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Distribution of Soil Organic Carbon in Ox-Drawn and Reduced Tillage System at Wuro Madi, Girei, Adamawa State, Nigeria

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ABSTRACT

Background and Objective: Tillage is one of the basic and important components of agricultural production technology that influences agricultural sustainability through its effects on soil processes, properties and crop growth. This research work aimed to investigate the distribution of soil organic carbon (SOC) in Ox-drawn and reduced tillage systems in semi-arid regions. **Materials and Methods:** The composite soil sample was collected after the harvest, at three different replicates each at Ox-drawn plough (OP) and RT, at three different depths, 0-15, 15-30 and 30-60 cm depth, the samples were air dry at room temperature in the laboratory, sieved and stored in a clean label polythene bag for the analysis. The analyzed data were subjected to analysis of variance using SAS statistical software and descriptive analysis was used to quantify the normal distribution. **Results:** Soil properties showed statistically significant differences between the two tillage practices. In OP the organic carbon ranges from 0.698 to 1.466%, while at the reduced tillage (RT) it ranges from 0.549 to 1.087%. There were significant ($p<0.05$) differences between the tillage treatment and the various sampling depth in soil organic carbon distribution. Soil organic carbon was higher in OP. Generally, the contents of SOC decreased with an increase in soil depth. Soil pH ranged from 4.50 to 5.74 in the two soil profiles and generally increased with increasing soil depth. According to the percentages distribution of sand, silt and clay, sand dominated and recorded the highest value in both OP and RT. Loamy sand dominates the textural class. The OP practices resulted in high soil organic carbon. **Conclusion:** It can be concluded that OP was found to be better in improving the soil organic carbon and other physical properties of the soil in the research area.

KEYWORDS

Ox-drawn, reduced tillage, distribution, organic carbon, soil pH

INTRODUCTION

Tillage is the manipulation of the soil into a desired condition by mechanical means: tools are employed to achieve some desired seedbed. Soil is plough to kill and suppress weeds growth, to improve soil spore space and to manage crop residues[1]. Soil tillage influences the sustainability of soil resources through its effects on soil properties. Proper practice of soil tillage can improve related soil-related problems, while improper tillage may cause a whole range of undesirable problems such as erosion. Tillage is one of the

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agricultural management practices that involve the pulverization of soil to create a good seedbed for seed place and plant growth by mechanical means. Soil is tilled to change its structure, control weeds and manage crop remains. Tillage, a basic and important component of agricultural production technology influences agricultural sustainability through its effects on soil processes, properties and crop growth[2].

A plough or plow is a farm tool used for pulverizing the soil before sowing seed or planting. Ploughs were originally drawn by oxen and horses (animals), but modern farms are drawn by machines. A plough may have a wooden or iron frame with a blade attached to cut and loosen the soil. Ox-drawn plough tillage refers to the series of operations "most commonly or historically used in a given field to prepare a field for planting or seed placement".

Soil is the largest carbon pool in the terrestrial ecosystem and has a strong ability to store organic carbon, which is critical for mitigating global warming caused by increasing atmospheric carbon dioxide[3]. Soil strongly interacts with the atmosphere and plants which makes soil an important role in regulating the global carbon cycle[4].

The distributions of soil organic carbon are influenced by many factors, including soil pH and soil texture. Although soil pH was generally said not to influence the mineralization processes of soil organic matter, the breakdown and nitrification processes of soil organic matter are quite sensitive to soil pH as reported by Kemmitt *et al.*[5]. Soil pH was reported to control a series of soil processes, such as soil organic matter turnover, nutrient bioavailability and microbial activity, through which soil pH greatly affects the decomposition of soil organic matter[6]. Soil texture refers to the soil particle size distributions of percentage sand, silt and clay and is believed to be essential for understanding soil physicochemical properties in terrestrial ecosystems[7]. Generally, clay and fine silt particles can protect soil organic matter from being decomposed by a physiochemical process due to their high surface activity and larger specific surface area[6].

Tillage practices may also influence the distribution pattern of soil organic carbon (SOC). It was observed higher SOC concentration in the surface layers in no-tillage than in conventional tillage practice, but a higher concentration of SOC in the deeper soil layers of reduced tilled plots where crop stubbles are incorporated through tillage[8]. Conservation tillage practices are operative management practices to increase SOC[9]. Conversely, other studies have reported that no-tillage without crop residue resulted in lesser or no change in SOC Govaerts[10]. Organic carbon is important for agricultural production because organic matter helps to improve soil structure and capacity for exchanging cations and holding water, thus exerting positive impacts on soil fertility[11,12].

Several research revealed that the concentration of soil organic carbon is affected by many factors; such as land use type, organic matter input and rate of decomposition[13]. The concentration of organic carbon is highly influenced by land use types and soil depth[14]. Therefore, studying the distribution of SOC is essential in providing a reference for the development of soil management strategies. The objective of this study was to quantify and compare the effect of tillage on the distribution of soil organic carbon under the Ox-drawn and reduced tillage system.

MATERIALS AND METHODS

Location and extent of the study area: The research was conducted at Mararaba Daware, Girei local government area of Adamawa State. Adamawa State is located in the North Eastern part of Nigeria. It lies between Latitude 7 and 11°N and between Longitude 11 and 14°E. It shares a boundary with Taraba State in the South and West, Gombe State in its North-west and Borno State to the North. The state has an international boundary with the Cameroon Republic along its eastern side. It has a land area of about 38,741 km^2 Alkasim *et al.*[15].

Methodology: The study was carried out at the end of the rainy season, immediately, after the harvest in October, 2021. The soil properties were determined at three soil depths (0-15, 15-30 and 30-60 cm) to capture the farming zone around the experimental area. The three soil depths were determined using the centimeter rule. Eighteen soil samples were collected randomly from the two fields, (OP and RT) using a soil auger.

To quantify the percentage of sand, silt and clay content, the hydrometer method was used as described by Bouyoucos[16]. Soil reaction (pH) was determined using supernatant suspensions of a 1:2 soil-to-water ratio, as described by Carter and Gregorich[17]. Organic carbon was determined using the Walkley and Black[18].

Statistical analysis: Descriptive Statistics was used to assess the normal distribution of the data for parameters analyzed in the laboratory. Data collected from the laboratory analysis were also subjected to a t-Test, using SAS Statistical (9.3 version) software. The significant means were separated using LSD at a 5% level of probability.

RESULTS AND DISCUSSION

The result of the particle size distribution revealed that tillage has an effect on the distribution of soil particles and shows a significant difference in the percentage of sand and silt, but no significant difference was observed with clay contents at ($p<0.05$). The percentage of sand ranges from 74-92% with a mean value of 82.11 at OP, while at RT it ranges from 72-82% with a mean of 78.67%, of silt ranges from 5.2-11.2 with a mean value of 7.91% at OP, while at RT it ranges from 10.2-13.2 with a mean value of 9.47%, while the percentage clay ranges from 2.8-14.8 with a mean of 9.98% at OP, while that of RT ranges from 4.8-14.8 with a mean of 11.87%. The OP recorded a higher percentage of sand, while RT recorded the highest percentage of silt and clay. There was also a significant difference at various sampling depths (Table 1). In this case, particle sizes have differed significantly due to soil disturbance. The predominance of sand particles in arid and semi-arid climates is not uncommon because many of them were formed from Aeolian and water deposits carried from several kilometres, as reported by Imadojemu *et al.*[19]. The predominance of sand particles in this research work was in line with the finding of researchers[20-22].

Distribution of soil organic carbon: The soil organic carbon at reduced tillage increase and then decrease with sampling depth, while in conventional tillage, SOC decreases with an increase in sampling depth. SOC at OP ranges from 0.7-1.47%, with a mean of 1.08, while at the RT it ranges from 0.5-1.09% with a mean of 0.89%. There was a significant difference observed at ($p<0.05$), between the different tillage operations. There was also a significant difference between the various sampling depth, at 0-15 cm depth the SOC ranges from 1.27-1.47% with a mean value of 1.05, at 15-30 cm depth it ranges from 0.83-1.16 with a mean value 1.04 and at 30-60 cm depth it ranges from 0.70-1.10% with a mean value 0.86% (Table 1). Ox-drawn plough recorded the highest mean value of SOC (1.09%), while reduced tillage was recorded (0.89%). Tillage operation incorporates and brings crop residues closer to microbes thereby increasing organic matter decomposition as reported by Lal[23].

Table 1: Ranking of means of some selected soil properties of the study area

Tillage operation	Sand (%)	Silt (%)	Clay (%)	pH (H_2O)	SOC (%)
Tillage					
Ox-drawn plough	82.11^a	9.98^b	7.91^a	7.216^a	1.080^a
Reduced tillage	78.67^b	11.87^a	9.47^a	6.262^b	0.886^b
LSD ($p<0.05$)	3.201	1.062	3.292	0.3526	0.1494
Depth (cm)					
0-15	84.167^a	10.03^b	5.80^b	7.097^a	1.05^a
15-30	80.0^b	11.2^{ba}	8.8^{ba}	6.702^{ba}	1.04^{ba}
30-60	77.00^b	11.53^a	11.4^a	6.418^b	0.858^{ba}
LSD ($p<0.05$)	3.92	1.3	4.03	0.4319	0.1829

Mean with the same letter in the column are not significantly different, SOC: Soil organic carbon and H_2O: Water

The SOC contents of soils above 30 cm in the two soil profiles were higher than those of deep soils, which might be attributed to the external input of organic matter. The topsoil of the two soil profiles would receive more organic matter from trees and grass because plant and soil microbe residues were the main raw materials of soil organic matter that were the main holder of SOC[12].

There was a significant ($p<0.05$) difference at the different sampling depths (Table 1), this can be attributed to the effect of tillage on the decomposition and incorporation of the plant residues in the soils. The highest value was recorded at the surface layer of conventional tillage (1.47%), while the lowest was recorded at reduced tillage (0.55%) at 0-15 cm depth and shows a trend of increasing and decreasing with depth at the reduced tillage field, this is in agreement with findings of Tesfaye *et al.*[14]. This can be attributed to less green biomass or plant cover as observed during the research period. More plant cover was seen at the OP field and this material is the source of soil organic carbon when incorporated and decayed in soil. SOC contents mostly depended on the compositions of parent materials, but the leaching and disintegration processes of soil organic matter will change the OC contents, making it important to explore the profile distributions of OC, contents and various soil properties[3]. Figure 1 displayed the difference between OC and the difference tillage, this show that tillage affects OC and on the y-axis organic carbon is high in OP than the RT. Figure 2 showed the effect of depth on the OC, suggesting that a change from deep would result in a greater increase of organic carbon at the surface layer. The percentage of organic carbon on the y-axis decreases with an increase in depth on the x-axis, which indicates that the depth has an effect on the vertical distribution of organic carbon. The higher OC at the surface can be a result of the decomposition of organic materials. Figure 3 showed the difference in OC between tillage and depth; the difference in OC with depth indicates that the RT results in less OC on the y-axis as can be seen and compared with the OP, which can be a result of less pulverization or less incorporation of organic materials. OP has a higher value at the surface area with a change from shallow to deep layer on the x-axis, showing a greater loss (and greater variability around the mean) than shallow RT. Overall, SOC contents decreased with increasing soil depth in the two tillage operations.

The result of soil reaction (pH) in water ranges from 5.46-6.75 in the reduced tillage plot, while convention tillage ranges from 6.41-7.66, with conventional tillage having a mean value of 7.22 and reduced tillage with a mean value of 6.26. The soil reaction was rated slightly acidic to neutral reaction, according to the

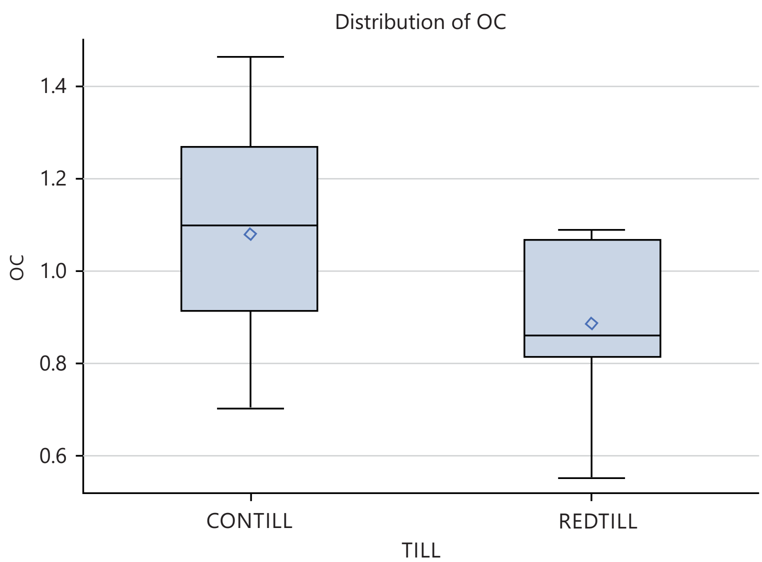

Fig. 1: Distribution of SOC at CONTILL (OP) and REDTILL

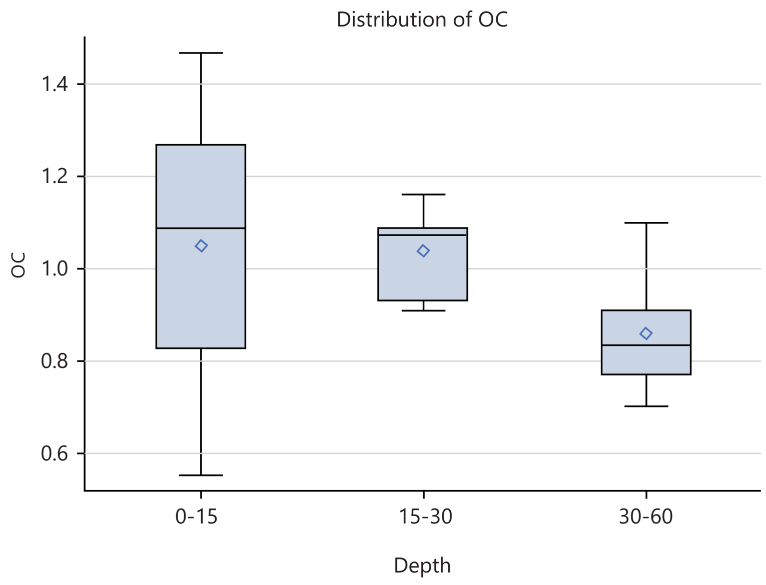

Fig. 2: Distribution of SOC at different depths

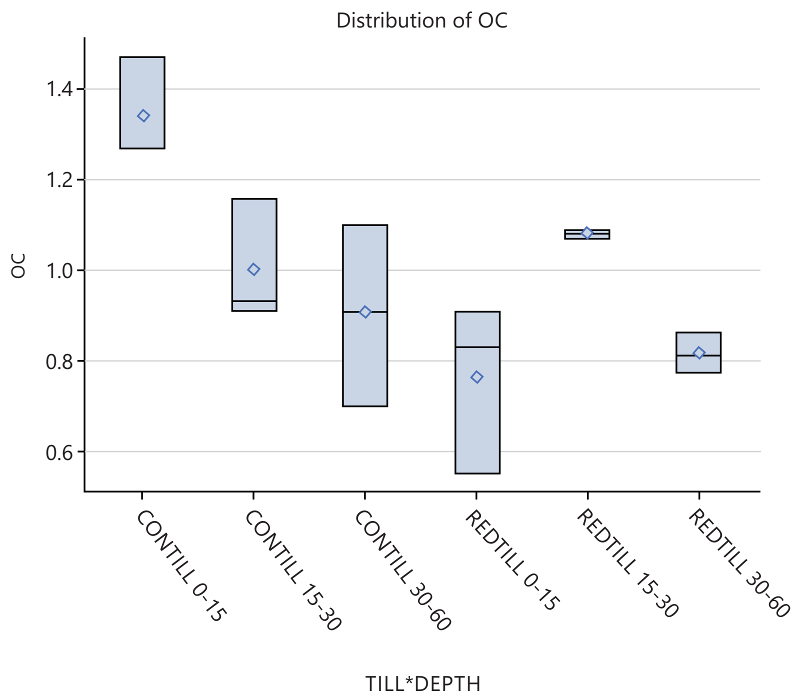

Fig. 3: Distribution of SOC at different depths in CONTILL (OP) and REDTILL

Braus and Whitman[24] rating scale. There was a significant ($p<0.05$) difference between conventional and reduced tillage operations, this can be as a result of tillage operation, which affects the rate of leaching.

There was also a significant ($p<0.05$) difference across the sampling depth, the increase and decrease in soil reaction can be attributed to the nature of organic matter and the availability of H^+ ions released from the decomposition of organic materials. In some soil sampling depths, pH values tend to increase and then decrease along with soil depth, which is particularly obvious in the ox-drawn plough. This can be a result of suspected iron and manganese nodules, which is a combination of iron and manganese oxides essentially. These oxides react with hydrogen ions (H^+) and thus the pH values would not be too low in that layer, as also reported by Zhou *et al.*[12]. Generally, pH values fall within the normal range for crop growth and for optimum release of plant nutrients. Soil pH values in the two soil profiles generally tended to decrease with soil depth which was in line with the distribution of SOC contents.

As one of the most important soil chemical properties, soil pH might influence the plant utilization of organic matter and the structure of the terrestrial ecosystem by regulating biogeochemical processes in soils and affecting other soil properties[25].

Based on the findings of this study, the major limitation against sustainable conservation of soil moisture content is overgrazing and lack of cover crops. The low moisture content recorded in the minimal tillage might be a result of high water infiltration and low organic matter content. The low organic matter and high bulk density recorded can be improved by increasing the organic matter level through the incorporation of organic residues such as plant residues, farmyard manure and mulching. This practice will improve water retention capacity and soil's physical and chemical properties.

In view of the results obtained, it suffices to recommend that ox-drawn plough utilization should be encouraged in areas with low soil moisture content as it effectively conserves valuable physical and chemical soil properties. The effect of tillage practices on soil moisture content as observed in this research has significantly affected the soil moisture content and other soil properties.

CONCLUSION

The study revealed that tillage systems significantly ($p<0.05$) affect the distribution of soil organic carbon in the study area, with OP recording the highest value as compared with the RT, soil organic carbon decreases with the increase in depth. The OP should therefore be encouraged in an area with similar soil and weather condition.

SIGNIFICANCE STATEMENT

This study discovered that OP can benefit in the restoration, incorporation and storage of SOC in an area with similar soil and weather condition. This study will the researcher to revile the effect of different tillage on the distribution, storage and plant uptake of SOC that many researchers were not able to explore. Thus, a new theory on tillage and SOC distribution may be postulated or arrived at.

REFERENCES

1. Bekele, D., 2020. The effect of tillage on soil moisture conservation: A review. Int. J. Res. Stud. Agric. Sci., 6: 30-41.
2. Khursheed, S., C. Simmons, S.A. Wani, T. Ali, S.K. Raina and G.R. Najar, 2019. Conservation tillage: Impacts on soil physical conditions-an overview. Adv. Plants Agric. Res., 9: 342-346.
3. Saint-Laurent, D. and L. Arsenault-Boucher, 2020. Soil properties and rate of organic matter decomposition in riparian woodlands using the TBI protocol. Geoderma, Vol. 358. 10.1016/j.geoderma.2019.113976.
4. Yu, X., W. Zhou, Y. Chen, Y. Wang and P. Cheng *et al*., 2020. Spatial variation of soil properties and carbon under different land use types on the Chinese Loess Plateau. Sci. Total Environ., Vol. 703. 10.1016/j.scitotenv.2019.134946.
5. Kemmitt, S.J., D. Wright, K.W.T. Goulding and D.L. Jones, 2006. pH regulation of carbon and nitrogen dynamics in two agricultural soils. Soil Biol. Biochem., 38: 898-911.
6. Zhou, W., G. Han, M. Liu, J. Zeng, B. Liang, J. Liu and R. Qu, 2020. Determining the distribution and interaction of soil organic carbon, nitrogen, pH and texture in soil profiles: A case study in the Lancangjiang River Basin, Southwest China. Forests, Vol. 11. 10.3390/f11050532.

7. Zhao, C., M. Shao, X. Jia and C. Zhang, 2016. Particle size distribution of soils (0-500 cm) in the Loess Plateau, China. Geoderma Reg., 7: 251-258.
8. Dolan, M.S., C.E. Clapp, R.R. Allmaras, J.M. Baker and J.A.E. Molina, 2006. Soil organic carbon and nitrogen in a Minnesota soil as related to tillage, residue and nitrogen management. Soil Tillage Res., 89: 221-231.
9. Obour, A.K., M.M. Mikha, J.D. Holman and P.W. Stahlman, 2017. Changes in soil surface chemistry after fifty years of tillage and nitrogen fertilization. Geoderma, 308: 46-53.
10. Govaerts, B., N. Verhulst, A. Castellanos-Navarrete, K.D. Sayre, J. Dixon and L. Dendooven, 2009. Conservation agriculture and soil carbon sequestration: Between myth and farmer reality. Crit. Rev. Plant Sci., 28: 97-122.
11. de Blécourt, M., A. Gröngröft, S. Baumann and A. Eschenbach, 2019. Losses in soil organic carbon stocks and soil fertility due to deforestation for low-input agriculture in semi-arid Southern Africa. J. Arid Environ., 165: 88-96.
12. Zhou, W., G. Han, M. Liu and X. Li, 2019. Effects of soil pH and texture on soil carbon and nitrogen in soil profiles under different land uses in Mun River Basin, Northeast Thailand. PeerJ, Vol. 7. 10.7717/peerj.7880.
13. Zhang, J., X. Wang and J. Wang, 2014. Impact of land use change on profile distributions of soil organic carbon fractions in the Yanqi Basin. CATENA, 115: 79-84.
14. Tesfaye, M.A., F. Bravo, R. Ruiz-Peinado, V. Pando and A. Bravo-Oviedo, 2016. Impact of changes in land use, species and elevation on soil organic carbon and total nitrogen in Ethiopian Central Highlands. Geoderma, 261: 70-79.
15. Alkasim, A., A.A. Hayatu and M.K. Salihu, 2018. Estimation of land surface temperature of Yola, North Eastern Nigeria using landsat-7 ETM+ satellite image. Energy Power Eng., 10: 449-456.
16. Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analyses of soils. Agron. J., 54: 464-465.
17. Carter, M.R. and E.G. Gregorich, 2007. Soil Sampling and Methods of Analysis. 2nd Edn., CRC Press, Boca Raton, Florida, ISBN: 9781420005271, Pages: 1264.
18. Walkley, A. and I.A. Black, 1934. An examination of the degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29-38.
19. Imadojemu, P.E., D.N. Osujieke and S.N. Obasi, 2017. Evaluation of fadama soils along a toposequence proximal to River Donga in Wukari Area of Northeast Nigeria. Int. J. Agric. Rural Dev., 20: 3150-3158.
20. Sauwa, M.M., U.U. Waniyo, A.L. Ngala, M. Yakubu and S.S. Noma, 2014. Influence of tillage practices on physical properties of a sandy loam in semi-arid region. Bayero J. Pure Appl. Sci., 6: 76-83.
21. Mukungurutse, C.S., N. Nyapwere, A.M. Manyanga and L. Mhaka, 2018. Pedological characterization and classification of typical soils of Lupane District, Zimbabwe. Int. J. Plant Soil Sci., Vol. 22. 10.9734/IJPSS/2018/39609.
22. Salem, H.M., C. Valero, M.Á. Muñoz, M.G. Rodríguez and L.L. Silva, 2015. Short-term effects of four tillage practices on soil physical properties, soil water potential, and maize yield. Geoderma, 237-238: 60-70.
23. Lal, R., 2004. Soil carbon sequestration impacts on global climate change and food security. Science, 304: 1623-1627.
24. Braus, M.J. and T.L. Whitman, 2021. Standard and non-standard measurements of acidity and the bacterial ecology of northern temperate mineral soils. Soil Biol. Biochem., Vol. 160. 10.1016/j.soilbio.2021.108323.
25. Hong, S., P. Gan and A. Chen, 2019. Environmental controls on soil pH in planted forest and its response to nitrogen deposition. Environ. Res., 172: 159-165.