

Assessment of Organic Carbon and Available Nitrogen in the Soil of Some Selected Farmlands Located at Modibbo Adama University of Technology, Adamawa State, Nigeria

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Abstract

The study was carried out to assess the Organic Carbon (OC) and available Nitrogen in the soils of the Teaching and Research Farmlands of Modibbo Adama University of Technology, Adamawa State, Nigeria. Soil samples were collected from three locations to make up nine composite samples at a depth of 0-20 cm and the soil samples were analyzed for particle size distribution, soil reaction (pH), Electrical Conductivity (EC), OC, available Nitrogen, available Phosphorus, exchangeable bases, and Total Exchangeable Acidity (TEA). The soil samples were slightly acidic with a pH mean of 6.26. The textural class of the soil samples varied from sandy loam to loamy and with sand ranging from 75.30-80.30%, silt 7.00-11.30% and clay 12.30-13.30%. The OC and organic matter were recorded low and moderate in the three locations. For sustainable crop production; good soil management practice such as crop rotation, addition of quality crop residue, Organic Manure (OM) and application of organic fertilizer is recommended.

Keywords: Nitrogen; Phosphorus; Soil; Fertilizer

Abbreviations:

OC: Organic Carbon; OM: Organic Manure; EC: Electrical Conductivity; TEA: Total Exchangeable Acidity.

Introduction

Soil OC and soil Nitrogen have long been identified as factors that are important to soil fertility in both management and natural ecosystem [1]. It is well established that Nitrogen is the macro nutrient often limiting the growth of plants on soil [2,3]. Moreover, soil organic matter and consequently soil OC is one of the most important attributes of a soil because it affects nutrient cycling, soil structure and water availability. Maintaining or increasing soil organic content is an important measure of the sustainability of a cropping system. In this direction, the United States Department of Agriculture (USDA) has developed a soil conditioning index that is a tool that can predict the consequence of cropping system and tillage practices on the trend of soil OC accumulation [4]. A positive index is the criteria used in the conservation security program [5]. Overall, management practices that contribute to increasing soil OC levels includes those that add more OC to the soil than the amount removed from the system (i.e., crop residue), increase the diversity of OC added (e.g., manure) or decrease the rate of OC loss [6].

Soil OC is the largest terrestrial Carbon store and its dynamics are important for understanding the global cycle. In addition, soil OC is the main source of energy for soil microbes and therefore, the amount of soil OC will influence the availability of essential plant nutrients. One of these essential nutrients, Nitrogen, is required in relatively large concentration for plant growth and its availability can limit vegetation distribution. Both soil OC and organic Nitrogen form a part of the soil organic matter pool which is derived from plants. Soil is generally considered to comprise 50% of soil organic matter while almost 95% of soil Nitrogen is closely associated with soil OC [7]. Soil organic matter consists of a range of compounds from simple monomers to complex biopolymers and charcoal, which are often define by their decay rates and classified into fast, stable and inert turnover pools [8]. Soil total Nitrogen consists of both ammonium nitrite and nitrate. Analysis of soil OC may be performed on whole soil sample or fractions that separate pools of soil OC which decompose at different rates e.g., micro aggregate-protected Carbon. A different set of procedures may be performed for separation of soil Nitrogen into different plant available fraction.

One hypothesized goal of sustainable agriculture is to increase soil OC and soil native level [9]. Soil quality is the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health and productivity of a given ecosystem and the environment related to it. The soil microbial biomass is a small but key component, it has been used to understand soil nutrient dynamics and as an ecosystem marker. The soil organic matter and soil Nitrogen are

the major determinant and indicator of soil quality and fertility and are closely related to soil productivity in an agriculture ecosystem. The reduction of soil OC and soil Nitrogen will lead to a decrease in soil fertility, soil nutrient supply, porosity and an increase in soil erosion. In this study, we have assessed the OC and available Nitrogen in the soil samples Teaching and Research Farmlands of Modibbo Adama University of Technology, Adamawa State, Nigeria, in furtherance to sustainable agriculture.

Materials and Methods

Study area

The study was carried out in the Agricultural Teaching and Research Farm of Modibbo Adama University of Technology, Girie Local Government Area, Adamawa State, Nigeria. Girie Local Government is located within the northern guinea savannah of Nigeria between latitude 7 and 11 degrees north, and longitude 11 and 14 degrees east.

Temperature of the region is usually high throughout the year because of the high radiation income which is relatively distributed throughout the year. Maximum temperature of about 40°C is observed while minimum temperature can be as low as 18°C between December and January. Mean annual temperature ranges between 26.9 and 27.8°C [10].

Rainfall is the most variable element of the tropical climate. Most of its characteristics such as amount, frequency and intensity vary with time and space. The movement of Inter Tropical Discontinuity (ITD) associated with zones of rainfall during the course of year is the major factor controlling rainfall in the region [10]. The amount of rainfall ranges between 700-1000 mm annually and humid months range from May to October. Relative humidity is very low between January and March (20-30°C); it starts increasing from April and reaches its peak in August and September with about 80% relative humidity.

Sample collection and preparation

The soil samples of the experimental area were collected from nine (9) plots in three locations (upper, middle and lower slope). Each plot covers an area of 100 m² whereby five (5) soil samples were collected at 0-20 cm depth, randomly mixed to make up a composite sample. All the soil samples were labeled properly in polythene bags and moved to the laboratory. In the laboratory, the samples were pounded with the aid of mortar and pestle then passed through a 2 mm wire mesh. The sieved samples were used for the basic characterization of the physical and chemical properties of the soil samples.

Particle size distribution

The particle size was determined using the Bouyoucocus Hydrometer method as described by Jaiswal [11], where 50 g of air-dried soil sample was transferred into 25 ml beaker and 50 ml of 5% Sodium hexametaphosphate was added to it. 100 ml of distilled water was added to the suspension, followed by stirring and the suspension was allowed to settle for some minutes then, transferred into a measuring cylinder. After shaking, the first and second hydrometer readings were taken at 2 hrs and 40 sec intervals, respectively along with the temperature readings. The percentage sand, silt, and clay were calculated using the following relationship;

$$\% \text{ Clay} = (H_2 - H_1) + R \times 100 / W$$

$$\% \text{ Silt} = [(H_2 - H_1) + R \times 100] \times (\% \text{ Clay}) / W$$

$$\% \text{ Sand} = 100 - (\% \text{ Clay} + \% \text{ Silt})$$

Where; H₁=first hydrometer reading; H₂=second hydrometer reading; R=temperature reading; W=weight of the soil sample taken.

Chemical analysis of the soil samples

Soil pH and Electrical Conductivity (EC): The pH was determined using Jaiswal 3015 electrode pH meter as described by Jaiswal [11] in 1:2 soil water ratio. In a typical experiment, 10 g of soil was measured and transferred into a 50 ml beaker and 20 ml of distilled water was added. The suspension was stirred and allowed to stand for 30 min. The reading on the pH meter was recorded as soil pH in water. To the same suspension, the EC was determined by inserting the EC electrode into the suspension and the EC value meter was recorded [11].

OC determination: Soil OC was determined using the method described by Jaiswal [11] where Potassium dichromate was used as an oxidizing agent. The filtrate was titrated with Ferrous ammonium sulphate in the presence of diphenylamine indicator to a dull green end point. The OC was thus calculated using the relation as below;

$$\% \text{ C} = (B - T) N \times 0.003 \times 1.33 \times 100 / W$$

Where; B=Blank; T=Sample titre value; N=Normality of Ferrous sulphate used

And the percentage organic matter was calculated by multiplying the percentage OC by 1.724 [11].

Available phosphorus determination: The available Phosphorus was determined using Bray number one method as described by Jaiswal [11]. In a typical experiment, 2 g of soil sample was measured into 50 ml centrifuge tube, 14 ml of the extracting solution was added and the suspension was shaken for 30 min then, filtered into 100 ml conical flask. This was repeated two times and made up to mark with the extracting solution, then 2 ml of clear supernatant was poured into 2 ml of Ammonium molybdate, 1 ml of stannous chloride was diluted with 5 ml of distilled water and the percentage transmittance was measured using the electrospectrophotometer at 660 micrometer wavelength after about 5 min but not later than 20 min. The graph of concentration (ppm) of Phosphorus was plotted against transmittance percentage.

Exchangeable bases determination: The exchangeable cations in the soil were determined from aliquot extract with Ammonium acetate. The exchangeable Calcium and Magnesium contents of the soil were determined by EDTA titrimetric method while the exchangeable Potassium and Sodium was determined via flame photometer.

Determination of available nitrogen: 10 g of soil sample was weighed into a dry kjedahl distillation tube, 10 ml of distilled water was added, 50 ml of Potassium permanganate was added, and 50 ml of 2.5% Sodium hydroxide was added. The solution was distilled to 10 ml of 2% boric acid. The distillate was collected up to 75 mL and was titrated with 0.01 N H₂SO₄. The percentage Nitrogen was determined using the formula;

$$\% \text{ N} = (a - b) \times 0.00014 \times 100 / W$$

Where, a=titre value of the sample; b=titre value of blank; w=weight of the sample; 0.00014=normality of Nitrogen.

Results and Discussion

Particle size of the soil sample

The results of the soil particle size are presented in Table 1. The table shows the percentage of sand, silt and clay location A, B and C of the study area. In location A (upper slope), the percentage of sand ranged from 73-81% with the mean of 77.6%, clay ranged from 12-13% with the mean of 12.3% and silt ranged from 7-14% with the mean of 10%. In location B (middle slope), the percentage of sand ranged from 79-82% with the mean of 80.3%, clay ranged from 12-14% with mean of 12.6%, and silt ranged from 6-8% with the mean of 7%. In location C (lower slope), the percentage sand ranged from 72-77% with the mean value of 75.3%, clay ranged from 13-14% with the mean of 13.3% and silt 10-14% with the mean of 11.3%. The textural class of the soils in the study area is dominated by sandy loam, except in location B plot 2 which is loamy may be due to high portion of sand in this location. The above result agrees with the mean values of 77.70% sand, 9.40% silt, and 15.73% clay recorded by Hosea.

Chemical properties of the soil samples

Soil pH: The soil pH (in water) of the soil samples are presented in Table 2. The values ranged from 5.82-6.37 with the mean of 6.12 in location A, 6.12-6.51 with the mean of 6.34 in location B, and 5.99-6.57 with the mean of 6.32 in location C.

Locations	Soil samples	% Sand	% Silt	% Clay	Textural class
A	1	73.00	14.00	13.00	sandy loam
	2	79.00	9.00	12.00	sandy loam
	3	81.00	7.00	12.00	sandy loam
	Mean	77.60	10.00	12.30	
B	1	79.00	7.00	14.00	sandy loam
	2	82.00	6.00	12.00	loamy sand
	3	80.00	8.00	12.00	sandy loam
	Mean	80.30	7.00	12.60	
C	1	77.00	10.00	13.00	sandy loam
	2	77.00	10.00	13.00	sandy loam
	3	72.00	14.00	14.00	sandy loam
	Mean	75.30	13.30	13.30	

Table 1: Particle size distribution of the study area.

Location	Sample	pH ds/m	EC %	OC %	OM mg/kg	AVN ppm	AVP Cmol/g	Ca Cmol/g	Mg Cmol/g	Na Cmol/kg	K Cmol/kg	TEA meq
A	1	6.37	1.53	1.40	2.41	0.23	9.30	2.99	2.47	0.09	0.33	0.40
	2	6.19	1.66	1.53	2.63	0.21	9.90	3.99	2.52	0.09	0.28	1.40
	3	5.82	1.55	0.78	1.34	0.24	8.80	1.99	3.10	0.09	0.28	0.80
	Mean	6.12	1.58	1.23	2.12	0.22	9.33	2.99	2.69	0.09	0.29	0.86
B	1	6.51	1.53	1.48	2.57	0.13	7.10	1.99	2.47	0.13	0.31	2.00
	2	6.41	1.63	1.21	2.08	0.37	8.20	0.99	1.65	0.09	0.28	1.20
	3	6.12	1.71	1.27	2.18	0.16	9.20	4.99	2.64	0.09	0.28	180
	Mean	6.34	1.62	1.32	2.27	0.22	8.16	2.49	2.25	0.10	0.29	1.66
C	1	5.99	1.83	1.37	2.36	0.11	8.70	5.99	0.82	0.13	0.28	1.40
	2	6.40	1.73	1.20	2.06	0.18	8.50	1.99	1.64	0.09	0.28	1.60
	3	6.57	1.9	1.38	2.37	0.30	8.10	0.49	2.92	0.13	0.28	1.40
	Mean	6.32	1.82	1.31	2.26	0.10	8.43	2.82	1.79	0.11	0.28	1.46

Table 2: Chemical properties of the study area.

The soil pH is moderately to slightly acidic in agreement with what was reported by Usman [12].

Soil Electrical Conductivity (EC): The result of the EC of the study area ranges from 1.53-1.66 ds/m with the mean of 1.53 ds/m in location A, 1.53-1.71 ds/m with the mean of 1.62 ds/m in location B, and 1.73-1.90 ds/m with the mean of 1.82 ds/m in location C. The result shows that the soil is saline. According to Usman [12], soil EC value greater than 1.2 ds/m is termed saline.

Organic Carbon (OC): The OC of the soil samples ranged from 0.78-1.53% with a mean of 1.23% in location A, 1.21-1.48% with a mean of 1.32% in location B, and 1.20-1.38% with a mean of 1.31% in location C. The OC content of the soil samples in the study area falls within the medium range. This is in agreement with those observed by Emerson [13].

Available phosphorus: The result of the available phosphorus of the study area ranges from 8.80-9.90 ppm with a mean of 9.33 ppm in location A, 7.10-9.20 ppm with a mean of 8.16 ppm in location B, and

8.10-8.70 ppm with a mean of 8.43 ppm in location C. The available Phosphorus level falls within the medium range. This could be due to low decomposition of organic materials and slow release of mineral nutrients [14].

Exchangeable bases (Ca⁺, Mg⁺, Na⁺ and K⁺): The results for the exchangeable bases presented in Table 2 shows that the distribution of the exchangeable cations falls within the low and medium range. Again, this may be due to low decomposition of organic matter and slow release of chemical element into the soil [14,15].

Correlation coefficient analysis

The Pearson's correlation coefficient was used to know the correlation of parameters between replicates; pH between the upper slope (A) and middle slope (B) shows a negative correlation with the value of -0.327 non-significant, between the upper and lower slope (C) the correlation is negative with the value of -0.807 non-significant, between the middle and lower slope the correlation is positive with value 0.822 non-significant. EC between the upper and middle slope had value of 0.956 which positive correlation an non-significant, between the upper and lower slope the correlation is positive with value 0.890 non-significant, the middle and lower slope had value of 0.717 which is positive correlation and non-significant. OC of the upper and middle slope was correlated and had the value -0.228 which was negative and non-significant between the upper and middle slope correlation was positive with value 0.084 non signification, between the middle and lower slope the value was -0.989 which is negative correlation and non-significant. AVN correlation between the upper and middle slope was positive with the value 0.561 and non-significant, the upper and middle slope had value of -0.77 which is negative correlation and non-significant, AVN correlated between the middle and lower slope was negative with the value -0.957 non-significant. AVP correlated between the upper and middle slope was positive with value 0.817 non-significant, between the upper and lower slope the AVP correlation was negative with the value -0.584 non-significant, and correlation of AVP between the middle and lower slope was negative with the value -0.010 non-significant. The correlation of Ca in the upper and middle slope was positive with value 0.052 non-significant; between the lower and upper the correlation of Ca was negative with the value -0.911 and non-significant. Ca correlated between the middle and lower was negative with the value -0.459 non-significant. The correlation of Mg between the upper and middle slope was positive with the value 0.509 non-significant, Mg correlated between the upper and lower slope was negation with the value of -0.125 non-significant, between the middle and lower slope the correlation was positive with the value 0.791 non-significant. The correlation of Na between the upper and middle slope was negative the value -0.277 non-significant, between the lower and upper slope the correlation of Na was positive with the value 0.693 non-significant, between the middle and lower slope the correlation of Na was positive with value 0.500 non-significant. The correlation of K between the upper and middle slope was positive with the value 0.596 non-significant, K correlation between the upper and lower slope was negative with the value -0.7373 non-significant and K had negative correlation between the middle and lower slope with the value -0.982^{NS} non-significant. TEA correlated between the upper and middle slope was negative with the value -0.371 non-significant, the correlation of TEA between the upper and lower slope was significant (1.000*) at 0.05 level of probability.

Conclusion

This work was conducted to assess the OC and available Nitrogen of soil of the teaching and research farmlands at Modibbo Adama University of Technology, Yola, Adamawa State, Nigeria. The study area is located within northern guinea savannah of Nigeria (Lat. 7 to 11° N and log 11 to 14° E). A total of nine (9) composite soil samples were collected from nine (9) plots in three locations (upper, middle and lower slopes) at a depth of 0-20 cm. The soil samples were analyzed for particle size distribution, EC, OC, available Nitrogen and available phosphorus, exchangeable bases, and TEA. The results obtained from the present study revealed that the soil at these locations are slightly acidic and have average structural stability due to medium organic matter content which also affects the availability of Nitrogen in soils.

We observed that the pH of soil samples from the study area is slightly acidic with mean value of 6.26. The EC of the study area has the mean value of 1.70 ds/m. The result of the exchangeable bases show that the distribution of exchangeable cation parameters falls within the low and medium range. The soil textural class is dominantly sandy loam which indicates that the soil samples of the study area has high portion of sand.

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