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Assessment of fertility status of Ferric Acrisols in the humid area of Nigeria

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Abstract

The study assessed the fertility status of Ferric Acrisols in the humid area of Nigeria. The objectives of the study were to provide data on the physical and chemical properties of the soils and to identify any constraints inherent in them that could adversely affect their productivity. Subsequently, appropriate measures to adequately ameliorate the constraints were recommended so as to enhance the fertility status and the overall productive potentials of the soils for upland crops. Among the fertility constraints identified were low effective cation exchange capacity and soil acidification. In addition, the clayey texture of the subsoil made these soils susceptible to erosion as well as caused harvesting difficulties. Liming was recommended to ameliorate the acidity constraints. Liming together with incorporation of organic materials into the soils were the measures needed to enhance their effective cation exchange capacity. Soil erosion control was to be given high priority especially by maintaining adequate surface cover and ensuring that tillage was limited to only when soil was drier than the plastic limit.

Keywords: Fertility status, inherent constraints, Ferric Acrisols, Upland crops, Humid area, Nigeria.

1. Introduction

The growing food insecurity and increasing poverty in many countries of Africa including Nigeria has been attributed to declining soil productivity arising mainly from land degradation [**24**]. Land degradation has been defined by [**9**] as the loss of production capacity of land in terms of soil fertility, soil bio-diversity, and degradation of natural resources. Various agricultural and non-agricultural uses of soils are pointed out to cause land degradation in Africa. This is often due to the lack of appropriate land use planning and to the mismanagement of natural resources by land users, particularly by resource – poor farmers [**1**]. Other causes for land degradation have been identified as poor soil management and intrinsic characteristics of fragile soils in diverse agro-ecological zones [**23**].

Land degradation is a widespread problem that affects soils, landscapes, and human welfare. At least 485 million Africans are affected by land degradation, making it one of the continent's urgent development issues with significant costs. While the cumulative loss of crop productivity from land degradation worldwide between 1945 and 1990 has been estimated at 5%, as much as 6.2% of productivity has been lost in sub-saharan Africa [**23**] The study of [**18**] indicated that soils on about 5 million hectares of land in Africa have been degraded to a point where their original biotic functions have been fully destroyed and resilience reduced to such a level that rehabilitation to make them productive may be economically prohibitive. This though, was an empirical assessment which was based on the judgement of many persons and made in the absence of supporting data. To provide such data, African nations will have to return to fundamentals in terms of research and developmental initiatives [**8**]. With reliable resource inventories and monitoring of the resource base, better assessments and projections can be made. Such knowledge is as important as helping national planners and farmers to enhance their agricultural productivity.

The present study was initiated to characterize Ondo series, which is located in the humid agro ecological zone of Nigeria [**7**], in order to provide the data on the physicochemical properties that were needed to assess the productivity capacity of the soils.

2. Materials and Methods

This study was carried out at a previously classified site in Ondo town in Southwestern Nigeria, situated within latitudes 7^o 1^1 and 7^o 2^1 North and longitude 4^o 7^1 and 4^o 8^1 East, in the rain forest ecosystem with annual precipitation of 1600 mm. Ondo series is derived from medium – grained granite/gneiss. At the site a representative profile pit

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was systematically located, dug and described in accordance with the procedure outlined in '*Guidelines for Soil Profile Description*' [10]. Samples were collected from the genetic horizons of the profile, and transported to the laboratory for analyses for physicochemical properties.

Among the physicochemical properties studied were soil pH (H_2O), organic carbon, extractable bases, extractable acidity, extractable aluminum, cation exchange capacity (CEC), effective cation exchange capacity (ECEC), base saturation, aluminum saturation, soil texture, and soil depth.

Laboratory analysis: Percentages of the primary separates (sand, silt and clay) were determined by the hydrometer method [4]. Twenty milliliter of 4% NaOH was used as a dispersing agent. The textural classes were assigned according to '*Soil Taxonomy*' [22]. Organic carbon was determined by the chromic digestion method [12].

The soil pH was determined in 1:1 soil – water ratio and 1:1 soil – 1 N KCl suspensions [20].

Exchangeable acidity was determined by the neutral acetate method. The acidicity was obtained by difference between the CEC value determined by the Mg (OAc)7, pH 7 [12] and the sum of 1 N NH_4OAc exchangeable bases (Ca, Mg, Na, K). Separately, exchangeable acidity was again determined by the unbuffered potassium chloride method. Soil sample was successively extracted with 1 N KCl and then the amounts of exchangeable H and Al in the extracts were determined by the Fluoride titration procedure as described by [14].

A 1N NH_4OAc, pH 7 solution was used to extract the exchangeable bases. Subsequently, the concentrations of calcium (Ca), sodium (Na), and potassium (K) were determined by flame photometry, while magnesium (Mg) was determined by EDTA titration. The EDTA titration produced the sum of Ca and Mg; Mg was obtained by difference – by subtracting the Ca as determined by the EEL flame photometer from this sum. The CEC was determined by the method described by [12]. The ECEC was taken as the sum of the extractable bases and the unbuffered KCl- extractable acidity.

Finally, from the physicochemical properties of the soils their individual attributes and constraints were systematically identified by the '*Soil Constraints and Management Package (SCAMP)*' [15] assessment.

3. Results and Discussion

The physicochemical properties of Ondo soil series are shown in **Table 1**. Ondo series have been classified as Oxic Paleustults in *Soil Taxonomy* and as Ferric Acrisols in FAO soil classification system in an earlier work [17]. Acrisols occur in the southern part of the sub-humid zone of West Africa and in Southern Guinea, most of Cote d' Ivoire, Southern Ghana, Togo, Benin, Nigeria and central Cameroon [5].

Ondo series are deep, therefore they are capable of supporting both shallow and deep rooted crops. However, these soils have a weak surface soil texture, sandy loam. Below the surface soil is a dense clayey subsoil. This textural arrangement places Ondo soils in the *SCAMP* [15] as texture type LC (i.e., loamy topsoil over clayey subsoil). A critical soil constraint associated with this kind of textural class is severe soil degradation, should erosion reduce the depth of the topsoil or expose undesirable subsoil (eg. sodic).

Ranking of erosion hazard is based on a consideration of slope and observed erosion. According to the *SCAMP* erosion hazard ranking, Ondo series had very high potential erosion hazard. For Ondo soil series therefore, management options should give high priority to erosion control. In an earlier work, [5] had similarly observed that special care was strongly needed to protect Acrisols from soil erosion due to the compact textural B horizon which hampered the internal drainage of the soils.

Also, if positioned low in the landscape, these soils may experience the soil constraint of periodic water logging due to perched water tables. The root system will be restricted to topsoil resulting in water stress during dry periods and possible nutrient deficiencies due to the limited rooting depth.

Ondo series were acidic, having a mean pH (H_2O) being less than 7.00 and a base saturation less than 100% [3]. The acidic characteristic of Ondo soils may be attributed partly to the high annual precipitation which leaches away the basic cations by rainwater and many of them being replaced by H^+ [19]. The pH (H_2O) ranged from 5.0-5.35. These pH values fall within the *SCAMP* diagnostic pH range of 4.6-5.5, which denotes significant soil acidification. This may be attributed to natural processes such as leaching of basic cations by heavy rainfall, or to the long term use of highly intensive acidifying agricultural practices like high application rates of ammonium-based nitrogen (N) fertilizers, or removal of large amounts of harvested product, or mineralization of nitrate from decomposing leguminous plant species. Probable soil constraints associated with this pH range include aluminum (Al) toxicity, and this may in turn lead to deficiencies of molybdenum (Mo), calcium (Ca), magnesium (Mg) and potassium (K^+). Also the activity of some soil microorganisms, especially nitrifiers may be reduced. In order to maintain productive yields it will be necessary to ameliorate these soils and often this is economically viable. Use should be made of acid-tolerant species, and organic materials should be incorporated into such soils to ameliorate the acidity constraint. The soils also had the constraint of aluminum toxicity, estimated from aluminum saturation value expressed as a percentage of ECEC. This constraint could be corrected by liming. The aluminum saturation of Ondo series ranged from 2 to 41%. Drawing upon the findings of [6], 1- 4 tonnes/ha of lime would be required to lower the aluminum saturation of Ondo series to 10-20%, to make the soils productive for the cultivation of several upland crops such as soybean and mungbean, within the prevailing pH range of the soils.

Table 1:Physicochemical Properties of Ondo Series

	Soil Depth (cm)					
Properties	0-8	8-24	24-54	54-88	88-122	122-152
pH (H_20)	5.00	5.00	5.00	5.15	5.30	5.35
Organic carbon (g kg^{-1})	2.04	0.20	0.16	0.16	0.12	0.08
Ex. H	0.14	0.17	0.07	0.07	0.07	0.07
Extract aluminum (Al) ($cmokg^{-1}$)	0.05	0.55	0.88	0.69	0.88	0.88
Extractable bases (cmol kg^{-1}):						
Calcium (Ca)	1.10	0.25	0.25	0.25	0.35	0.40
Magnesium (Mg)	1.66	0.66	0.64	1.26	0.78	1.07
Sodium (Na)	0.06	0.05	0.06	0.05	0.07	0.12
Potassium (K)	0.03	0.01	0.02	0.01	0.02	0.02
Extractable acidity (cmol kg^{-1})	0.14	0.72	0.95	0.76	0.95	0.95
ECEC (cmol kg^{-1})	2.99	1.69	1.92	2.33	2.17	2.56
Neutral acetate CEC (cmol kg^{-1})	8.25	10.25	10.50	4.25	3.75	3.00
Base Saturation (g kg^{-1})	95	57	51	67	56	63
Al Saturation (as % of ECEC)	2	33	46	30	41	34
Sand (%)	66	66	54	22	22	18
Silt (%)	13	9	9	9	9	13
Clay (%)	21	25	37	69	69	69
Gravel (%)	16	34	40	28	13	7
Textural Class	SL	SCL	SC	Clay	Clay	Clay

Key: CEC = Cation exchange capacity SL = Sandy loam
ECEC = Exchangeable cation exchange capacity SCL = Sandy clay loam
Ex. H = Exchangeable hydrogen ions SC = Sandy clay
C = Clay

The common range of cation exchange capacity (CEC) of soils is from 3 - 50 $cmolkg^{-1}$ [2]. The CEC of Ondo series was recorded to be low, with a mean value of 6.67 cmol kg^{-1}. Such a low CEC is an important constraint to soil productivity. The low CEC could be attributed to the characteristic low content of soil organic carbon, clay type, oxides and hydroxides of iron and aluminum in soils of the humid tropics. Soil organic carbon is a depletable natural resource capital, and its decline threatens soil productivity. The land use history revealed a continuous cultivation due mainly to increasing population and tenure issues. Continuous cultivation of crops leads to rapid decline in the levels of soil organic carbon [1]. Results from long-term soil fertility trials indicated that losses of up to 0.69 tons of carbon/ha/year in the soil surface layers were common in Africa even with high levels of organic inputs (Nandwa, 2003). Soils of the humid tropics have very little 2: 1 clay minerals, and their clay is predominantly kaolinitic [11].

Ondo series had low effective cation exchange capacity (ECEC). A low ECEC (<4 $cmolkg^{-1}$) is a soil constraint because this implies a low capacity to hold cations against leaching. Therefore applying high rates of a cation such as K^+ in fertilizer can increase the likelihood of losses as a result of leaching [15].

One of the ways to ameliorate this constraint of low ECEC is to enhance the pH of these soils by liming. Liming will result in an increase in ECEC, a benefit to variable charge soils that is often not recognized [15]. A second ameliorative option for the constraint of low ECEC is to increase organic carbon levels of these soils. The various ways of achieving this include mulching and incorporation of green-manure crops such as legumes or forage grasses into the topsoil, retaining all crop residues such as maize or rice straw in the field where the crop has been grown [15]. The practice of minimum or zero tillage farming systems should be encouraged so as to mitigate loss of soil organic carbon from cultivation. Other ameliorative measures should include strip and alley cropping, and application of organic materials (e.g., animal manure, composted municipal waste, sewage sludge and locally available industrial organic wastes) obtained from off-site. Burning of crop residues should be avoided since such practice causes the loss of carbon as carbon dioxide gas and exposes the soil surface to erosion. Erosion is particularly detrimental to soil organic carbon because of the off-site movement of topsoil, which is richer in soil organic carbon than subsoil. Hence effort should be made to control erosion.

4. Recommendation and Conclusion

This study assessed the fertility status of Ferric Acriosols in the humid area of Nigeria. The fertility status of these soils was reduced due to inherent constraints such as soil acidity, low effective cation exchange capacity, and a clayey subsoil which caused harvesting difficulties as well as predisposed the soils to erosion. It is therefore recommended that farmers in the area adopt liming practice to ameliorate the soil acidity constraint. Adequate soil cover should be maintained round the year to prevent soil erosion. Also, tillage should be limited to only when soil is drier than the plastic limit. These measures if undertaken will enhance the fertility status of the soils.

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