DISCOVERY

58(319), July 2022

Effects of land uses on soil organic carbon stock and soil total nitrogen stock in Anyigba, Kogi State, Nigeria

Paul Omaye Joseph[1]*, Ojomah Frank Ojochegbe[2]

To Cite:
Paul OJ, Ojomah FO. Effects of land uses on soil organic carbon stock and soil total nitrogen stock in Anyigba, Kogi State, Nigeria. *Discovery*, 2022, 58(319), 800-806

Author Affiliation:
[1,2]Department of Soil and Environmental Management, Faculty of Agriculture, Kogi State University, Anyigba, Nigeria.

***Corresponding author:**
Department of Soil and Environmental Management, Faculty of Agriculture, Kogi State University, Anyigba, Nigeria.
E-mail: joseph.po@ksu.edu.ng

Peer-Review History
Received: 06 May 2022
Reviewed & Revised: 11/May/2022 to 15/June/2022
Accepted: 20 June 2022
Published: July 2022

Peer-Review Model
External peer-review was done through double-blind method.

ABSTRACT

Soil organic carbon (SOC) and soil total nitrogen (STN) contents and stocks are crucial for enhancing soil quality and increasing C - reservoir. To understand how land use may impact these concentrations in the study area, Guinea savannah zone of Nigeria, we analysed the effects of different land uses (oil palm plantation, cashew plantation, forest land and arable land) on SOCs and STNs in Anyigba. Soil samples (192) were collected from the land uses at different soil depths (0 – 15 and 15 – 30 cm) with three replications and analysed using standard methods. Land use significantly affected all parameters measured and depths. The study reveals that the effects of land use on SOCs and STNs is greater in the topsoil than the subsoil. Oil palm plantation exhibited the highest SOCs (7.21 %) and STNs (0.36 %). The content of SOCs and STNs at 0 - 15 cm depth was in the order; oil palm plantation (7.21 %) > forest land (5.52 %) > cashew plantation (4.93 %) > arable land (3.84 %) and oil palm plantation (0.36 %) > forest land (0.28 %) > cashew plantation (0.25 %) > arable land (0.19 %) respectively, which revealed the potentials of oil palm plantation, forest land and cashew plantation for SOC and STN sequestration. The study provides land users with the information to improve soil quality, conserve C and N stocks for ecological sustainability and climate change mitigation by practising agroforestry.

Key words: Soil organic carbon, Soil total nitrogen, Forest land, Arable land, Oil palm plantation, Cashew plantation

1. INTRODUCTION

Humanity is currently facing increasingly severe challenges, such as climate change, nitrogen deposition, increased carbon-dioxide concentrations, and related impacts on the changes of land use, which require a toss-up between the protection of ecosystems against unhelpful land use for goods and services and direct human needs (Sanderman *et al.*, 2017, Smith *et al.*, 2016). Supplying the demand for food and fibre production and the reduction of greenhouse gases (CO_2, CH_4, and N_2O) to the atmosphere is a great challenge being faced by humanity (Conti *et al.*, 2014; Magnusson *et al.*, 2016), Forest systems are efficient in carbon sequestration, storage and resulting reduction of carbon dioxide emissions from soils (Silva *et al.*, 2016). Research on the significance of land-use as

DISCOVERY
SCIENTIFIC SOCIETY

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

a carbon sink (Aquino *et al.*, 2017; Asaye and Zewdie, 2013) or source (Kassa *et al.*, 2017) in recent decades has gained prominence in studies on reducing the emission of greenhouse gases to the atmosphere (Lal, 2018). For food and fibre production, we must adopt management practices that promote total organic carbon stock and total nitrogen stock in the soil.

Soil organic carbon (SOC) and nitrogen (N) storage is directly or indirectly affected by humans, land use changes, soil erosion, climate change, microbe's communities and its activities and soil physicochemical properties (Manning *et al*., 2015, Smith *et al*., 2016, Morrison *et al*., 2019, Zhu *et al*., 2021). Soil has the highest organic carbon stocks in the terrestrial ecosystem which twice exceeds the atmospheric content, and about three times more than the quantity found in vegetation. Soil as the largest terrestrial reservoir of carbon plays vital role in conserving plant nutrients as well as ameliorating excess CO_2 emission. Climate change caused by increasing levels of CO_2 and other greenhouse gases has been recognized as a reproving issue of global environment worry. This present-time model of global warming is attracting expert attention to carbon and nitrogen cycles attributable to swift potential to emission of atmospheric oxides.

Soil is not only a large C - sink but also a fundamental reservoir of nitrogen that can supply essential for plant use. Any infinitesimal change in the soil C or N stocks might cause mark-able impact on the atmospheric carbon dioxide and nitrous oxide concentrations. Conserving the C and N stocks might cause are mark-able impact on the atmospheric carbon dioxide and nitrous oxide concentration. Consequently, conserving C and N stocks is a healthy process that enhance Soil fertility, reduce global warming, and invariably promote sustainable food security and environment safety.

The soil carbon pool is interrupted by various disturbances that influence its storage capacities. Researches in the terrestrial ecosystems have observed changes in land use, urbanization and soil composition as major threats to SOC and STN stock (Shrestha *et al.,* 2012). Other threats to SOC and STN have been agriculture and management practices, vegetation, soil depth and bulk density, slope and topographical characteristics, induced climate factors, soil erosion and landscape position (Shrestha *et al.,* 2012). Primarily, this study focused on vertical distribution of SOC and STN in various land use. However, there is still a wide gap in understanding the dynamic of SOC and STN stock that are influenced by different Land use.

In the past, the government established several land use and soil management programs (such as Directorate of Food-Roads and Rural infrastructure [DFRRI], National agriculture scheme and Green resolutions) which were designed towards sustaining the ecosystem. Sadly, these projects ceased to function since the last two decades because they failed to enhance soil quality. Therefore, with the growing population, demand for more food, and the risks of global warming, there is an urgent need to restore and conserve the soil (Ghimire *et al.,* 2018). This research aims to solve the following problems (i) the spatial distribution of SOC and STN contents (ii) which land use has the greatest potential to retain C and N stored in the soil (iii) how do soil physicochemical properties affect SOC and STN. In order to answer these questions, this study to assess soil organic carbon and total nitrogen stocks as affected by land use was developed. The knowledge of soil organic carbon and soil total nitrogen concentrations and stock is indispensable for improving soil quality, food production and mitigating carbon emission.

2. MATERIALS AND METHODS

Study area

The experiment was conducted in Anyigba (Lat. 7° 29′ N and Long. 7° 11′ E) in the Guinea savannah zone of Nigeria. Kogi State has a bimodal rainfall that peaks in July and September. The mean annual rainfall is 1,808 mm at Anyigba (Amhakhian *et al.,* 2012). The temperature shows some variation throughout the year. Average monthly temperature varies from 17°C to 36.2°C. Relative humidity is moderately high and varies from an average of 65 - 85% throughout the year (Amhakhian *et al.,* 2012).

Sample collection

The random sampling technique was used to collect soil from the study area. The number of sampling points was 32. The depths of the soil layers were 0 – 15 cm and 15 – 30 cm, each of which was repeated 3 times, for a total of 192 soil samples. The soil samples were collected from four (4) land use types (oil palm plantation, arable land, cashew plantation and forest land).

Soil properties

In this study, soil organic carbon (SOC) content was determined according to Walkley and Black (1934) after 2 mm sieving and drying at 40°C, and kjeldahl method was used in the determination of soil total nitrogen content in samples collected. The soil samples were digested with concentrated H_2SO_4 in the presence of a catalyst to determine the nitrogen content of the samples. Percentage total nitrogen was thereafter calculated (Sparks *et al.*, 1996). The pH of the soil solution was taken using the pH electron (McLean, 1982). The particle-size distribution was measured with hydrometer after sample dispersion with sodium

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

hexametaphosphate (Gee and Bauder, 1985). The textural class of the soil was determined using the USDA textural triangle classification system for soil (USDA, 2008).

The soil bulk density was determined using core sampler method where samples contained in the core rings of known weight, height and diameter were weighed and the fresh weights recorded, then oven dried at 105^{0}C until constant weight was obtained after which the dry weight were also recorded (Al-Shammary *et al.*, 2018). The following equation was then used for determining the bulk density.

$$\text{Bulk Deansity} = \frac{\text{Mass of oven dried soil}}{\text{Bulk volume of the soil}}\ \text{g/cm}^3$$

Total porosity was determined from the relationship between bulk density and particle density assuming a particle density value of 2.65 g cm^{-3}.

$$f_t = 1 - \frac{Bulk\ density}{Particle\ density} \times 100\ (cm^3/cm^3\ or\ \%)$$

Data calculations

SOC and STN stocks were computed using the following formula by Ellert and Bettany (1995);

$SOC\ stock\ (SOCs) = SOCc \times BD \times SD \times 10{,}000\ m^2 ha^{-} \times 0.001\ mg\ kg^{-}$

$STN\ stock\ (STNs) = STNc \times BD \times SD \times 10{,}000\ m^2 ha^{-} \times 0.001\ mg\ kg^{-}$

Where;

SOCs or STNs = Soil Organic Carbon Stock or Soil Total Nitrogen stock

SOCc or STNc = Soil Organic Carbon contents or Soil Total Nitrogen contents

BD = Bulk density

SD = Soil depth

Statistical analysis

Data collected were analysed using Analysis of Variance (ANOVA) of GENSTAT Discovery Software to test the differences in SOC contents, STN contents, SOC stock, STN stock, bulk density, total porosity, pH, soil depths, land use changes and their interactions. Significant means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of probability. The Pearson correlation coefficient was used to determine whether there is a significant correlation between soil properties.

3. RESULTS

The result of the soil analysis is presented in Table 1. Results revealed that the pH of the soils are slightly acidic across land uses and depth. The organic carbon contents of the soil ranged from 1.05 – 2.02 and 0.64 – 1.09 % at 0 – 15 and 15 – 30 cm depth respectively, with oil palm plantation having the highest concentration at both depths. Oil palm plantation had the highest concentration of total nitrogen (0.101 %) at 0 – 15 cm depth, while cashew plantation had the highest concentration (0.064 %) at 15 – 30 cm depth. Oil palm plantation had the lowest concentration of bulk density (1.19 g cm^{-3}) at 0 – 15 cm, while cashew and oil palm plantations had the lowest (1.10 g cm^{-3}) at 15 – 30 cm depth. Oil palm plantation had the highest level of porosity (55%) at 0 – 15 cm depth, while cashew and oil palm plantations the highest level at 15 – 30 cm depths. Oil palm plantation had the highest concentration of SOC and STN at both depths (7.21, 3.60 and 0.36, 0.18 respectively). Results obtained from this study revealed that the textural class of the various different land uses at both depths were loamy sand except for oil palm plantation which was sandy loam.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

Table 1: Effect of land use on soil physical and chemical properties at 0 – 15 and 15 – 30 cm depths

Land Use	pH	%OC	%TN	BD (g cm^{-3})	TP (%)	SOCs (%)	STNs (%)	Sand (%)	Silt (%)	Clay (%)	Textural Class
						0 – 15 cm					
Forest land	6.03^{a}	1.45^{b}	0.073^{b}	1.27^{b}	52^{c}	5.52^{b}	0.28^{b}	84.37^{c}	2.77^{d}	12.86^{c}	Loamy Sand
Oil palm plantation	5.87^{d}	2.02^{a}	0.101^{a}	1.19^{e}	55^{b}	7.21^{a}	0.36^{a}	78.37^{e}	4.77^{b}	16.86^{a}	Sandy Loam
Cashew plantation	5.94^{c}	1.19^{c}	0.060^{bc}	1.22^{c}	54^{b}	4.93^{c}	0.25^{c}	85.37^{b}	3.77^{c}	10.86^{e}	Loamy Sand
Arable land	5.77^{f}	1.05^{e}	0.053^{cd}	1.38^{a}	48^{d}	3.84^{d}	0.19^{e}	83.37^{d}	3.77^{c}	12.86^{c}	Loamy Sand
						15 – 30 cm					
Forest land	6.00^{b}	0.84^{f}	0.042^{de}	1.20^{de}	55^{b}	3.02^{f}	0.15^{f}	84.37^{c}	3.77^{c}	11.86^{d}	Loamy Sand
Oil palm plantation	5.83^{e}	1.09^{d}	0.055^{cd}	1.10^{f}	58^{a}	3.60^{e}	0.18^{e}	77.37^{f}	6.77^{a}	15.86^{b}	Sandy Loam
Cashew plantation	5.88^{d}	0.72^{g}	0.064^{bc}	1.10^{f}	58^{a}	2.61^{g}	0.21^{d}	83.37^{d}	4.77^{b}	11.86^{d}	Loamy Sand
Arable land	5.75^{g}	0.64^{h}	0.036^{e}	1.21^{cd}	54^{b}	2.11^{h}	0.13^{g}	86.37^{a}	2.77^{d}	10.86^{e}	Loamy Sand
LSD	0.02	0.03	0.005	0.04	1.15	0.48	0.01	0.92	0.73	0.88	

4. DISCUSSION

Anthropogenic activities were an important factor influencing the vertical distributions of SOC and STN concentrations and stocks. This fact is supported in this study with the findings that forest land, oil palm and cashew plantation land use types showed higher nutrients when compared to arable land. For example, oil palm plantation had more than 16 % content of SOC relative to the value obtained under arable land. This result was consistent with recent studies (Chukwudi *et al.,* 2018; Liu *et al.,* 2018). Higher SOC and STN concentrations in oil palm plantation might be attributed to increased residues decomposition from surface litter addition which increased SOC. And increase in SOC content has been strongly correlated with high STN content (Diwediga *et al.,* 2017). On the other hand, low SOC and STN contents as observed in arable land might be explained by unfavourable soil conditions due to the use of plant residues as livestock feed, along with unsustainable management practices which intensify soil erosion (Negasa *et al.,* 2017; Li *et al.,* 2017). Frequent harvesting and uprooting of the plants as a result of grazing and farming inevitably removed nutrients from the soil and exposed the available organic matter (OM) to soil moisture, aeration and unfavourable decomposing agents (Haileslassie *et al.,* 2005). This practice promoted rapid degradation and mineralization of the available OM, thus decreasing SOC and STN concentrations and stocks. Vegetation types and root systems under different land use have also been reported as a primary factor influencing the stocks of SOC and STN (Li *et al.,* 2017). For instance, leguminous plant species (such as *Leucaena leucocephala, Gliricidia sepium, Pentaclethra macrophylla*), and plant species with broad leaves, large canopies, and extensive fine root systems dominated forest land, cashew and oil palm plantation. These flora species contributed to high SOC and STN in forest land, cashew and oil palm plantation relative to arable land (Table 1).

Soil depth also showed a significant effect on SOC and STN contents with high concentrations found in the topsoil (0 – 15 cm) layer. This result was consistent with several studies in this concept (Chukwudi *et al.,* 2018). Large input from plant litter fall and residues might be the reason for high SOC and STN contents in the topsoil. However, variations the concentrations of SOC and STN between the top and sub-soil layers have been observed in various studies. Some researchers observed high SOC concentration on the top soil (Chukwudi *et al.,* 2018), while others observed more in the sub-soil layer (Gelaw *et al.,* 2014). Therefore, this differs based on land use types.

The BD in arable land was higher than that found in other land use types. This could be related to the traditional agricultural practices including tillage, litter removal, and intensive cultivation which in turn decreased SOC (by rapid mineralization of SOM)

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

and consequently elevated the BD. Several studies have confirmed the effects of tillage on BD and SOC (Chukwudi *et al.*, 2018; Negasa *et al.*, 2017). A study in the northern highlands of Iran reported the compaction of surface soil layer as a result of intensive cropping which evidently led to the increase in BD (Emadi *et al.*, 2008). Oil palm and cashew plantations recorded lower BD when compared to the disturbed arable land; this might be related to the natural attributes of these ecosystems. A contrasting result was reported in a loess hilly-gully catchment of China, where cropland had the lowest BD (Liu *et al.*, 2018). The disparity in the results could be attributed to differences in physical geographical features (climate, soil, slope) and agricultural management systems. Soils from forest land, oil palm and cashew plantations have higher SOC as compared to arable land due to continuous addition of SOM through litter input which decreased the BD. This result is in agreement with the studies from the watershed in Ethiopian highland, and Northern China as reported by Addis *et al.* (2016) and Wang *et al.* (2015), respectively. Another study in southern Nigeria by Udom and Ogunwole (2015) also observed lower BD in forested areas, but high in cultivated soil areas. With respect to soil depth, higher BD was found in topsoil across all land use types. This result was inconsistent with some authors' study which reported an increase in BD with depth (Qi *et al.*, 2018). Differences in soil make-up and predominant farming techniques might have caused the dissimilarity in results.

The soil total porosity significantly and negatively correlated with SOC and STN contents (Table 2). Similarly, some authors have reported that porosity decreases with an increase in SOC and STN owing to quick decomposition (Narayan and Anshumali, 2016). Chukwudi *et al.* (2018) reported a contrary finding. They observed significant positive correlation between soil porosity and SOC which could be attributed to the fact that SOC promotes binding between soil particles, leading to the formation of stable soil aggregates. Thus, soil porosity increases by absorbing more rainwater inflow and reducing the runoff. Total nitrogen significantly and positively correlated with organic matter. This could be as a result of the decomposition of plant residues leading to the release of nitrogen to the soil.

Table 2: Correlation matrix between soil chemical and physical properties under different depths (0–30 and 30–60 cm).

	pH	OC	TN	BD	TP	Sand	Silt	Clay	SOC	STN
pH	1									
OC	.227	1								
TN	.270	.806*	1							
BD	-.073	.174	-.025	1						
TP	.110	-.159	.022	-.978*	1					
Sand	.157	-.522*	-.479*	.399*	-.380*	1				
Silt	-.206	.094	.179	-.623*	.596*	-.860*	1			
Clay	-.109	.705*	.593*	-.218	.205	-.955*	.669*	1		
SOC	.290	.984*	.783*	.253	-.232	-.390*	-.021	.580*	1	
STN	.334	.893*	.869*	.043	-.038	-.397*	.063	.542*	.894*	1

5. CONCLUSION

The study observed high concentrations of soil properties in the topsoil across land use types. The study reveals that the effects of land use on SOCs and STNs is greater in the topsoil than the subsoil. The study showed that oil palm plantation exhibited the highest SOCs (7.21 %) and STNs (0.36 %). Land use and soil depth significantly affected SOC and STN concentrations and stocks as well as BD. Arable land had higher BD, while oil palm and cashew plantation had the lowest; indicating that undisturbed ecosystems have lower BD than disturbed systems. This might be related to a decrease in SOC due to poor agricultural practices without conservation methods in the arable land. The low SOCs (2.11 %) and STNs (0.13 %) in arable land call for an urgent introduction of conservative agriculture in the study area which will improve soil quality, conserve C and N stocks for food security and mitigation of climate change.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS

The study observed that the increase in soil porosity leads to the decrease of SOCs and STNs, but an increase in organic carbon leads to the increase in nitrogen in the soil. The conversion of arable land to agroforestry system will help to guide against the risk of releasing excess CO_2 from the topsoil.

Funding

This study has not received any external funding.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

REFERENCES AND NOTES

1. Addis, H., Klik, A. and Oweis, T. (2016). Linking selected soil properties to land Use and hillslope – a watershed case study in the Ethiopian highlands. Soil Water Res. 11:163–171.
2. Al-Shammary, A.A.G., Kouzani, A.Z., Kaynak, A., Khoo, S.Y., Norton, M. and Gates, W. (2018). Soil bulk density estimation methods; A review. Pedosphere, 28(4): 581-596.
3. Amhakhian, S.O. and Osemwota, I.O. (2012). Physical and chemical properties of soil in Kogi State, Guinea Savanna of Nigeria. Nigeria Journal of Soil Science, 22(1): 44 – 52.
4. Aquino, D.N., de Andrade, E.M., de Almeida Castanho, A.D., Pereira Júnior, L.R. and Palácio, H.A.Q. (2017). Belowground Carbon and Nitrogen on a Thinned and Un-Thinned Seasonally Dry Tropical Forest. Am. J. Plant Sci., 8: 2083 – 2100.
5. Asaye, Z. and Zewdie, S. (2013). Fine root dynamics and soil carbon accretion under thinned and un-thinned Cupressus lusitanica stands in, Southern Ethiopia. Plant Soil, 366: 261 – 271.
6. Chukwudi, N., Onyedikachi, J., Okeke, O. F. and Hycienth, N. (2018): Soil organic carbon and total nitrogen stocks as affected by different land use in an Ultisol in Imo Watershed, southern Nigeria, Chemistry and Ecology, 12: 102-121. DOI: 10.1080/02757540.2018.1508461
7. Conti, G., Harguindeguy, N.P. and Quètier, F. (2014). Large changes in carbon storage under different land-use regimes in subtropical seasonally dry forests of southern South America. Agric. Ecosyst. Environ., 197: 68 – 76.
8. Diwediga, B., Le, Q.B. and Agodzo, S. (2017). Potential storages and drivers of soil organic carbon and total nitrogen across river basin landscape: the case of Mo River Basin (Togo) in West Africa. Ecol. Eng., 99:298–309.
9. Ellert, B.H. and Bettany, E.T. (1995). Calculation of organic matter and nutrients stored in soils under contrasting management regimes. Can J Soil Sci. 75:529–538.
10. Emadi, M., Emadi, M. and Baghernejad, M. (2008). Effect of land use change on selected soil physical and chemical properties in north highlands of Iran. J. Appl. Sci., 8:496–502.
11. Gee, G.W. and Bauder, D. (1986). Particle size analysis. In: Dane, J.H. and Topp, G.C. (Eds). Methods of soil analysis. Part 4 Physical methods. Soil Sci. Soc. Am Book Series 5. ASA and SSSA, Madison, W1 pp. 255-293
12. Gelaw, A.M., Singh, B.R. and Lal, R. (2014). Soil organic carbon and total nitrogen stocks under different land uses in a semi-arid watershed in Tigray, northern Ethiopia. Agric. Ecosyst. Environ., 188: 256–263.
13. Ghimire, P., Bhatta, B., Pokhrel, B., Kafle, G., and Paudel, P. (2018). Soil organic carbon stocks under different land uses in chure region of makawanpur district, Nepal. SAARC J. Agri., 16(2): 13-23. DOI: https://doi.org/10.3329/sja.v16i2.40255
14. Haileslassie, A., Priess, J. and Veldkamp, E. (2005). Assessment of soil nutrient depletion and its spatial variability on smallholders' mixed farming systems in Ethiopia using partial versus full nutrient balances. Agric. Ecosyst. Environ., 108: 1 – 16.
15. Kassa, H., Dondeyne, S., Poesen, J., Frankl, A. and Nyssen, J. (2017). Impact of deforestation on soil fertility, soil carbon and nitrogen stocks: The MARK case of the Gacheb catchment in the White Nile Basin, Ethiopia. Agriculture. Ecosyst. Environ., 247: 273 – 282.
16. Lal, R. (2018). Saving global land resources by enhancing eco-efficiency of agroecosystems. J. Soil Water Conserv., 73: 100 – 106.
17. Li, Z., Liu, C. and Dong, Y. (2017). Response of soil organic carbon and nitrogen stocks to soil erosion and land use types in the loess hilly-gully region of China. Soil Till. Res. 166: 1 – 9.
18. Liu, C., Li, Z. and Chang, X. (2018). Soil carbon and nitrogen sources and redistribution as affected by erosion and

deposition processes: a case study in a loess hilly-gully catchment, China. Agric. Ecosyst. Environ., 253:11–22.
19. Magnússon, R.Í., Tietema, A., Cornelissen, J.H.C., Hefting, M.M., Kalbitz, K. (2016). Tamm Review: Sequestration of carbon from coarse woody debris in forest soils. For. Ecol. Manag., 377: 1–15.
20. Manning, P., deVries, F.T., Tallowin, J.R., Smith, R., Mortimer, S.R., Pilgrim, E.S., and Bardgett, R.D. (2015). Simple measures of climate, soil properties and plant traits predict national-scale grassland soil carbon stocks. J. Appl. Ecol., 52: 1188 – 1196.
21. McLean, E.O. (1982). Soil pH and Lime Requirement. In: Methods of Soil Analysis, Part 2: Chemical and Microbiological Properties, Page, A.L., R.H. Miller and D.R. Keeney (Eds.). 2nd Edn., ASA and SSSA, New York, USA., pp: 199-224.
22. Morrison, E.W., Pringle, A., vanDiepen, L.T., Grandy, A.S., Melillo, A.S. and Frey, S.D. (2019). Warming alters fungal communities and litter chemistry with implications for soil carbon stocks. Soil Biol. Biochem., 132: 120 – 130.
23. Narayan, C. and Anshumali (2016). Elemental composition of Sal forest soils around Chota Nagpur Plateau, India. Chem. Ecol. 32(6): 533-549.
24. Negasa, T., Ketema, H. and Legesse, A. (2017). Variation in soil properties under different land use types managed by smallholder farmers along the toposequence in southern Ethiopia. Geoderm. 290:40–50.
25. Qi, Y., Chen, T. and Pu, J. (2018). Response of soil physical, chemical and microbial biomass properties to land use changes in fixed desertified land. Catena. 160:339–344.
26. Sanderman, J., Hengl, T. and Fiske, G.J. (2017). Soil carbon debt of 12,000 years of human land use. Proc. Natl. Acad. Sci., 114: 9575 – 9580.
27. Shrestha, H.L., Bajracharya, R.M. and Sitaula, B.K. (2012). Forest and Soil Carbon Stocks, Pools and Dynamics and Potential Climate Change Mitigation in Nepal 1: 800–811.
28. Silva Araujo, J.K., de Souza Júnior, V.S., Marques, F.A., Voroney, P. and Sousa, R.A. (2016). Assessment of carbon storage under rainforests in Humic Hapludox along a climosequence extending from the Atlantic coast to the highlands of northeastern Brazil. Sci. Total Environ., 568: 339 – 349.
29. Smith, P., House, J.I., Bustamante, M., Sobocká, J., Harper, R., Pan, G. and Paustian, K. (2016). Global change pressures on soils from land use and management. Glob. Change Biol., 22: 1008 – 1028.
30. Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T. and Sumner, M.E. (1996). Methods of soil analysis: Part 3 chemical methods, Soil Science Society of America, American Society of Agronomy, Madison, 1390p
31. Udom, B.E. and Ogunwole, J.O. (2015). Soil organic carbon, nitrogen, and phosphorus distribution in stable aggregates of an ultisol under contrasting land use and management history. J. Plant Nutr. Soil Sci., 178:460–467.
32. UDSA. Tecture, (2008). United State Department of Agriculture (USDA). Conservation service.
33. Walkley, A. and Black, C.A. (1934). An examination of the methods for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science. 27: 29-38.
34. Wang, Z., Guo, S. and Sun, Q. (2015). Soil organic carbon sequestration potential of artificial and natural vegetation in the hilly regions of loess plateau. Ecol. Eng. 82:547–554.
35. Zhu, G.Y., Shangguan, Z.P. and Deng, L. (2021). Dynamics of water-stable aggregates associated organic carbon assessed from delta C-13 changes following temperate natural forest development in China**,** Soil Tillage Res., 205: 1047 – 1082.

ISSN 2278–5469 EISSN 2278–5450 I OPEN ACCESS