturation, higher surface area and are more physically and chemically active than sands [14]. Therefore, the generally low base saturation may be consequent upon the type and low clay particle size fraction in the area (Fig. 6).

## 4. CONCLUSION

The study assesses the fertility status of selected surface soils in Ondo State of Nigeria for sustainable crop production. Results revealed high sand fraction in the area. Soil reaction varied from slightly acidic to neutral. Percent organic carbon was low to moderate. The results generally revealed low nutrient status of the soils.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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