Journal of Agriculture and Environment Vol. 18 No. 2, 2022: 107-114
ISSN: 1595-465X (Print) 2695-236X (Online)

ASSESSMENT OF SOIL ORGANIC CARBON AND TOTAL NITROGEN AS INDICATORS FOR SOIL PRODUCTIVITY IN GIDAN AMAMATA EUCALYPTUS (*Eucalyptus globulus*) PLANTATION, SOKOTO STATE, NIGERIA

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ABSTRACT

The study was conducted in Gidan Amamata *Eucalyptus globulus* plantation to estimate the soil organic carbon and total nitrogen content of the plantation. Five (5) transects of 150 m were laid within the plantation, thereafter, 30 x 30 m plots were established along both sides of the transects. Using simple random sampling, two (2) plots were selected from each transect making a total of 10 plots for the study. Eighty (80) composite soil samples were randomly collected using soil auger from a total of ten (10) plots. Descriptive statistics was used to analyze the data and summarized in tabular presentation. Soil organic carbon content was determined using Walkley and black method which gave the average value of 0.64% and soil total nitrogen was determined using Micro-Kjeldahl method which gave the average value of 0.059%. It can, therefore, be concluded that the plantation is very low in soil organic carbon and total nitrogen due to sparse vegetative cover and presence of low organic matter. Hence, the fertility level is considered to be very low. It is therefore recommended that further studies should be carried out to estimate other aspects of macro and micro nutrient contents of Gidan Amamata Eucalyptus Plantation.

keywords: Walkley and black method; Micro-Kjeldahl method; soil fertility;

INTRODUCTION

Productive soils are the foundation of sustainable forest and forest soils are generally subjected to fewer disturbances than agricultural soils, particularly those that are tilled, so forest soils tend to have better preserved A-horizons than agricultural soils (U.S. EPA, 2007). Forest use of soil is by far the most important; foresters have shown soil to be a highly weathered material that developed from combined actions of chemical and biological factors acting upon rocks on the surface of the earth as moderated by topography and climate for plants' growth (Molindo, 2008). Soil can be judiciously used in forestry by ensuring its productivity, which is directly related to its ability to support plants' growth by supplying plants with nutrients and this ability to support plants' growth has been expressed by Gregory (2013) as the fertility of the soil.

Soil fertility is best maintained by understanding all its physical and chemical properties. One of such physical properties that aids in the maintenance of soil fertility when fully understood is the texture which is shown by USDA (2014) as perhaps the most nearly permanent characteristic of a soil. Soil organic carbon is an important element of the global carbon stock and contains approximately two times more carbon than the atmosphere or vegetation. Soil carbon pool estimations (both organic carbon and inorganic carbon) are essential for appraising global terrestrial carbon inventories; they also optimize the mitigation of carbon dioxide (CO_2) accumulation in the atmosphere (Gregory, 2013). Soil organic matter is a key component of soil fertility and quality; it plays an important role in water retention, soil aeration, biological activity, and nutrients provision (Ayuke *et al*., 2011). Savanna soils are generally low in total nitrogen; among the data for 295 well drained soil from all over the regions (India), examined by (Silver *et al*., 2000) values ranged from 0.008 to 0.29% with a mean of 0.05%. The reason behind this low level of nitrogen in savanna soils was due to low level of soil organic matter.

According to Augusto *et al*. (2002), plants require nitrogen than any other nutrients but only small portion of it is available to plants and that is why soil chemical analyses according to Lindner *et al.* (2002), are valuable for achieving efficient production of plants and solving problems of plant nutrient deficiencies and toxicities. Soil organic carbon and total nitrogen contents remain an intriguing component of soil fertility due to their significance in the growth and yield of any plant especially in Eucalyptus tree species. This importance is much more substantial when compared to other forms of mineral nutrients in the soil (FAO, 2011).

According to Brooker (2019), the Eucalyptus tree (*Eucalyptus globulus*) is a native to Australia as a prevalent tree belonging to the family Myrtaceae, it is a fast-growing species and can survive drought and poor soils, keeps its leaves all year round. It is a tall evergreen tree with clear foliage that grows up to 45 m (148 ft) but may sometimes only be stunted shrub, or alternatively under ideal conditions, can grow as tall as 90-100 m (300-330ft) with smooth and fast-growing stem with leafy spreading branches. Flowering time varies with subspecies and distribution, but the flowers are always white; with woody fruits (Monkany *et al*., 2006).

Increasing anthropogenic disturbances especially, on land use/cover change (LUCC), is the major cause of soil quality deterioration in the world (Six *et al*., 2002). According to Baldock (2000), Soil organic carbon has recently gained prominence in assessment of soil quality, since it completely affects chemical, physical and biological aspects of the soil. Soil organic carbon is often described by some as the least understood component of the soil because of its dynamism (Leifeld., 2005). The main aim of this study is to determine soil organic carbon and total nitrogen as indicators of soil fertility in the study area.

MATERIALS AND METHOD

Study Area

The study was conducted at Gidan Amamata Eucalyptus plantation which is an artificial plantation of Eucalyptus trees located at Gidan Kaura zone established in 2005 under the Forestry II Programme of 1987. It lies between latitude 13°46'N and longitude 5°40'E along Illela-Wauru-Gada Road in Sokoto state, Nigeria. The plantation covers an area of about 5ha (Ministry of Environment, Sokoto, 2005). The area falls within the Sudan savanna zone. It has about 70-125 days of rainy season (SERC, 2014). Temperatures are variable during the dry and rainy seasons with minimum average temperature of 16.5°C and the maximum average temperature of 39 °C. The mean maximum ranges from 35-37°C. Relative humidity is between 52- 56% (SERC, 2014). It is characterized by alternating rainy and dry seasons. The soil is reddish brown with very little profile differentiation, generally described textually as sands and sandy loamy with low organic matter content (Shinkafi, 2000).

Sampling Procedures and Soil Sample Collection

Five (5) line transects of 150 m each were laid within the plantation, thereafter, 30x30m plots were established along both sides of the transects. Using simple random sampling, two (2) plots were selected from each 150 m line transect and a total of ten (10) plots were selected from the whole plantation.

Soil Sample Collection

A total of Eighty (80) composite soil samples were collected using soil auger. Sample spots were selected from plots of the Gidan Amamata plantation, employing simple random sampling technique, whereby, each plot was demarcated into 5 sub-plots of 6 x 6 m and 4 sample sub-plots being selected randomly (through balloting) from each plot.

In each of the selected sub-plots, six (6) samples were collected with 3 m distance between one sampling spot and another. These soil samples were collected at a sample depth of 0-15cm, and 15-30cm to make the composite sample. However, 240 samples were collected from 0-15cm depth from the whole 40 sub plots; 6 samples per sub plot and also 240 samples from 15-30cm depth were equally collected, 6 samples per sub plot, making it a total of 480 samples. Soil samples were taken to the laboratory for chemical analysis.

Soil Sample Preparation and Experimental Procedure

Soil samples collected were air dried, ground with the use of pestle and mortar and sieved through 2 mm sieve to remove materials larger than 2 mm, the sieved fractions were stored in a clean polythene bag for further analyses in the laboratory.

Determination of Soil Organic Carbon

The organic carbon content of the soil samples was determined using wet oxidation procedure as described by (Walkely and Black, 1934; IITA, 2017): 1g of sieved soil samples was placed in a 500 mL Erlenmeyer flask. I0 ml of potassium dichromate ($K_2Cr_2O_7$) 1N and 20ml of concentrated sulfuric acid (H_2SO_4) were added to the soil samples while stirring it to ensure that digestion is completed with good mixing of the soil with the reagents and allowed to rest for 30mins, 200 ml of distilled water, 10 ml of auto phosphoric acid (H_3PO_4) and 1 ml or few drops of 0.16% diphenylamine indicator were slowly added to make the solution violet in color. Then the solution was titrated using 0.5N ferrous ammonium sulphate

($FeNH_4SO_4$) till when the colour changed from violet to green. The percentage organic carbon was then calculated using equation 1:

$$POC = \frac{MeK_2Cr_2O_7 - MeFeSO_4 \times 0.003 \times 1.33}{weight\ of\ soil\ sample\ used} \times 100 \text{ .... Eq. 1}$$

Where:
POC = Percentage organic carbon
$MeK_2Cr_2O_7$ = ml equivalent of potassium dichromate used
$MeFeSO_4$ ml = equivalent of ferrous ammonium sulphate used
0.003 = the correction factor
1.33 = the conversion factor

Determination of Soil Total Nitrogen

Soil total nitrogen was determined using Micro-Kjeldahl digestion method as modified (Jones, 1991). The method requires two steps: first, high temperature (330 to 350°C) digestion in concentrated sulfuric acid (H_2SO_4) using the digestion distillation apparatus in the presence of a catalyst (such as Cu), which converts organic N to inorganic ammonium (NH_4) and, second, is the distillation using distillation apparatus where the formed NH_4 will be determined by titration using equation 2.

$$PSTN = \frac{TV \times M \times NF \times VD}{weight\ of\ soil\ sample\ used \times aliquot} \times 100 \text{ .... Eq. 2}$$

Where:
PSTN = Percentage soil total nitrogen
TV = Titre value
M = Molar
NF = Nitrogen factor
VD = Volume of the distillate

Statistical Analysis

Data collected were subjected to descriptive statistics, whereby values obtained were summarized in tables with the estimated mean and standard error.

RESULTS

Soil Organic Carbon

The soil organic carbon in Gidan Amamata Eucalyptus plantation was estimated and the averages with corresponding standard errors from the selected plots are presented in Table 1. the result showed that soils from the plantation has very low content of soil organic carbon (0.64%). Values of organic carbon obtained within the sample depth of 0-15cm ranged from 0.36 to 1.06% with a mean of 0.73%, while values obtained within the sample depth of 15-30cm ranged from 0.28 to 0.86% with mean of 0.54%. However, soil organic carbon was more on the surface (0-15cm) depth than on the sub-soil (15-30cm), except in plot four (4) and six (6) where soil organic carbon within the depth of 15-30cm (0.78%) is higher than that of the topsoil (0.69%), within sample depth of 0-15cm (0.36%) and 0.40% for 15-30cm was obtained respectively.

Table 1: Soil organic carbon in Gidan Amamata Eucalyptus Plantation

Plots	Sample Depth (0-15cm) (%)	Standard Error	Sample Depth (15-30 cm) (%)	Standard Error
1	0.86	0.14	0.63	0.08
2	1.04	0.10	0.74	0.07
3	0.76	0.37	0.60	0.17
4	0.69	0.10	0.78	0.18
5	1.06	0.12	0.86	0.20
6	0.36	0.09	0.40	0.21
7	0.52	0.17	0.35	0.05
8	0.56	0.22	0.28	0.06
9	0.83	0.24	0.47	0.19
10	0.58	0.07	0.29	0.09
Mean	0.73	0.16	0.54	0.13
Grand Mean			0.64	

Soil Total Nitrogen

The values of soil total nitrogen and standard error are presented in Table 2, revealed that the plantation soils have relatively low content of soil total nitrogen (0.059%). Considering the total nitrogen values obtained within the sample depth of 0-15cm, low values were recorded which ranged from 0.040 to 0.075% with the mean of 0.062%, while within the sample depth of 15-30cm, values obtained ranged from 0.039 to 0.067% with the mean of 0.056%. However, soil total nitrogen seems to be concentrated at the topsoil (0-15cm) than at the sub-soil (15-30cm) despite being very low.

Table 2: Soil total nitrogen in Gidan Amamata Eucalyptus Plantation

Plots	Sample Depth (0-15cm) (%)	Standard Error	Sample Depth (15-30cm) (%)	Standard Error
1	0.068	0.0092	0.057	0.0067
2	0.070	0.0063	0.067	0.0082
3	0.060	0.0075	0.055	0.0067
4	0.066	0.0097	0.061	0.0083
5	0.068	0.0078	0.060	0.0087
6	0.065	0.0035	0.057	0.0046
7	0.075	0.0084	0.066	0.0056
8	0.062	0.0037	0.053	0.0093
9	0.049	0.0090	0.043	0.0075
10	0.040	0.0070	0.039	0.0013
Mean	0.062	0.0072	0.056	0.0067
Grand Mean			0.059	

DISCUSSION

Generally, the values of soil organic carbon obtained in all the plots of study site vary with respect to vegetative cover and depth. It however agrees with what was reported by McCarty *et al*. (2010), that soil organic carbon tends to be concentrated in the topsoil, topsoil ranges from 0.5 to 3.0% organic carbon for the most upland soils and soils with less than 0.5% organic carbon are mostly limited to desert areas.

Soil organic carbon tends to be more concentrated in the topsoil (McCarty *et al*., 2010), however, it is applicable in this plantation except in some parts of the site (plots four and six) where deviation was observed in which soil organic carbon within the sub-soil were higher than that of the topsoil and this can be attributed to leaching as a result of lack of vegetative cover due to indiscriminate felling of the planted trees and this agreed with what was reported by USDA (2014), that leaching is the sinking down of dissolved soil nutrients beyond the topsoil.

Nevertheless, it is also important to know that the concentration of soil organic carbon within the topsoil of most of the plots of can be possibly because of its vegetative cover, thereby giving room for more leave litters, however this fall within what was reported by Hughes *et al*. (2010) that soil organic carbon is divided between living soil biota and dead biotic material derived from biomass, together which comprises the soil web.

Basically, total nitrogen increases with increase in organic matter. According to Jha *et al*. (2000), if the soil is rich in organic matter, it is rich in total nitrogen. Moreover, Haans (2001) reported that the availability of nitrogen depends upon the amount of properties of organic matter.

Considering the total nitrogen values obtained from the study site, soil total nitrogen seems to be concentrated at the topsoil than at the sub-soil despite being very low. These low values must be due to the relatively low organic matter content of the soil which agreed with what Silver *et al.* (2000) reported that savannah soils are generally low in total nitrogen with values ranging from 0.008 to 0.29%.

According to USDA (2014), total nitrogen tends to be relatively low in soils with little or no vegetative cover as a result of tree felling (plant removal) and also Nitrate-nitrogen is usually more subject to loss as a result of plant removal.

The low soil total nitrogen observed in study site can also be attributed to the low amount of the properties of organic matter content of the soil as analyzed by Haans (2001).

Moreover, due to the indiscriminate felling of Eucalyptus trees in the plantation, volatilization can easily set in which agreed with what was reported by USDA (2014), that volatilization is one of the significant loss mechanisms through which total nitrogen leaves the soil.

CONCLUSION

It can be concluded from the findings of this study that soils from Gidan Amamata Eucalyptus Plantation have relatively very low soil organic carbon content (0.64%), which still serves as carbon sink due to presence of trees and also being a plantation enhances the possibility for more organic carbon to be sequestered.

However, soils from the study area indicated that the soil total nitrogen content is relatively very low (0.059%), which is as a result of presence of low organic matter and properties of the organic matter content. Hence, the soil of the study site is considered to be low in fertility.

There is need for the management of this plantation to invest in sustainable land management (SLM) practices that have the potentials of improving land productivity such as soil carbon enhancing practices (SCEPs); like composite manure, contour planting.

Illegal felling of Eucalyptus stands should be prevented or at least reduced in order to curtail the emission or the liberation of nitrogen into the atmosphere.

Further research should be carried out to estimate other aspects of macro and micro nutrient contents of the study area.

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