Assessment Of Fertility Status Of Some Pedons On Basement Complex In The Forest Environment 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 of 89ha land in Oyo state, Southwestern Nigeria. Random sampling technique was employed with aid of soil auger and total of 37 soil samples were collected at depth of 0 – 30cm. following the standard procedures employed in soil laboratory, the collected samples were analysed to evaluate their texture, organic carbon, pH, N, K, Ca, Mg, Na, Fe, Cu, Zn, Cu and Mn. The observed data revealed that soil was grayish brown in colour and sub-angular blocky in structure. The Sand content was 71±10.72%, Clay - 21±6.42% while Silt was 8±4%. The textural class for the soils falls within sandy loam, sandy clay loam and loamy sand. The soil was moderately acidic in 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), Ca (4.84±0.43Cmol/kg) and P (11.80±1.91mg/kg); were low in status. The Cu content (7.08±0.73mg/kg), Zn (11.46±0.52 mg/kg) and Na (0.63±0.06Cmol/kg) exhibited medium in status. In addition, Mn (104.49±3.26) and Mg (3.2±0.16Cmol/kg) were high in status. Furthermore, available Fe (143.82±5.61 mg/kg) was very high in status. Therefore, proper nutrient management strategy should be adopted in order to ensure optimal yield of crops within the region.

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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 (Buzuayehu 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-proned 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 (Benton, 2003). Sound management of cropping systems requires knowledge of physical and chemical status of soils and crops during the growing season for profitable production (Benton, 2003).

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 (IFPRI, 2010).

A decline in soil fertility is becoming one of the major challenges for establishing sustainable agriculture in sub Saharan African countries (Muchena, 2008) This is enhanced 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 (Roy et al., 2003).

Mostly, soil fertility parameters are influenced by rugged topography, steep slopes and land mosaic which results in exacerbating soil erosion rate through its morphological characteristics (Azene, 1997; Demel, 2001). 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 critically important component of the earths biosphere, functioning not only in the production of food and fiber, but also in the maintenance of local, regional, and worldwide environmental quality (Negassa, 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 (IFPRI, 2010). Therefore, this study was undertaken to provide basic information on the present morphological, physical and chemical characteristics of the study area with 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 approximately 89ha located between Alaho an 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 3^0 51′ and 3^0 52′ E; and latitudes 7^0 9′ and 7^0 11′ N of the equator.

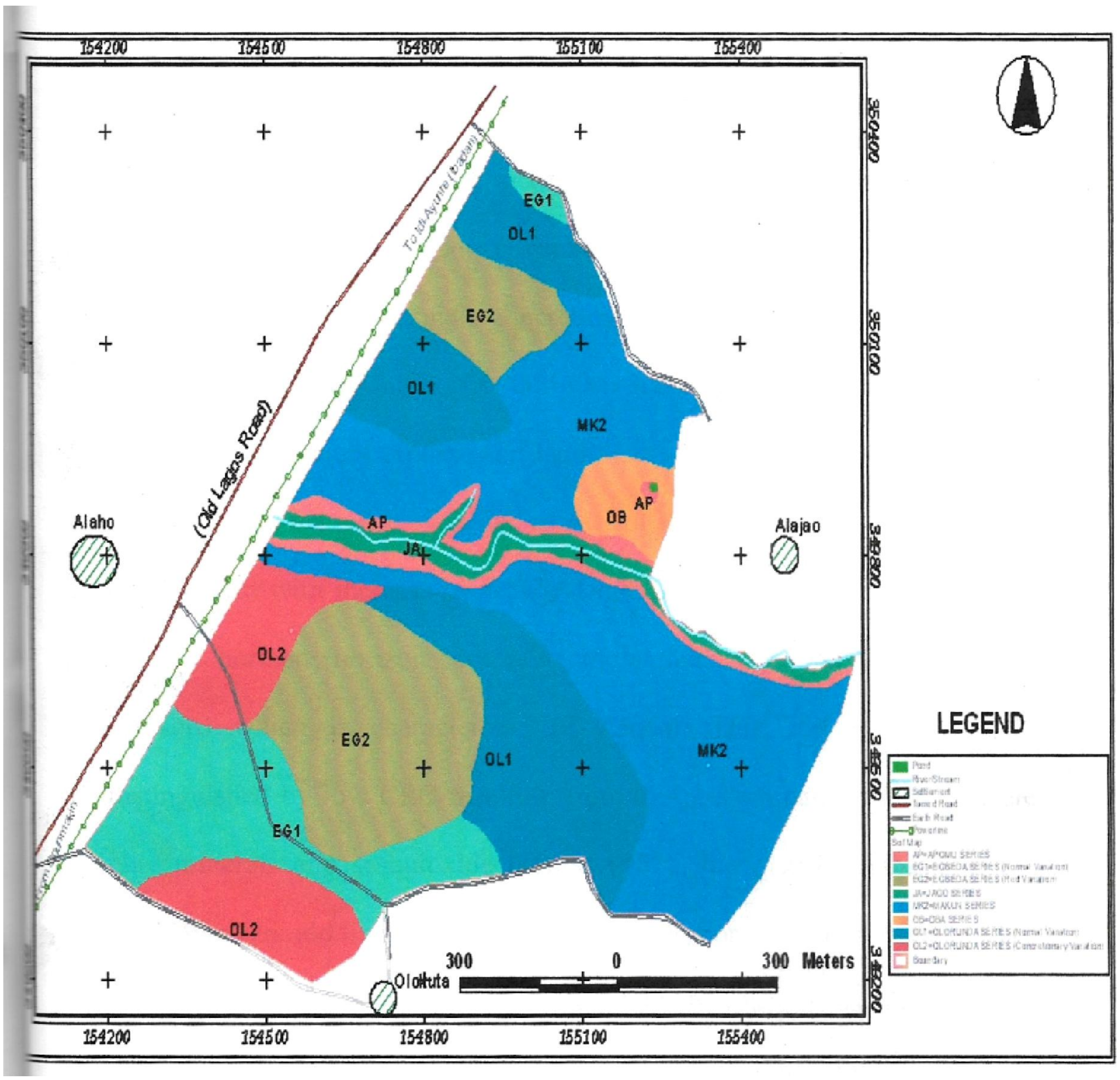

Figure 1: Soil map of the study area

Soil Sampling

The surface soil samples (0 – 30cm depth) were collected from the study area using Soil sampling auger. The random method based on the variability of the land was used to collect soil samples. Total of 37 samples were collected. At each location, soil morphology was recorded.

Laboratory Analysis

The soil samples were processed and analysed in the laboratory or physical and chemical properties. Particles size analysis was performed by the method of Gee and Bauder (1996). Soil pH was determined at the soil to liquid ratio of 1:1 in H_2O. Exchangeable bases and available Phosphorus were extracted using the methods described by Udo et al., (2009). 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). Available Phosphorus was determined calorimetrically. Total organic Carbon was determined by wet oxidation in acidified dichromate. Total Nitrogen determination was by Kjedahl distillation and titration.

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). Map of the study area was prepared using Arc software.

Nutrient Index (N.I)

$= (N_L \text{ X } 1 + N_M \text{ X } 2 + N_H \text{ X } 3) / N_T$

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 as shown in Table 1.

Table 1. Rating Chart of Nutrient Index

S/N	Nutrient Index	Value
1	High	>2.33
2	Low	< 1.67
3	Medium	1.67 – 2.33

Results

Texture

The Sand of the soil samples were ranged from 492% to 866% with mean value of 713.95% and that of Silt were 40% to 220% with mean value of 75.14% while the range of Clay were 88% to 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).

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

pH

The pH of the study area varied from 4.72 to 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).

Organi Carbon (OC)

The organic carbon content varied from 1.47% to 37.8 with mean value of 10.9%. It indicates that the OM content was relatively low. 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% to 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 was ranged from 6.14 to 66.23mg/kg with a mean value of %11.80. This show 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).

Table 3: Some Chemical Properties of Soil

Descriptive Statistics	Chemical parameters				
	pH	Total N (%)	Organic C (%)	Available P (mg/kg)	C/N ratio
Mean	6.02	0.158	10.9	11.80	82.27
Standard Deviation	0.56	0.13	9.66	11.64	42.88
Standard Error	0.09	0.02	1.59	1.91	7.05
Minimum	4.72	0.45	1.47	6.14	18
Maximum	7.56	0.03	37.8	66.23	184
CV%	9.30	82.28	88.62	98.60	52.12

Potassium (K)

The K content was ranged from 0.81 to 1.13Cmol/kg with a mean value of 0.98mg/kg. This suggests medium status of K. Potassium showed low variability (8.27%) among the analysed soil samples (Table 4).

Calcium (Ca): The Ca content was ranged from 2.18 to 13.90Cmolkg with mean value of 4.84Cmol/kg. Calcium showed moderate variability of 53.51% (Table 4).

Magnesium (Mg)

The magnesium content was ranged from 0.95 to 4.22Cmol/kg with a mean value of 3.2Cmol/kg. Magnesium showed low variation (30%) among the observed samples (Table 4).

Table 4: Chemical analysis of Exchangeable Bases

Descriptive Statistics	Cation Exchangeable Bases (Cmol/kg)			
	Na	k	Ca	Mg
Mean	0.63	0.98	4.84	3.2
Standard Deviation	0.36	0.081	2.59	0.96
Standard Error	0.06	0.013	0.43	0.16
Minimum	0.00	0.81	2.18	0.95
Maximum	1.10	1.13	13.90	4.22
CV%	57.14	8.27	53.51	30

Micronutrient

Fe: The available Fe content was ranged from 97.1 to 210.3mg/kg with mean value of 143.82mgkg. Generally, available Fe status was high. Available Fe showed low variability (23.7%) among the soil samples (Table 5).

Zn

The available Zn content was ranged from 6.4 to 21mg/kg with mean value of 11.46mg/kg. The available Zn showed low variability (27.66%) among the soil samples.

Cu: The available Cu content was varied from 1.9 to 14.3mg/kg with the mean value of 7.08mg/kg. This indicates low status of Cu. Fairly high variability (62.71%) in available Cu was recorded among the soil samples. (Table 5).

Mn

The available Mn content was ranged from 69.4 to 161.1mg/kg with mean value of 104.49mg/kg. This indicates high status of available Mn. The Mn showed a low variability (19%) among the studied soil samples.

The concentration of available micronutrients was found in the order of Fe>Mn>Zn> Cu.

Table 5: Chemical analysis of Micronutrients

Descriptive Statistics	Micronutrients (mg/kg)			
	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

Discussion

Soil Texture

Soil texture affects the soil sustainability. The sand, silt and clay are the three components of soil texture. It affects absorption of nutrients, microbial activities the infiltration and retention of water, soil aeration, tillage and irrigation practices (Gupta 2004). The soil 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 (Asomoa, 1973). The high silt/clay ratio could be due the parent materials of the soils sampled were composed of Granite gneiss.

Soil colour: Soil color 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 level.

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 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 & 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 10.9. 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 plant by plants in greatest quantity net 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%, indicates low content of TN according to Landon (2014). The TN content is not satisfactory. Therefore, regularly N adding organic and inorganic materials should be incorporated to make N balanced in soils.

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 (Forth and Ellis, 1997). The surface soils have average available P content of 11.8mg/kg indicating low content of P in the sampled soils. 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).

Potassium

Next to N and P, Potassium is the third most important essential element that limit plant productivity. The average content of K was 0.98mgkg indicating low content of the nutrient element.

Extractable Calcium (Mg)

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

Magnesium (Mg)

Magnesium is a water soluble cation necessary for chlorophyll pigment in green plants (Mahajan & Billore, 2014). The Mg content had averaged of 3.3 Cmol/kg. 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 greater than 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 greater than 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 & Sahoo, 2015).

In overall, available Fe status was high with average value of 143.82 mg/kg (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 mgkg 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) and Mulugeta and Sheleme (2010).

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 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.

Table 6: Nutrient Indices of sampled Soils

		% Distribution of Samples						
S/N	Parameters	Very Low	Low	Medium	High	Very High	N.I	Remarks
1	N	62	21	3	Nil	14	1.31	Low
2	P	86	8	3	Nil	3	1.09	Low
3	K	Nil	Nil	Nil	14	86	1.00	Low
4	Ca	3	89	Nil	Nil	8	1.16	Low
5	Mg	Nil	13	3	35	49	2.74	High
6	Na	16	24	8	11	41	2.20	Medium
7	OC	62	19	6	8	5	1.32	Low
8	Cu	27	22	10	19	22	1.84	Medium
9	Mn	Nil	Nil	40	49	11	2.60	High
10	Fe	Nil	Nil	35	35	30	2.65	High
11	Zn	Nil	14	47	33	6	2.11	Medium

N.I = nutrient Index, OC = Organic Carbon.

Conclusion

In general, the colour of soil was grayish brown and structure was sub-angular blocky. Soils were acidic in reaction and it is advisable to apply agricultural lime periodically for its amelioration. The crops such as maize, rice yam etc; may suffer from deficiency of low and toxicity of very high plant nutrient elements. Thus proper nutrient management strategy should be adopted especially for the concerned nutrients elements. Considering the low status of soil organic matter; practices like manure or compost incorporation, crop residue retention, green manuring etc could be suggested for its improvement. The data on soil fertility status of the study area could serve as baseline information towards achieving food security within and beyond the region.

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