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Original Research Paper

Soil Fertility Status of the Research Farm of the University of Agriculture, Makurdi, Benue State, Nigeria.

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The current fertility status of the soils of the research farm of the University of Agriculture, Makurdi, Benue State (Students' Industrial Work Experience Scheme farm unit) was assessed by analysing the physical and chemical properties of soils at depths of 0-15 cm and 15-30 cm in the laboratory. Results for soil physical properties indicated that the soils had a predominant sandy loam texture. The bulk densities of the soils were low and increased with depth with a low total porosity. For chemical properties, the soils were moderately to slightly acidic with a pH range of 5.56-6.17. The Cation Exchange Capacity (CEC), available P, Ca and total N were low at both depths. CEC and total N decreased with depth. Exchangeable K was very low while Mg and Na were moderate at both depths. The % base saturation ranged from high to very high. The soils were low in fertility and need the adoption of proper management in terms of organic and inorganic fertilizer application to resuscitate and sustain the soil fertility. Adequate monitoring of the fertility status of the farm should also be carried out at regular intervals.

Keywords: Physical and chemical properties, Fertility.

INTRODUCTION

Agriculture, one of the mainstays of Nigeria's economy, constitutes a major cause (man-made) of soil degradation (Adaikwu *et al*., 2012). Global drive for sustainable agricultural systems involves optimizing agricultural resources to satisfy human needs and at the same time maintaining the quality of the environment and conserving natural resources (FAO, 1989). However, in many parts of the world today, large areas of arable lands are inadequately managed for long term sustainable production (Ibrahim and Idoga, 2013). The success of soil management to achieve productivity and maintain soil fertility depends on the understanding of how the soil responds to agricultural use and practices (Negassa and Gebrekidan, 2004). The chemical properties of a soil give a strong indication of its fertility.

Cation exchange capacity (CEC) for instance, does not only help to evaluate soil fertility, but also to classify it (Hesse, 1971). It determines the capacity of a soil to hold nutrients and eventually release them for plant uptake. Agbenin and Goladi (1997) reported a rapid decline of organic matter, followed by extensive leaching of basic cations and rapid development of acidity when most savanna soils undergo continuous cultivation. Continuous and unguided use of soils has greatly reduced land capacity to feed mankind, especially in the tropics (Nigeria inclusive). In the research farm of the University of Agriculture, Makurdi, where scientific methods of farming are in place, declining soil productivity has recently been experienced after less than 10 years of use. This brings to question the reliability of research results and the problem of unintended variability in crop yields over time. The decline in soil productivity is believed to be a resultant effect of declining soil quality (fertility). This necessitated a study to understand the chemical properties of the soils, especially as they relate to fertility being a pre-requisite for efficient use of soil resources (Khan *et al*., 1998; Mustapha *et al*., 2001).

This could form a basis for monitoring the fertility status of the soils at regular intervals. The study had the objectives of determining the actual levels of some chemical properties as they relate to fertility status of the soils and the pattern of variation of these properties across the area and with depth. This will ensure proper use of the land and also give recommendations on practices that will help in maintaining fertility of the soils so as to sustain/improve crop yield.

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MATERIALS AND METHODS

The Study Area

The study was carried out at the Students Industrial Work Experience Scheme (SIWES) farm, University of Agriculture, Makurdi. Makurdi lies between latitudes $7^{0}44^{'}$ N and $7^{0}50^{'}$ N and between longitudes $8^{0}30^{'}$ E and $8^{0}45^{'}$E. The area which is within the flood plain of River Benue is underlain by consolidated Makurdi sandstone, Turanian Eze-Aku shales and Alluvium. Superficial deposits such as weathered rocks, laterites and alluvium cover the study area extensively. The principal crops commonly cultivated in the area include maize, cassava, soybeans, cowpea and rice, as well as a variety of vegetables such as okra, pepper, fluted pumpkin and amaranthus.

Field Sampling

At the site, an area of about ten (10) hectares representing the cultivated area of the farm was chosen. For a good representative coverage of the area, the farm was divided into four units. Within each unit, bulk samples consisting of fifteen (15) surface soil (0-15 cm) and fifteen (15) sub-surface (15-30 cm) core samples were collected randomly using a soil auger, giving a total of 8 composite samples. Also, a core sampler was used to collect soil samples from each unit for bulk density determination. Samples collected were subjected to physical and chemical analysis.

Laboratory Analysis

The bulk samples were air-dried and gently crushed and passed through a 2 mm sieve. Core samples were trimmed to the height of the core sampler for bulk density determination. Particle size distribution was determined by the Bouyoucos hydrometer method (1951). Bulk density was determined using the core method. Soil pH was determined electrometrically in water using 1:1 soil/water ratio and 1:1 soil/KCL ratio (Jackson, 1969). Organic carbon was determined by the macro-kjeldahl method (Jackson, 1969) and the Bray-1 method was used to determine the extractable phosphorus.

Cation exchange capacity was determined using the 1N ammonium acetate method (Chapman, 1965). Exchangeable bases were determined using the 1N NH4OAC (Hesse, 1971). Na and K were determined using the flame photometer while Ca and Mg were determined using Atomic Absorption Spectrometer (AAS). Base saturation was calculated by dividing the sum of exchangeable bases by the CEC and multiplying by 100.

Soil fertility Assessment

The fertility of a soil refers to its status with respect to the amount and availability of essential nutrient elements for plant growth (Singh, 1999). Organic matter plays a key role and occupies a central position in the provision of some of these essential plant nutrients (Brady and Weil, 1999) and stabilizing the soil environment (Mustapha *et al*., 2001). Of the many nutrients required by crop plants, the macronutrients N, P, K, Ca, and Mg are the major determinants of soil fertility. In this study, the levels of fertility of the soils were assessed using the Critical limits for interpreting levels of analytical parameters (Esu, 1991) as well as the Methods of chemical analysis of soil survey samples (Metson, 1961). The estimation of the fertility status was based on the physical and chemical parameters.

RESULTS AND DISCUSSION

Table 1 shows the physical properties of the soils of the research farm. All the four units showed relative differences between the surface (0-15 cm) and the subsurface (15- 30 cm) horizons. Soil bulk density (Db) values were relatively lower (1.36-1.61 g/cm3) in the surface horizons than in the subsurface horizons (1.55-1.66 g/cm3). This may be due to the little differences in soil organic matter and clay contents between the two horizons. Soil organic matter is light and therefore tends to lower soil Db values when present in high amount in the soil (Idoga *et al*., 2007).

Total porosity is adversely influenced by soil bulk density. This may account for the lower values of total porosity in the more compacted subsurface horizons. The chemical properties of the soils (Table 2) also varied in amount between the two layers. Soil pH, total N, exchangeable bases and CEC were relatively higher in the 0-15 cm layer than in the subsurface layer. This can be explained by the fact that these soil properties are largely associated with organic matter which, to a large extent, is confined to the soil surface (Kparmwang and Esu, 1995).

Organic carbon

Data in Table 2 show that the content of organic carbon in the soils ranged from 6.0-9.6 g/kg with a mean of 7.9 g/kg indicating low organic C content (Esu, 1991). This could be attributed to organic matter decline. Solarin (1993) found that the organic carbon content of uncultivated soils of the same area ranged from 1.1% to 1.55% as against the present findings of 0.68% to 0.96%. Soil organic matter is known for its high influence on soil chemical properties (Agbede, 2009). Soil organic matter contributes greatly to soil N, P, S, CEC and exchangeable cations. Where organic matter is lacking, these soil properties will be adversely affected.

Greenland (1994) identified soil organic matter as the most important property in sustainable soil productivity. This was the basis for the practice of shifting cultivation in the past. The rate of decline in soil organic matter in this study can be said to be rapid going by the number of years of land use (6 years). This also is in agreement with Greenland s findings that organic matter decline is very rapid in the first few years and later stabilizes in the long run. Even at that, it is important to sustain and/or improve soil organic matter content in any agricultural production systems.

Total nitrogen

Table 2 shows that the total N at both soil depths was low and ranged from 0.069-0.091% with a mean value of 0.080% and slightly decreased with depth. The results obtained agree with reports of Agboola (1990) that tropical soils are intrinsically low in N. Nitrogen has been reported to be the most limiting plant nutrient in tropical soils (Brady and Weil, 1999). The findings confirm the fact that total N decreases with soil depth (Brady and Weil, 1999). The low N status of the soils might have been as a result of uptake by plant exacerbated by continuous cropping. The continuous cultivation exposed the soil to sheet erosion, which washed away parts of the top soils and plant nutrients and also exposed the soil to high temperatures.

Table 1: Physical properties of the soils of the research farm

Location	Depth (cm)	Bulk density (g/cm^3)	Total porosity (%)	Sand (%)	Silt (%)	Clay (%)	Textural class
Unit 1	0-15	1.36	60	80.4	10.2	9.4	Loamy sand
	15-30	1.55	50	77.3	10.4	12.3	Sandy loam
Unit 2	0-15	1.44	65	77.1	12.4	10.5	Sandy loam
	15-30	1.63	45	68.8	16.0	15.2	Sandy loam
Unit 3	0-15	1.47	56	75.0	12.6	12.4	Sandy loam
	15-30	1.58	42	72.7	14.1	13.2	Sandy loam
Unit 4	0-15	1.61	50	68.3	17.2	14.5	Sandy loam
	15-30	1.66	41	66.2	18.2	15.6	Sandy loam

Table 2: Chemical properties of the soils of the research farm

Location	Depth (cm)	pH	Organic C (g/kg)	N (%)	P ppm	Na^+	K^+	Ca^{2+}	Mg^{2+}	CEC	BS (%)
						←		cmol/kg		→	
Unit 1	0-15	6.17	7.7	0.083	2.9	0.40	0.13	3.69	1.95	7.05	87.52
	15-30	6.15	7.1	0.070	3.2	0.38	0.10	3.4	1.87	7.29	78.88
Unit 2	0-15	5.85	6.8	0.088	4.4	0.42	0.12	4.2	2.1	8.5	80.47
	15-30	5.7	6.0	0.079	3.7	0.39	0.11	3.4	1.77	8.11	69.91
Unit 3	0-15	6.13	9.6	0.091	3.7	0.40	0.14	4.7	2.35	8.8	86.25
	15-30	6.08	9.2	0.077	2.5	0.38	0.12	3.8	1.8	7.9	77.22
Unit 4	0-15	5.79	8.4	0.086	3.1	0.41	0.13	4.85	2.41	8.96	87.05
	15-30	5.56	8.0	0.069	2.95	0.39	0.11	3.3	2.07	8.18	71.76
mean		5.93	7.9	0.080	3.31	0.40	0.12	3.92	2.14	8.46	79.9

The high temperatures could break down organic matter and inhibit nitrogen fixation by rhizobacteria.

***Available* P**

Available P of the soils in the study area was low and ranged from 2.5-4.4ppm with a mean of 3.31ppm. Phosphorus is the second most critical element influencing plant growth and crop production. Available P which was low, however, did not follow the same trend as the total N and CEC, but rather not consistent with a slight increase with depth. The slight increase in available P with depth could be explained by the slight decrease in pH with depth, at which P compounds are more soluble and therefore, higher available P were obtained at the subsurface.

Cation Exchange Capacity

The overall cation exchange capacity (CEC) range was 7.05-8.96 (mean = 8.0) cmol (+) kg^{-1} and it decreases with depth. All the soils were placed in the "low" category (Metson, 1961). This may be due to lack of return of crop residues, common with the practice in the study area. In addition, the findings confirm the fact that CEC decreases with soil depth (Brady and Weil, 1999). The low CEC values could be an indication that kaolinite is the dominant clay fraction of the soil as reported by Hamdan *et al.* (1998).

Exchangeable cations

Calcium and magnesium were the dominant bases in the soils studied (Table 3). Similar observations have been made in the past for West African savanna soils in general (Kowal and Knabe, 1972) and in other states in Nigeria (Singh, 1997; Singh *et al.*, 1996). The overall means of Ca and Mg (cmol (+) kg^{-1}) in the present study were 3.92 and 2.14 respectively. The soils are, therefore, rated "low" in Ca and "moderate" in Mg fertility (Metson, 1961).

The result obtained for Ca is similar to, but that for Mg is lower than those reported earlier by Mustapha (2003). Results showed that exchangeable K in the soils ranged from 0.10-0.14 (mean = 0.12) cmol (+) kg^{-1} and were rated very low (Metson, 1961). Na ranged from 0.38-0.42 (mean = 0.40) cmol (+) kg^{-1} and was rated moderate (Metson, 1961). The results of the exchangeable bases supports the soil pH values obtained and explains the high average base saturation values obtained; mean of 79.9% for the respective depths.

CONCLUSION

Based on the results obtained, it can be concluded that the soils of the Student' Industrial Work Experience farm unit of the research farm of the university of Agriculture, Makurdi is generally low in most of the fertility parameters considered.
In order to resuscitate and sustain the fertility of the soils, the following recommendations are suggested:

1. Application of mineral fertilizer nutrients, especially N, P and K is necessary to achieve a reasonable yield. This can only succeed with improvement in CEC through the incorporation of organic matter. Otherwise, the applied mineral fertilizer nutrients will be lost through leaching.
2. The use of organic manure such as plant residues and animal dung is recommended to improve organic matter content as well as productivity of the degraded soils. Plant residues should neither be burnt nor consumed by livestock.
3. Adequate monitoring of the fertility status of the research farm should be carried out at regular intervals.

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