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# Assessment of Fertility Status of Some Pedons on Basement Complex in the Forest Ecological Zone of Southwestern Nigeria

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**Abstract:** Soil test-based fertility management is indispensable for sustainable soil management. This investigation was conducted to evaluate the soil fertility status of selected pedons formed on the basement complex in Oyo State, Southwestern Nigeria. A total of 37 soil samples were collected at depth of 0-30 cm and analysed for routine parameters following standard procedures. The statuses of the following parameters were determined: texture, organic carbon, pH, N, K, Ca, Mg, Na, Fe, Cu, Zn, Cu and Mn. The observed data revealed that the sand content was 71±10.72%, silt: 8±4% while clay was 21±6.42%. The textural class for the soils fall within sandy loam, sandy clay loam and loamy sand. The soil was moderately acidic (pH: 6.02±0.09). The organic carbon (10.9±1.59%) total N (0.16±0.02%), K (0.98±0.013 Cmol $kg^{-1}$), Ca (4.84±0.43 Cmol $kg^{-1}$) and P (11.80±1.91 mg $kg^{-1}$) were low to moderate in status. Based on nutrient index classification, the Cu content (7.08±0.73 mg $kg^{-1}$), Zn (11.46±0.52 mg $kg^{-1}$) and Na (0.63±0.06 Cmol $kg^{-1}$) exhibited moderate status. In addition, Mn (104.49±3.26 Cmol $kg^{-1}$) and Mg (3.2±0.16 Cmol $kg^{-1}$) were high in status. Furthermore, available Fe (143.82±5.61 mg $kg^{-1}$) was very high in status. The results showed that most of the nutrient elements were moderate to high in the soils. Therefore, proper nutrient management strategy should be adopted in order to maintain optimal yield of crops in the area.

**Key words:** Soil fertility, nutrient index, basement complex, morphological, physical and chemical soil properties, sandy loam

## INTRODUCTION

Land is an essential resource particularly for agrarian society like Nigeria. It is also a scarce resource with a carrying capacity that can be stretched only to a limited extent with the help of technology. As population grows rapidly, imbalance between supply for land resource and demand for it emerges. The consequences of imbalanced relationship are brought about either by natural or human factors such as deforestation, land degradation, soil erosion and conflict over land uses as a result of limited care of the resources and lack of awareness of the long-term effects (Bezuayehu *et al*., 2002).

Agricultural lands have expanded to meet the additional food demand for an increasing population. Expansion of agriculture has led to the cultivation of problem-prone soils including soils that have severe limitations as acidity, salinity, sodicity and other low fertility characteristics. Soil is an indispensable component of land resources. Soil is a vital natural resource and must be well managed for sustainable agricultural production. Sound management of cropping systems requires knowledge of physical and chemical status of soils and crops during the growing season for profitable production. Nigeria is one of the Sub Saharan African countries where low levels of agricultural productivity are the key cause of hunger. Decades of farming without replenishment of soil nutrients through applications of fertilizer and manure have stripped the soils of vital nutrients needed to support plant growth.

Decline in soil fertility is becoming one of the major challenges for establishing sustainable agriculture in Sub Saharan African countries (Muchena, 2008). This is worsened by changes in land use, alteration of the ecosystem and susceptibility of the land to external pressure which significantly affect soil physical, chemical and biological properties. Due to these trends, agricultural productivity per unit of land is declining through time and food production could not keep pace with population growth.

Mostly, soil fertility parameters are influenced by rugged topography, steep slopes and land mosaic which result in exacerbating soil erosion rate through its

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morphological characteristics (Azene, 1997; Tekatay, 2000). The suitability of soil for crop production is based on the quality of the soil's physical, chemical and biological properties. Soil physical and chemical properties are necessary to define and evaluate soil fertility status under given condition of management.

Recent interest in evaluating the quality of our soil resource has therefore been simulated by increasing awareness that soil is a critically important component of the earth's biosphere, functioning not only in the production of food and fibre but also in the maintenance of local, regional and worldwide environmental quality (Wakene, 2001). On the other hand, feeding the ever-increasing human population is most challenging in areas like Southwestern Nigeria where there is a very high population density.

Despite its immense contribution to agricultural production and food security, data on soil fertility in Nigeria is largely out of date at a national level and locally is fragmented and difficult to access. Therefore, this study was undertaken to provide basic information on the present morphological, physical and chemical characteristics of the study area with the aim of relating such data to fertility status of the soils. These data will serve as baseline information towards sustainable crop production in the area.

## MATERIALS AND METHODS

**The study site:** The study area is located between Alaho and Olokuta village in Oluyole Local Government area of Oyo State Nigeria. It is close to the Southern boundary of Oyo Ogun States. It is defined within longitude 3°51 and 3°52'E and latitudes 7°9 and 7°11'N of the equator.

**Soil sampling:** The surface soil samples (0-30 cm depth) were collected from the study area using a stainless steel soil auger. A total of 37 surface samples were randomly collected. At each location, soil morphology was described.

**Laboratory analysis:** The soil samples were processed and analysed in the laboratory for physical and chemical properties. Particles size analysis was performed by the method of Gee and Bauder (1986). Soil pH was determined at the soil to water ratio of 1:1. Exchangeable bases and available phosphorus were extracted using the methods described by Udo *et al*. (2009). Exchangeable potassium and sodium were read with the aid of flame emission spectroscopy while calcium magnesium and micronutrients were read with the aid of Atomic Absorption Spectroscopy (AAS). Total organic carbon was determined by wet oxidation in acidified dichromate. Total nitrogen determination was by kjeldahl distillation and titration.

Table 1: Rating chart of nutrient index

| Nutrient index | Values |
|---|---|
| High | >2.33 |
| Low | <1.67 |
| Medium | 167-2.33 |

Ramamoorthy and Bajaj (1969)

**Statistical analysis:** Descriptive statistics (mean, range, standard deviation, standard error and coefficient of variation) of the soil parameters were computed using the Minitab 17 package. The coefficient of variation was ranked according to the procedure of Aweto (1982) where CV<25% = low variation, CV>25 = 50% = moderate variation, CV>50% = high variation. The nutrient index was determined by the formula given by Ramamoorthy and Bajaj (1969). Nutrient Index (NI) was determined by equation:

$$NI = (N_L X_1 + N_M X_2 + N_H X_3)/N_T$$

where, $N_L$, $N_M$ and $N_H$ indicates number of samples falling in low, medium and high classes of nutrient status, respectively while $N_T$ means total number of samples analysed for a given area. Interpretation was done as value given by Ramamoorthy and Bajaj (1969) as shown in Table 1.

## RESULTS AND DISCUSSION

**Texture:** The stability of soil is a function of clay content. Stable aggregates can be formed only in soils containing clay that will flocculate. Chemical reactions which control fertility status of soils depend on functional groups such as carboxyl groups and phenolic hydroxyl groups that are in turn dependent on nature and properties of the charged surfaces on the clay particle.

The sand of the soil samples were ranged from 492-866% with mean value of 713.95% and that of silt were 40-220% with mean value of 75.14% while the range of clay were 88-388% with a mean of 210.38%. The Coefficient of Variation (CV) between the soil samples were 9.13% for sand, 32.28% for silt and 18.50% for clay (Table 2).

**pH:** The pH of the study area varied from 4.72-7.56 with mean of 6.02 (Table 3). This indicates moderate acidic to neutrality. The CV (9.30%) of soil pH is low among soil samples (Table 3).

Table 2: Physical properties of soil

| | Soil separates (g cm⁻3) | | | |
|---|---|---|---|---|
| Descriptive statistics | Sand | Silt | Clay | Silt:Clay |
| Mean | 713.95 | 75.14 | 210.38 | 0.43 |
| Standard deviation | 65.16 | 24.25 | 39.01 | 0.31 |
| Standard error | 10.72 | 3.99 | 6.42 | 0.05 |
| Minimum | 492 | 40 | 88 | 0.16 |
| Maximum | 866 | 220 | 388 | 1.64 |
| CV % | 9.13 | 32.28 | 18.50 | 72.10 |

Table 3: Some chemical properties of soil

| | Chemical parameters | | | | |
|---|---|---|---|---|---|
| Descriptive statistics | pH | Total N (%) | Organic C (g $kg^{-1}$) | Available P (mg $kg^{-1}$) | C/N ratio |
| Mean | 6.02 | 0.158 | 10.9 | 11.80 | 82.27 |
| Standard deviation | 0.56 | 0.130 | 9.66 | 11.64 | 42.88 |
| Standard error | 0.09 | 0.020 | 1.59 | 1.91 | 7.05 |
| Minimum | 4.72 | 0.030 | 1.47 | 6.14 | 18 |
| Maximum | 7.56 | 0.450 | 37.8 | 66.23 | 184 |
| CV% | 9.30 | 82.280 | 88.62 | 98.60 | 52.12 |

Table 4: Chemical properties of exchangeable bases

| | Cation exchangeable bases (Cmol $kg^{-1}$) | | | |
|---|---|---|---|---|
| Descriptive statistics | Na | k | Ca | Mg |
| Mean | 0.63 | 0.980 | 4.84 | 3.20 |
| Standard deviation | 0.36 | 0.081 | 2.59 | 0.96 |
| Standard error | 0.06 | 0.013 | 0.43 | 0.16 |
| Minimum | 0.00 | 0.810 | 2.18 | 0.95 |
| Maximum | 1.10 | 1.130 | 13.90 | 4.22 |
| CV % | 57.14 | 8.270 | 53.51 | 30.00 |

**Organic Carbon (OC):** The organic carbon content varied from 1.47-37.8 g $kg^{-1}$ with mean value of 10.90 g $kg^{-1}$. It indicates that the OM content was relatively low to moderate in status. Organic carbon showed high variability (88.62%) among the soil samples (Table 3).

**Total Nitrogen (TN):** The total N content was ranged from 0.03-0.45% with a mean value of 0.16% indicating medium content of TN. High variability (82.28%) in total N was observed among the sampled soils (Table 3).

**Phosphorus (P):** The P ranged from 6.14-66.23 mg $kg^{-1}$ with a mean value of 11.80 mg $kg^{-1}$. This showed a high status of available P. Phosphorus showed a high CV (98.6%) among the tested soil. The available P content was found to be very low (Table 3).

**Potassium (K):** The K content ranged from 0.81-1.13 Cmol $kg^{-1}$ with a mean value of 0.98 mg $kg^{-1}$. This suggests medium status of K. Potassium showed low variability (8.27%) among the analysed soil samples (Table 4).

**Calcium (Ca):** The Ca content ranged from 2.18-13.90 Cmol $kg^{-1}$ with mean value of 4.84 Cmol $kg^{-1}$. Calcium showed moderate variability of 53.51% (Table 4).

Table 5: Chemical properties of micronutrients

| | Micronutrients (mg $kg^{-1}$) | | | |
|---|---|---|---|---|
| Descriptive statistics | Fe | Cu | Zn | Mn |
| Mean | 143.82 | 7.08 | 11.46 | 104.49 |
| Standard deviation | 34.09 | 4.44 | 3.17 | 19.84 |
| Standard error | 5.61 | 0.73 | 0.52 | 3.26 |
| Minimum | 97.1 | 1.9 | 6.4 | 69.4 |
| Maximum | 210.3 | 14.3 | 21 | 161.1 |
| CV % | 23.7 | 62.71 | 27.66 | 18.99 |

Table 6: Nutrient indices of sampled soils

| | Distribution of samples (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| Parameters | Very low | Low | Medium | High | Very high | NI | Remarks |
| N | 62 | 21 | 3 | Nil | 14 | 1.31 | Low |
| P | 86 | 8 | 3 | Nil | 3 | 1.09 | Low |
| K | Nil | Nil | Nil | 14 | 86 | 1.00 | Low |
| Ca | 3 | 89 | Nil | Nil | 8 | 1.16 | Low |
| Mg | Nil | 13 | 3 | 35 | 49 | 2.74 | High |
| Na | 16 | 24 | 8 | 11 | 41 | 2.20 | Moderate |
| OC | 62 | 19 | 6 | 8 | 5 | 1.32 | Low |
| Cu | 27 | 22 | 10 | 19 | 22 | 1.84 | Moderate |
| Mn | Nil | Nil | 40 | 49 | 11 | 2.60 | High |
| Fe | Nil | Nil | 35 | 35 | 30 | 2.65 | High |
| Zn | Nil | 14 | 47 | 33 | 6 | 2.11 | Moderate |

NI = Nutrient Index, OC = Organic Carbon

**Magnesium (Mg):** The magnesium content ranged from 0.95-4.22 Cmol $kg^{-1}$ with a mean value of 3.20 Cmol $kg^{-1}$. Magnesium showed low variation (30%) among the observed samples (Table 4).

**Micronutrients:** The available Fe content ranged from 97.10-210.30 mg $kg^{-1}$ with mean value of 143.82 mg $kg^{-1}$. Generally, available Fe status was high. Available Fe showed low variability (23.7%) among the soil samples (Table 5).

The available Zn content ranged from 6.4-21 mg $kg^{-1}$ with mean value of 11.46 mg $kg^{-1}$. The available Zn showed low variability (27.66%) among the soil samples. The available Cu content varied from 1.90-14.30 mg $kg^{-1}$ with the mean value of 7.08 mg $kg^{-1}$ . This indicates low status of Cu. Fairly high variability (62.71%) in available Cu was recorded among the soil samples (Table 5).

The available Mn content ranged from 69.40-161.10 mg $kg^{-1}$ with mean value of 104.49 mg $kg^{-1}$ high status of available Mn. The Mn showed a low variability (19%) among the studied soil samples. However, the concentration of available micronutrients was in the following order: Fe>Mn>Zn>Cu.

**Nutrient index classiffication:** Based on the Nutrient Index; N, P, K, Ca and OC were of low status; Na, Cu and Zn were of moderate status while Mg, Mn and Fe were off high status (Table 6 and 7).

Table 7: Critical limits for interpreting levels of analytical chemical parameters

| Parameters | Low | Medium | High |
|---|---|---|---|
| CEC ($Cmol\ kg^{-1}$) | <6.00 | 6.0-12.0 | >12.0 |
| Org. carbon ($g\ kg^{-1}$) | <10.0 | 10.0-15.0 | >15.0 |
| TN ($g\ kg^{-1}$) | <00.1 | 0.1-0.2 | >0.2 |
| Available P ($mg\ kg^{-1}$) | <10.00 | 10.0-20.0 | >20.0 |
| pH | <4.0>7.5 | 4.5-5.5 | 5.6-7.0 |

(Esu, 1991)

**Soil texture:** Soil texture affects the soil sustainability. It affects absorption of nutrients, microbial activities, the infiltration and retention of water, soil aeration, tillage and irrigation practices (Gupta, 2004). The texture of the study area was dominantly sandy loam with very high sand content (>70%). The silt/clay ratios were greater than 0.42, indicating that the soils were relatively young with high degree of weathering potential. Young parent materials usually have silt/clay ratio above 0.25 (Asamoa, 1973). The high silt/clay ratio could be due to the parent materials of the soils sampled which were predominantly of granite gneiss origin.

**Soil colour:** Soil colour is an important property and is especially useful as a guide to the extent of mineral weathering, the amount of organic matter and the state of aeration in the soil. Soil colour reflects on the transformation and translocation occurred in the soil to chemical, biological and physical attributes (Ponnamperuma and Deturck, 1993). It shows water drainage, aeration and organic matter content in soil. In the majority of the study area, grayish brown (10YR 6/1) colour was observed indicating well drained soil with deep water table.

**Soil structure:** Soil structure refers to the pattern of spatial arrangement of soil particles in a soil mass (Brady and Weil, 2004). In the majority of the area sub angular blocky structure was observed. Soil structure is granular in the surface horizon and prismatic in the rest of the soil profile. Surface horizons are non-sticky and non-plastic. The granular structure at the surface could be attributed to the dispersal effect of sodium.

**Soil pH:** Soil pH is important chemical parameter of soil that affects nutrient availability (Brady and Weil, 2004). The pH of the soil varied from 4.72-7.56 with average value of 6.02 indicating moderate acidity. The availability of various nutrients for plants (maize, yam, etc.) may be reduced. The low value of soil pH observed in some sampled soils could be due to loss of base forming cations down the soil profiles. Therefore, periodically agricultural lime incorporation is imperative for improvement of soil pH.

**Organic matter:** Organic matter is an important source of plant essential nutrients after their decomposition by microorganisms. It supplies plant nutrient improve the soil structure, water infiltration and retention feeds soil micro flora and fauna and retention and cycling of applied fertilizer (Johnson, 2007). The organic carbon had average value of 10.90 $g\ kg^{-1}$. It indicates that the organic matter content was low (Table 6). Thus, the low OC content of the soil could be due to intensive agricultural activities that deplete soil organic matter content.

**Total nitrogen:** Nitrogen is a macronutrient that is required by crops in large amounts and is frequently deficient in agricultural soils, limiting crop production. Nitrogen is taken by plants in greatest quantity next to carbon, oxygen and hydrogen but in the tropics for crop production it is one of the most deficient elements (Mesfin, 1998). Average N content in sampled soil was 0.16%, indicating low content of TN according to Landon (2014). The TN content is not satisfactory. Therefore, this soil require routine basal nitrogen input (between 60-90 kg N/ha.

**Available phosphorus:** Phosphorus is the master key to agriculture. The growth of both cultivated and uncultivated plants is limited by availability of P in the soils (Foth and Ellis, 1997). The surface soils have average available P content of 11.80 $mg\ kg^{-1}$ indicating low content of P in the sampled soils (Table 6). However, the low content of available P in the soils was consistent with the high sand content of the soil. The observed low content of available P could be attributed to fixation by Ca content as Calcium Phosphate (Ca-P).

**Exchangeable cations:** Next to N and P, potassium is the third most important essential element that limits plant productivity. The average content of K was 0.98 $mg\ kg^{-1}$ indicating low content of the nutrient element.

Calcium is a secondary nutrient important for cell division in plants. In overall low status of extractable Ca (4.84 $Cmol\ kg^{-1}$) was observed among the soil samples. Calcium and Mg are the dominant cations in the sampled soils (Table 4).

Magnesium is a water soluble cation necessary for chlorophyll pigment in green plants (Mahajan and Billore, 2014). The Mg content had averaged of 3.30 $Cmol\ kg^{-1}$. This revealed high content of extractable Mg (Table 6).

The Ca:Mg ratio is used as a measure to evaluate the potential impact of Ca on the uptake of Mg and P. On average, the Ca:Mg ratio for the sampled soil is >5:1 and this reduced the availability of P in the sampled soils. This observation agrees with the earlier work done by Landon (2014) which reported that a Ca:Mg ratio >5:1 may reduce the availability of both Mg and P.

**Micronutrients**

**Iron:** is an essential micronutrient for almost all living organisms because of it plays critical role in metabolic processes such as DNA synthesis respiration and photosynthesis (Rout and Sahoo, 2015). In overall, available Fe status was high with average value of 143.82 mg $kg^{-1}$ (Table 5). The high content of extractable Fe is consistent with the acidic nature of this soil as the solubility of Fe increases at low pH. There may have high possibility for stress of Fe toxicity as well deficiency of antagonistic elements in plants. Therefore, nutrients like K, P, etc. should be applied in adequate amount for reducing Fe toxicity stress in plants.

**Zinc:** is essential for several biochemical processes in plants such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation and the maintenance of membrane integrity (Havlin *et al*., 2010). The mean value of 11.46 mg $kg^{-1}$ was recorded for Zn in the sampled soil indicating medium status of the element. There may be possibility of Zn deficiency symptoms like white bud in maize and khaira disease in rice, etc. Therefore, different organic and inorganic sources of Zn should be applied in the field regularly to reduce Zn stress in plants.

**Copper:** is also important micronutrient for plants and required for lignin synthesis and acts as a constituent of ascorbic acid, oxidase, phenolase and plastocyanin (Havlin *et al*., 2010). The content of Cu in the sampled soils was 7.08 indicating medium status of Cu (Table 5). Therefore, Cu management strategy should be adopted to balance the Cu content in the soil.

Generally, the distribution of available Cu and Zn decreased consistently from the surface to the subsurface layers. These results were in agreement with earlier reports of Alemayehu (2007).

**Manganese:** Plays an important role in oxidation and reduction processes in plant (Mousavi *et al*., 2011). The Mn had average value of 104.49 mg $kg^{-1}$ in the sample soil indicating high content of the element. There may have high possibility for stress of Mn toxicity as well deficiency of antagonistic elements in plants. Therefore, nutrients like K, P, organic manure etc should be applied in adequate amount for reducing Fe toxicity stress in plants.

## CONCLUSION

The data on soil fertility status of the study area could serve as baseline information towards achieving food security within and beyond the area. In general the soils were acidic in reaction. The organic carbon content varied from 1.4-37.8 g $kg^{-1}$ with mean of 10.9 g $kg^{-1}$ while total N, available P and exchangeable K had mean of 0.16, 11.8 and 0.98 mg $kg^{-1}$, respectively. The micro-nutrients were generally moderately in the soils. Thus, proper nutrient management strategy should be adopted especially for the concerned nutrients. Considering the low to moderate status of soil organic matter manure or compost incorporation, crop residue retention, green manuring, etc. are suggested for its improvement.

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