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ORIGINAL RESEARCH ARTICLE

Determination of soil organic carbon content of agricultural soils for proper soil management in Matazu and Musawa, Katsina State, Nigeria

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ABSTRACT
Soil organic carbon is a significant parameter for estimating the global carbon cycle, which makes great sense in soil management and future climate scenario prediction. This work uses 30 heterogeneous soil samples from agricultural and non-agricultural farmlands and soil erosion areas in Matazu and Musawa LGAs to determine soil organic carbon content at the field level in Matazu and Musawa Local Government Areas, Katsina State, Nigeria. Soil samples were meticulously collected from the 0-10cm depth using a hand auger. These samples were obtained from three distinct clusters: agricultural and non-agricultural farmlands and soil erosion areas. The selection of sample locations considered the varied soil types, historical land use, and management practices. Ten soil samples were randomly gathered within each cluster, ensuring a representative and diverse set of samples for analysis. The Warlkey and Black and Hydrometer methods were used to determine the soils' organic carbon contents and particle size distribution, respectively. The data obtained were analyzed using SPSS 23 software. Two-sample t-tests and analysis of variance (ANOVA) were carried out. The soil organic carbon contents of the studied area were 0.29 ± 0.16 g/kg (0.16 – 0.34 g/kg) and 0.28 ± 0.14 g/kg (0.14 - 0.36 g/kg) for Matazu and Musawa, respectively. The study concludes that the organic carbon content helps improve sustainable agricultural productivity due to proper and efficient land use management practices.

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soil organic carbon, soil quality, soil fertility, carbon cycle, particle size distribution

INTRODUCTION

Soil Organic Carbon (SOC) is a part of the much larger global carbon cycle that involves carbon cycling through the soil, vegetation, ocean, and the atmosphere. The SOC pool stores an estimated 1500 pgC in the first meter of soil, which is more carbon than contained in the atmosphere (roughly 800 pgC) and terrestrial vegetation (500 pgC) combined (FAO and ITPS, 2015). This phenomenal SOC reservoir is not static but is constantly cycling between the different global carbon pools in various molecular forms (Kane, 2015). While CO_2 (carbon dioxide) and CH_4 (methane) are the main carbon-based atmospheric gases, autotrophic organisms (mainly plants), as well as photo- and chemo-autotrophic microbes, synthesize atmospheric CO_2 into organic materials. Dead organic material (mainly in plant residues and exudates) is incorporated into the soil by soil fauna, leading to carbon inputs through organic material transformation by heterotrophic microorganisms (FAO and ITPS, 2015). This organic material transformation process results in a complex biogeochemical mixture of plant litter compounds and microbial decomposition products at various stages of decomposition (Von Lützow *et al.*, 2016) that can be associated with soil minerals and occluded within aggregates, enabling SOC persistence in soil for decades, centuries or even millennia (Schmidt *et al.*, 2011). CO_2 is emitted back into the atmosphere when microorganisms decompose soil organic matter (SOM) (or mineralize). SOC considerably influences soil quality and plant growth and governs various physical, chemical, and biological processes in the soil environment (Gomez *et al.*, 2018).

Due to climate change, land degradation, and biodiversity loss, soils have become one of the most vulnerable resources in the world (FAO and ITPS, 2015). Notwithstanding the enormous scientific progress, protecting and monitoring soil resources at national and global levels still face complicated challenges impeding effective on-the-ground policy design and implementation that varies widely from region to region (FAO and ITPS, 2015). There is still insufficient global support for

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protecting and conserving the world's soil resources (FAO and ITPS, 2015).

The importance of Organic Carbon (OC) in soils abounds in literature and cannot be overemphasized. SOC influences soil physical fertility (Blair *et al*., 2006), soil chemical properties (Carter, 2002), and soil biological properties (Bauer and Black, 1994). It also improves soil quality (Lal, 2006), and crop productivity as well as improvement in sustainable use of agricultural soils (Nwite and Okolo, 2017).

The presence of SOC and its related nutrients contribute positively and effectively to soil resilience. Most recently in a systematic review, Obalum *et al*. (2017) highlighted the importance of soil organic matter as the sole indicator of soil degradation thus stressing the need for preserving the SOC pool. Nevertheless, owing to the disastrous environmental consequences of global climate change, recent concern have shifted from importance of Carbon in food production to more concerted studies on the quantities, distribution, kinds, and dynamics of carbon in different ecosystems (Onweremadu *et al*., 2007; Lal *et al*., 2007; Anikwe, 2010; Gelaw *et al*., 2014; Nwite and Okolo, 2017).

Akpa *et al*. (2016) reported a SOC concentration range of 4.2 and 23.7 g kg^{-1} in the top 30 cm and a range of 2.6 and 9.2 g kg^{-1} at 0-15 cm soil depth. However, almost half of the SOC stock was found in the topsoil (0–30 cm) layer, which represents the rooting depth of many agronomic crops and is more easily affected by management practices. Many studies have provided evidence that the retention or incorporation of crop residues may increase carbon input while decreasing the soil's carbon loss rate (Anikwe 2010; Nwite and Alu, 2017; Mbah *et al*., 2017). Agricultural and other land use practices have a significant influence on the amount and duration of carbon sequestration in the soil before it is returned to the atmosphere (Anikwe, 2010).

Research on soil organic carbon for the last couple of decades has focused on changes in carbon storage due to changes in land use and management practices. With diverse climates and soil types, results of SOC storage under different land uses and soil management practices in Nigeria are often conflicting and, in some cases, inconsistent with the findings of Nwite and Okolo, 2017. This work aims to determine soil organic carbon contents of agricultural soils for proper soil management in Matazu and Musawa, Katsina State, Nigeria.

MATERIALS AND METHODS

Site Description

The experiment was carried out in two different locations in the Southern Part of Katsina State, namely Matazu and Musawa (Longitude 7^{0}4^0'E and Latitude 12^{0}14' N and 7^{0}40'11 East of the Greenwich Meridian and latitude 12^{0}7'48 North of the equator, respectively. The rainy season of the Matazu and Musawa areas is between May and September, and it peaks in August. The rainfall ranges from 5 – 6 months (750 – 850 mm annually), based on the average of 10 years from 2000 to 2009. It is characterized by conventional rainfall (dry and wet climate) followed by the long dry season of 6 – 7 months(Meteorological Unit, 2012). The mean maximum temperature of the Musawa area is 39 ^{o}C in April and May. During the high rainy season, the average maximum temperature is 38 ^{o}C; in December, the average temperature is 20 ^{o}C (Meteorological Unit, 2012). When fully saturated, water vapor in the atmosphere (air) is compared to what the air can hold. The minimum relative humidity of Musawa is 18% from December to January and the maximum is 95 % around July to September (Meteorological Unit, 2012). Soils are a mixture of rock particles loosened by weathering, mineral salts, and dead vegetation matter. In the southern part of Katsina State, the covering material is largely clayey soil, about five meters deep, and very fine in texture. The soils of Musawa are light clay in nature, but due to drift deposits resulting in sandy soils (Chude *et al*, 2012). The land in the study areas is used to cultivate crops such as guinea corn, maize, millet, sorghum, groundnut, soybean, rice, melon, and other vegetable crops. Tree crops such as mango, cashew, and other economic trees are also found in the areas.

Sample Collection

Thirty (30) soil samples were meticulously collected from 0 -10 cm depth using a hand auger. These samples were carefully obtained from three distinct clusters: agricultural farmlands, non-agricultural farmlands, and soil erosion areas. The selection of sample locations considered the varied soil types and the historical land use and management practices. Ten soil samples were randomly gathered within each cluster, ensuring a representative and diverse set of samples for analysis. Different sections of neighboring soil were combined and thoroughly mixed to create composite samples during collection.

Sample preparation is recognized as the major source of errors and may affect the final results if not done properly. Therefore, close attention was paid to every sample to avoid cross-contamination of the soil samples, amongst other precautions.

Laboratory Methods

Soil Organic carbon contents were determined using standard laboratory procedures for Warlkey and black(dry combustion) method situated at the Soil Science Research Laboratory, Department of Soil Science, Faculty of Agriculture, Ahmadu Bello University Zaria, Kaduna State, Nigeria. The particle size distribution was determined by Gee and Bauder's (2018) method. The soil samples were sealed in a polyethylene bag, firmly tied, and labeled to avoid cross-contamination of the samples. Samples were spread on cardboard sheets, and all foreign materials were removed. Then, the textural classifications of the thirty (30) soil samples from the Agricultural, Non-Agricultural, and Soil Erosion Areas were contrasted with

USDA soil degradation standards (USDA, 2001) and discussed under fertility-related variables.

Determination of Particle Size Distribution

The determination of the particle size distribution of < 2 mm size fractions was measured by the hydrometer method as described by Gee and Bauder (1986), using sodium hexametaphosphate ($NaPO_3$) as the dispersing agent. This was conducted by adding 100 mL of $NaPO_3$ to 50 g of soil sample and mechanically agitating using a mechanical shaker for 15-20 minutes. Then, the concentrated hexanosulphate was transferred slowly into a 1000 mL measuring cylinder. Then time was set to mark the level of 1000 mL of addition of deionized water, then the temperature reading of the samples was taken after 40 seconds. The samples were also stirred after 2 hours using a plunger to determine the percentage of clay content in the soil samples.

The corrected hydrometer readings C_R(g/L) were obtained by subtracting the blank reading R_L(g/L) from the hydrometer readings in the soil suspensions (g/L) and adding 0.36 g/L for temperature readings above 20 ^{0}C.

The mathematical expression can be shown as follows;

$$C_R = R - R_L + (0.36\ T) \times 100 \quad (1)$$

Where T = Room temperature at 20 ^{o}C

The percentages by weight of the SILT + CLAY and SAND fractions are given by;

$$\text{Clay} = \frac{(\text{corrected 2 hours reading} - \text{Blank}) \times 100}{weight\ of\ dry\ soil\ taken} \quad (2)$$

$$\text{Silt} = \frac{(\text{corrected 40seconds reading} - \text{Blank}) \times 100 - \%\ \text{Clay}}{weight\ of\ dry\ soil\ taken} \quad (3)$$

Sand = 100 – (clay + silt)

Therefore, the samples can now be classified according to the USDA or International Systems of Textural Classification (ISTC).

Determination of Soil Organic Carbon

The SOC was measured by weighing 1g of soil into a 250 mL Erlenmeyer flask, then 5 mL of $K_2Cr_20_7$ was added using a pipette, and the flask was swirled gently to disperse the soil. 10 mL of concentrated hydrogen Tetraoxosulphate (vi) (H_2SO_4) was rapidly added from a measuring cylinder and swirled for 1min. The time was set to allow the flask to stand on asbestos sheets for 10 minutes. 100 mL of distilled water was also added to the flask to let it cool, then 3 drops of phenanthroline were added to the indicator. Titration was conducted with Ammonium Ferrous Sulphate Solution for the burette to determine the endpoint by observing from the blank, which served as a control for titration. The second portion of the soil samples was passed through a 2 mm sieve to determine particle size distribution in H_2O. Therefore, the test soils were non – calcareous, with only organic soil carbon. Before analyses, all visible plant and animal residues were removed from soil samples, and then the remaining soil samples were sieved using a 0.25mm or 0.5mm sieve. Elemental Carbon Analyzer was used in this research.

$$\text{Organic Carbon (OC)} = \frac{(5mL\ k_2cr_2o_7 - 10mL\ H_2so_4) \times 0.003 \times 100 \times f}{weight\ of\ dry\ soil\ taken}\ \text{g/kg} \quad (4)$$

Where f = 1.33 as a correction factor

w = 1g of dry soil taken

$$\text{Organic Carbon (OC)} = \frac{(\text{Blank titre} - \text{Actual titre}) \times 0.3 \times m \times f}{weight\ of\ dry\ soil\ taken}\ \text{g/kg} \quad (5)$$

Where m is the concentration of ferrous ammonium sulfate.

f is the correction factor.

Data Analysis

The field data were analyzed using SPSS version 23.0 and MINITAB 17.0 computer packages to determine the mean, Standard Deviation (SD), and Coefficient of Variance (CV %). The Analysis of Variance (ANOVA) was performed on SOC contents to determine the mean differences.

RESULTS AND DISCUSSION

Soils Characteristics

The descriptive statistics of the results for the studied sites (Matazu and Musawa) were presented in Figures 1 and.2, respectively. The particle size distribution of the soil indicates Sandy Loam (SL) texture at 0.15 cm depth at its locations. Sand is the dominant fine earth fraction in the Matazu Farming System Area with a mean value of 73.60, followed by silt, which is also dominant in the Matazu Soil Erosion Areas with a mean value of 20.40 and clay, which is the highest or dominant in Matazu soil erosion areas with a mean value of 12.00. The clay is highest or dominant in Musawa Farming System Area with a mean value of 13.60, and the silt is dominant in Musawa SEA. Lastly, sand is the same in all sites of the Musawa LGA, with a mean value of 70.80.

In general, the texture of the soils showed an irregular decreasing trend, with sandy loam greater than sandy silt loam greater than sandy clay. The soils of the study sites exhibited an irregular trend in particle size distribution with a high proportion of sand in Matazu FSA. There is a high proportion of clay with a value of 13.60 % in Musawa FSA, which shows that the Agricultural farmland of Musawa had the highest percentage of clay content in the soil compared with Matazu, which has the lowest value of 11.20%. It also indicates that Musawa Agricultural farmland has more soil nutrients and fertility, which may translate to the production of higher agricultural products since the land is favorable for the farming system. For Matazu, the percentage contents are displayed in Figure 1. Clay is the same for all sites in Matazu Farming System Area (MTZFSA); the contents range from 15.20% to 20.40% for silt. For sand, the percentage (%) of sand ranges from 68.40% to 73.60%, with FSA having the highest and SEA having the lowest percentage. All these are presented in Figure 1.

For Musawa, the percentage contents are displayed in Figure 2. Looking at the figure, the clay content ranges from 8.80% to 13.60%, as for silt, the percentage ranges from 15.60% to 20.00%, the figures for sand showed a maximum concentration of 71.20 in Soil Erosion Area (SEA) and a minimum concentration of 70.80% for both Farming System Area (FSA) and Non Farming System Area (NFSA).

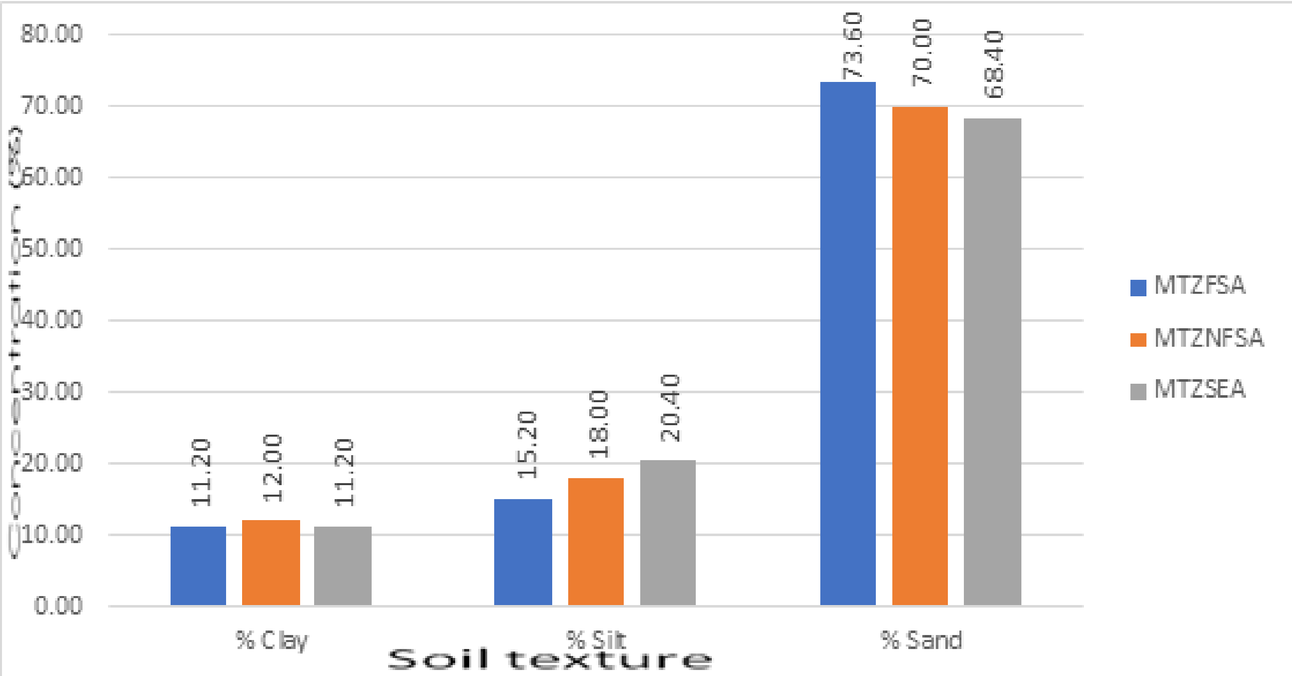

Figure 1: Soil textural classification for all the Matazu Local Govt Area sites.

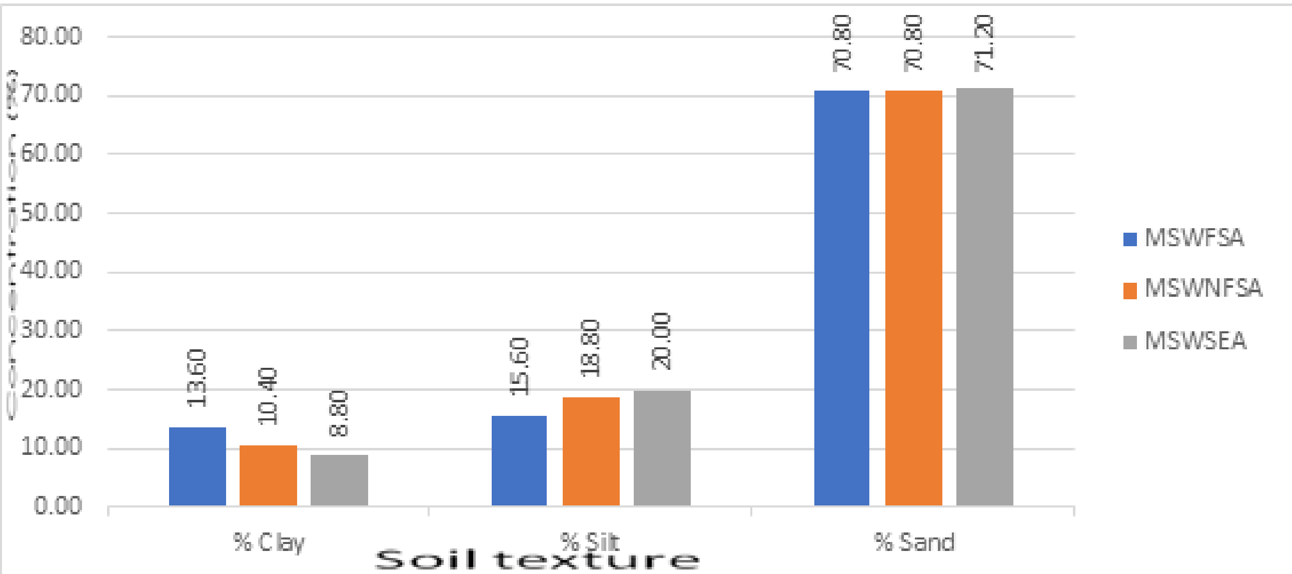

Figure 2: Soil textural classification for all Musawa Local Govt Area sites.

Soil Organic Carbon Contents

The results of the soil organic carbon as obtained using automated carbon analyzer were analyzed using SPSS version 23 and the descriptive statistics of the results were presented in Table 1. The results obtained for soil organic carbon revealed that the mean value for OC content is 0.3622 g/kg with a standard deviation of 0.1185 g/kg in the Matazu Farming System Area (FSA). Meanwhile, the mean value for OC content is lower in Musawa FSA, 0.3420 g/kg, with a standard deviation of 0.2250 g/kg, than in Matazu. This indicates that Matazu Farming

System Area (FSA) has a higher amount of organic carbon content in its farmland than Musawa LGA. This result corroborates that of (Martin *et. al.,* 2019). T-test and ANOVA were carried out to ascertain the level of difference between the soil organic carbon content in all the considered sites (farming, non-farming, and erosion) between the two local governments (Musawa and Matazu). The results indicate a statistically insignificant difference ($P > 0.05$) between the soil organic carbon contents of the two local governments for all the considered sites.

The soils' Organic Carbon (OC) content ranged from (0.16 g/kg – 0.36 g/kg). The OC content is dominant or higher in Matazu FSA compared with other sites and all the sites from Musawa. This indicates that Matazu soils have a high percentage of OC compared to Musawa, and also Matazu soils will be suitable for farming and in terms of agricultural production that will yield many crops as a result of the richness in soil nutrients, organic decayed matter and soil fertility of the soils of the site.

According to the guidelines for rating soil fertility indicators suggested by Esu (2011), the soils of the study area could be categorized as moderate to low amounts of organic carbon content (0.35 g/kg). Compared with copious literatures (Esu, 2011; Akpan and Oyetola, 2021), the OC content decreased with increasing depth. The surface soils (0 -15 cm depth) contained higher organic carbon content than subsurface soils (20 - 30 cm depth). The high organic carbon content could be attributed to the high litter and crop residues at the surface layers and the rapid rate of organic matter mineralization. This agrees with the findings of (Amara and Momoh, 2014).

Table 1: Descriptive Statistics of Concentration of Organic Carbon (g/kg) across the sites.

Variable	N	Mean(g/kg)	SD(g/kg)	Minimum	Maximum
MTZFSA(OC)	5	0.36	0.11	0.25	0.50
MTZNFSA(OC)	5	0.33	0.15	0.08	0.50
MTZSEA(OC)	5	0.16	0.10	0.01	0.30
MSWFSA(OC)	5	0.34	0.22	0.11	0.62
MSWNFSA(OC)	5	0.24	0.15	0.06	0.47
MSWSEA(OC)	5	0.31	0.13	0.16	0.45
MTZA(OC)	15	0.28	0.14	0.01	0.50
MSWA(OC)	15	0.29	0.16	0.06	0.62
GFSA	10	0.35	0.17	0.11	0.62
GNFSA	10	0.28	0.15	0.06	0.50
GSEA	10	0.24	0.13	0.01	0.45

MTZ-Matazu, MSW-Musawa, FSA- Farming System Area, NFSA-Non Farming System Area, SEA-Soil Erosion Area, A-All sites, GFSA-General Farming System Area, GNFSA-General Non Farming System Area, GSEA-General Soil Erosion Area, OC-Organic Carbon, N-Number of samples, SD-Standard deviation.

CONCLUSION

The determination of soil organic carbon contents of agricultural soils for proper soil management in Matazu and Musawa was the primary objective of this study, and soil analysis was carried out to determine the level of organic carbon contents in the soils. The soils of the study sites were moderate in organic carbon contents and were favorable for agricultural farm practices. The soils of the study sites had suitable particle size distribution. Mainly the soils are Sandy Loam (SL).

Therefore, It is recommended that enough compost manure be artificially supplemented to soils of the study sites for growth and yield of crops needing higher levels of nutrients and to enhance the level of carbon storage in the farm lands for proper and efficient farm management practices.

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AUTHOR CONTRIBUTIONS

Matazu M.B. and Bello S. contributed substantially to the data's acquisition, analysis, and interpretation. Matazu M.B. performed the experiments. All authors discussed the basic structure of the manuscript, and Matazu M.B finished the first draft. Rabiu N, and Garba N.N, reviewed and edited the draft. All authors read and approved the submitted manuscript, agreed to be listed, and accepted the version for publication.

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