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What Regulates Soil Organic Carbon and Total Nitrogen in Agrifarms?

***Priyadarshani Pathak*[1*] *and A.S. Reddy*[2]**
[1]Research Scholar, Department of Biosciences,
Sardar Patel University, Vallabh Vidyanagar-388120, (Gujarat), India.
[2]Associate Professor, Department of Biosciences,
Sardar Patel University, Vallabh Vidyanagar-388120, (Gujarat), India.

(Corresponding author: Priyadarshani Pathak)*

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ABSTRACT: Various factors such as meteorological conditions, land use history, plant functional type, and management approaches can have a substantial impact on carbon and nitrogen dynamics in agro ecosystems. This study highlights how different land use patterns and crop management approaches affect the depth-wise distribution of soil organic carbon (SOC) and total nitrogen (TN) in agricultural lands. The investigation was place on three distinct agricultural farms in Anand, Gujarat. Three different types of selected land use patterns were *viz*. i) Wheat-pearl millet farm (seasonal cropping with one year crop rotation) ii) Banana farm (seasonal cropping with two years crop rotation) and iii) Amla orchard (perennial cropping standing for last fifteen years). The data generated through the present study suggest that plant functional type significantly alters the vertical distribution of SOC and TN. Though SOC at upper layer may be affected by chemical fertilizers and tilling process, but below 20 cm the vertical distribution of SOC is mainly affected by root distribution patterns in the soil. Whereas vertical distribution of TN in all land use patterns was affected by nitrogen based chemical fertilizers. A significant positive correlation was observed between soil organic carbon and total nitrogen at all three land use patterns. It is a crucial need of the hour to conduct accurate, regional based investigations of SOC and TN storage in order to detect variations in carbon and nitrogen sequestration capacity caused by land use pattern changes associated with modern agriculture practices.

Keywords: Sequestration, Soil organic carbon, Soil profile, Total nitrogen, Vertical distribution.

INTRODUCTION

Human-managed ecosystems for agricultural, pasture, and livestock management are known as agro-ecosystems. Agro-ecological studies are critical for sustainable agriculture (Shunfeng *et al*., 2013). Soil organic carbon (SOC) is one of the most significant components of sustainable agriculture since it improves the physical, chemical, and biological qualities of soil in terrestrial ecosystems, as well as helping to predict climate change and its impacts (Krischbaum 2000). SOC improves soil performance in a variety of ways, making it a useful indication of soil health (Liu *et al.*, 2006; Stockmann *et al.*, 2015). Carbon sequestration into soil is regarded as one of the most significant ecosystem services due to its function in climate management (IPCC 2007). Because agriculture occupies over a third of the world's arable land (World Bank 2015), increasing soil organic carbon in agricultural systems will be a critical component of utilizing soil as a sink. If maintained appropriately, the soil may sequester a significant amount of CO_2 from the atmosphere (about 1 Pg C per year) as SOC (soil organic carbon) (Jagadamma and Lal 2010). Around 1500 pg of SOC is held in the soil globally, which is twice as much as in the atmosphere and three times as much as in the biomass above the earth, respectively (Batjes 1996; Lal 2008; Schmidt *et al*., 2011). Because soil is the largest terrestrial source of organic carbon, even small changes in its stock can have a significant impact on atmospheric carbon levels (Stockmann *et al.*, 2013). Tillage, fertilizers, and other management practices have previously placed significant strain on agricultural soil's ability to store and cycle organic carbon, resulting in decreased soil organic carbon (SOC) stocks (Manna *et al.*, 2013). Reduced SOC pools in crop fields reduce soil carbon sink potential and increase greenhouse gas emissions into the atmosphere (Powlson *et al*., 2011; Milne *et al*., 2015; Hussain *et al.*, 2019; Milne *et al.*, 2019). SOC reduction has a significant impact on soil quality also Lal, (2006), particularly physical resistance and resilience (Kay, 1998). Regardless of climatic concerns, increasing SOC content is an environmental and agronomical emergency due to the various benefits of SOC on soil quality, particularly soil fertility in a wide sense (King *et al*., 2020). As a result, increasing the SOC pool on agricultural land by approved management measures has become a global environmental concern (Milne *et al.*, 2015; Ramesh *et al.*, 2019). It is the most realistic and long-term method for reducing soil degradation (Bationo *et al.*, 2007), improving soil health and long-term agricultural productivity (Syers 1997; Lal 2006; Cowie *et al.*, 2011), and lowering CO_2 levels in the atmosphere (Powlson *et al.*, 2011; Plaza-Bonilla *et al.*, 2014). Owing to their potential C-sink character (due to increased C unsaturation), broader land coverage (Murphy and Lugo 1986), and a strong inherent mechanism of nutrient immobilisation, dry tropical ecosystems are particularly relevant in this regard (Singh *et al*., 1989; Srivastava *et al.,* 2016).

In addition to carbon, soil nitrogen (N) is a vital plant mineral nutrient (Epstein, 1972), and it plays an important role in determining soil quality. The availability of nutrients such as nitrogen to enable the growth of new biomass is critical for carbon uptake in terrestrial ecosystems (Thornton *et al.,* 2009). Although nitrogen is necessary for life, its bio-available forms are typically insufficient, limiting plant growth. As a result, in many ecosystems, the N cycle regulates overall soil turnover as well as the functioning of C and N in organic matter (Batlle-Aguilar *et al.*, 2011). The terrestrial and atmospheric components of the feedback between the global climate and the carbon cycle are substantially driven by interactions between the C and N cycles, according to recent modeling by Sokolov *et al.,* (2008) and Thornton *et al.*, (2009). As a result, both managed and natural ecosystems have long identified soil organic carbon (SOC) and total nitrogen (TN) as critical elements that determine soil fertility (Kucharik *et al.*, 2001). They have a substantial impact on the chemical and physical qualities of the soil by releasing nutrients in a form that is favourable for plants through mineralization (Lal, 2004). It's crucial to conduct a regional examination of soil organic carbon (SOC) and total nitrogen (TN) storage to detect variations in C and N sequestration and emission potentials caused by land-use and cover type changes (Li *et al.,* 2014). The C:N ratio, which is the ratio of soil organic carbon (SOC) to total nitrogen (TN), consistently shows changes in decomposition, mineralization rates, and the soil C and N cycle (Huang *et al.,* 2007 and Wiesmeier, 2013). According to Kushwaha *et al.,* (2021) carbon and nitrogen status linked with C:N ratio may play an important function in regulating the mineralization of soil organic materials.

When natural forests are turned to agriculture, the soil structure is altered, allowing microbes to better mineralize organic matter, resulting in SOC loss (Golchin and Asgari 2008). As a result of changes in plant community and land management practices, land use patterns alter the balance between the rate of intake (e.g. plant litter) and output (e.g. SOC mineralization) of soil organic matter (SOM), hence one of the most important elements influencing the SOC pool is land use/land cover change (Dawson *et al.*, 2007, Poeplau and Don 2013). According to Gruneberg *et al.,* (2010) and Vanden Bygaart and Angers (2006) the depth of the soil has Sombrero and De Benito (2010) also pointed out that a complete profile is required to evaluate and compare SOC storage. Song *et al.,* (2016) suggests that deep soil layers provide significant amounts of carbon and should not be ignored when estimating soil carbon. Jackson *et al.,* (1996) found that above and belowground allocation patterns and vertical root distribution for terrestrial biomes and plant functional types, showing differences among grass-, shrub-, and tree-dominated systems. Root distributions affect the vertical positioning of C in the soil, and above- and belowground allocation affects the relative quantity of C that eventually falls to the soil surface from shoots, according to Jobbagy and Jackson (2000). Annual plants (that rely on cycles of ploughing and seed sowing to ensure sufficient productivity) dominate the majority of cropping systems, instead of perennial plants (that are capable of surviving several seasons and years face less disturbance). Perennial farming systems have lately been advocated as a way to maintain soil carbon, and because perennial plants rely on more extensive systems to ensure their survival, they are likely to produce more biomass below ground (Cox *et al.,* 2006). Many organizations, such as the Land Institute (Salina, KS), are striving to develop deep-rooted perennial cereal crops that can produce significantly more belowground biomass while still generating food for humans.

Although environmental factors such as climate (Jobbágy and Jackson 2000; Djukic *et al.* 2010), geography (Garcia-Pausas *et al.* 2007; Egli *et al.*, 2009), soil properties (Evgrafova *et al.*, 2018; Wiesmeier *et al.,* 2019), disturbances due to surface processes (Yoo *et al.*, 2006) and human activity (Bell and Worrall 2009; Morgan *et al.*, 2010) have a substantial impact on SOC variation, we hypothesized that the major determinant of the relative vertical distribution of SOC would be plant functional type, which differs in patterns of allocation. The goal of this study was to see how different types of land use patterns (or plant functional types) and management approaches affected soil biophysical parameters, particularly soil organic carbon and total nitrogen storage, under the same climatic circumstances at different depths. The study also looked into a number of elements that could boost organic carbon and nitrogen levels in these soils. In agro-ecosystems, such research is relatively uncommon.

MATERIALS AND METHODS

The study was conducted on three agricultural farms in Gujarat's Anand district between April and May 2019. Its latitude and longitude are 72º 93' E and 22º 57' N, respectively. The elevation is 39 metres above sea level. The study experiences tropical semi arid climate. The average yearly rainfall (as of 2017) is 715 millimeters. For the year 2017, the highest average temperatures are in May (around 42ºC) and the lowest are in January (around 12ºC). Soil was described as being moderately drained and dark in colour. The three land use patterns that were chosen were: (i) System 1 = wheat-pearl millet farm (seasonal crop with one year crop rotation) wherein life span of each crop is 4 months with shallow root distribution. Pearl millet crop is rotated with wheat crop. This pattern was repeated for more than 10 years. (ii) System 2 = Banana farm (seasonal plant with two year crop rotation). Banana crop stands in the field for about 16-18 months with medium range of root distribution. This pattern was also repeated for more than 10 years in this farm. (iii) System 3 = Amla (Indian gooseberry) orchard (perennial crop). This orchard is of 14 to 15 years old with deep root systems.

The details of farming practices including fertilizer application were obtained through interviews with the farm owners. In all the studied systems, agriculture is practised mostly based on chemical fertilizers.

According to farmers use of chemical fertilizers was maximum in pearl millet farm (three or four times in a year), moderate in banana farm (twice in a year) and very less in amla orchard (once in a year).

Soil sampling: In May 2019 (during the summer season), soil samples were taken and analysed in triplicate from each soil for all depths (from 0-10 cm, 10-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm) using a soil auger through the soil profile. To eliminate fine roots and rock residue, soil samples were combined separately and sieved through a 2 mm mesh screen. Texture, pH and moisture content were all measured in damp soil samples. Soil organic carbon and total nitrogen tests were performed on oven-dried soil samples.

Various physio-chemical properties of soil were analysed using standard methods such as: soil texture by using agriculture and horticulture soil texture kit (HIMEDIA- K108-1KT), pH by Anderson and Ingram method (1993), bulk density by using soil corer as given by Piper (1944), soil moisture by drying the known amount of soil at 105-110ºC for 24 hours, soil organic carbon (SOC) by Walkey Black method (1934), and total nitrogen (TN) by Kjeldahl method (Kjeldahl, 1883).

Statistical Analysis. Multivariate analysis of variance (MANOVA) was performed to examine the significant the studied systems. To analyse the significant variations across the studied systems (i.e. pearl millet farm, banana farm and amla orchard), a multivariate analysis of variance (MANOVA) was performed. Furthermore, Pearson correlation was used to determine the relationship between the various parameters of the investigated variables. All these statistical analyses were done using SPSS 16 statistics package (SPSS Inc., Chicago, IL, USA).

RESULTS

The texture of the investigated soils of different land use patterns was characterised by the content of sand particles ranged from 26 to 46% for pearl millet and banana while it ranged from 50 to 65 at amla orchard; silt ranged from 20 to 33% all the three systems; while clay ranged from 21 to 41% for pearl millet and banana but it only 10 to 25% at amla orchard (Table 1). This result indicates that the amla orchards have more sand and less clay than the pearl millet and banana farms. It could be due to more mechanical disturbance in these farms as a result of repeated ploughing and tilling as opposed to those in almond orchards. All the studied systems, sand particles increased with depth.

Table 1: Variation of soil texture class with soil depth (cm).

Soil Texture class in relation to site and soil depth (cm)									
Depth (cm)	**Sand (%)**			**Silt (%)**			**Clay (%)**		
	Pearl millet farm	**Banana farm**	**Amla orchard**	**Pearl millet farm**	**Banana farm**	**Amla orchard**	**Pearl millet farm**	**Banana farm**	**Amla orchard**
0 to 10	26.6	30	50	33	29	25	40.4	41	25
10 to 20	26.6	32	65	33	29	20	40.4	39	15
20 to 40	33	32	65	26	27	20	41	41	15
40 to 60	33.3	42	65	33.3	31	20	33.4	27	15
60 to 80	40	42	65	26.6	31	17.5	33.4	27	17.5
80 to 100	46	46	65	25	25	20	33.4	21	10

Table 2 shows that different land use patterns have resulted in observable and significant variations in soil physiochemical characteristics with depth (bulk density, pH, moisture, soil organic carbon and total nitrogen).

Soil bulk density, moisture and pH: All of the studied systems had substantial differences (P < 0.001) in bulk density, moisture (%), and soil pH (Table 2). Bulk density increased with depth in all the studied systems (Table 3). The rise in bulk density of soil with increasing soil depth has also been observed previously (Affule *et al.,* 2004; Sharma *et al.,* 2018, Kafle 2019; Magar *et al.,* 2020). Because of the reduced organic matter content and overburden of upper soil layers, bulk density increases with soil depth.

Moisture (%) showed higher values in pearl millet farms, followed by banana farms and then in the amla orchards (Table 3). It must be due to the intensive irrigation used on pearl millet and banana farms as opposed to almond orchards. The pH was also high at the pearl millet farm, followed by the banana farm and then in the amla orchard (Table 3). This must be due to the use of fertilizers (nitrogen based fertilizers), which increase the soil pH in pearl millet farms as compared to those in banana farms. Fertilizer was used sparingly in the amla orchard. In all three systems, the correlation matrix revealed that bulk density and pH were positively correlated with moisture percentage (Table 4).

Table 2: ANOVA table illustrating the association among land use patterns and depths with different physiochemical properties of soil.

Factor	*df*	BD	pH	M	SOC	TN	C/N
LUP	2	9852.8***	1465.2***	11814.2***	16.1***	180.9***	121.1***
D	5	251.1***	49.3***	75.4***	218.6***	667.5***	17.4***
LUPxD	10	38.8***	67.3***	331.0***	3.9***	88.02***	13.1***
Error	36						

*, **, ***, and NS denote significance levels of 0.05, 0.01, 0.001, and not significant respectively. LUP = Land Use Patterns (3 land use patterns i.e. Pearl millet farm, Banana farm and Amla orchard). D = Depth (6 depths i.e. 0 to10; 10 to 20; 20 to 40; 40 to 60; 60 to 80; 80 to 100 cm). BD (bulk density), M (moisture), SOC (soil organic carbon), TN (total nitrogen), C/N (carbon and nitrogen ratio).

Table 3: Variation between soil bulk densities, pH and moisture content with soil depth (cm).

Depth (cm)	Bulk density (g/cm^3)			pH			Moisture content (%)		
	Pearl millet farm	Banana farm	Amla orchard	Pearl millet farm	Banana farm	Amla orchard	Pearl millet farm	Banana farm	Amla orchard
0 to 10	1.7	1	1.3	7.7	7.5	7.2	18.33	13.91	4.1
10 to 20	1.8	1.09	1.4	7.8	7.4	7.2	17.44	9.18	3.87
20 to 40	1.8	1.09	1.4	7.5	7.4	7.3	18.21	7.41	5.6
40 to 60	1.8	1.16	1.5	7.5	7.4	7.3	19.26	5.68	5.9
60 to 80	1.8	1.16	1.6	7.6	7.6	7.3	17.41	5.03	8.3
80 to 100	1.85	1.13	1.6	7.6	7.6	7.3	18.57	5.3	8.6

Table: 4 (Here, N = 52 for all three land use patterns) Correlation matrix illustrating relationship among physicochemical parameters (0 to 100 cm depths). BD (bulk density), pH (soil pH), M (moisture), SOC (soil organic carbon), TN (total nitrogen) and C/N (carbon/nitrogen).

	BD	pH	M	SOC	TN
pH	0.22				
M	0.67^{**}	0.63^{**}			
SOC	-0.25	-0.13	-0.01		
TN	-0.12	0.18	-0.41^{**}	0.79^{**}	
C/N	-0.24	-0.49^{**}	-0.58^{**}	0.56^{**}	-0.79

Here *, ** Correlation is significant at the 0.05 level 0.01 level (two tailed) respectively

Soil organic carbon (SOC), total nitrogen (TN) and C/N ratio: Various factors, such as the history of land use patterns, meteorological conditions, vegetation composition, and land management practices, can have a substantial impact on the dynamics of the carbon stock (Lal, 2008). Tillage, crop and cropping system selection and fertilizer application can all alter the rate of soil organic matter decomposition by affecting soil parameters like moisture, temperature, aeration, and composition (Saljnikov *et al.*, 2013). ANOVA revealed that SOC (%), TN (%) and C/N ratio varied significantly ($P < 0.001$) with land use patterns (LUP), depths (D), and LUPxD (Table 1). For the pearl millet farm, banana farm, and amla orchard, the SOC (%) ranged from 0.54 to 0.10, 0.65 to 0.13, and 0.61 to 0.19, respectively. The Fig. 1 indicate that up to 20 cm statistically significantly higher SOC (%) was observed at the banana farm, followed by amla orchard and lower at pearl millet farm. It must be due to a higher chemical fertilizer input in banana farms than in amla orchard. In the case of the pearl millet farm, besides the high inputs of chemical fertilizers, the degree of tilling, physical disturbance and residue replacement is high and, therefore, the SOC (%) is comparatively lower than those of the other two farms. It showed that a combination of moderate physical disturbance to the soil and the use of fertilizers must be the favouring factors for high SOC (%) in the upper layer (0-20 cm) of the soil. Triberti *et al.*, (2008) found that reducing soil disturbance and incorporating organic material or manure tends to increase SOC stocks. Paudel *et al.*, (2006) showed that SOC deposition was affected significantly by the degree of tillage and residue level in the upper layer of 0 to 10 cm but not in the lower layers. Nevertheless, at all soil depths (up to 100 cm) after 20 cm carbon sequestration potential of amla orchard was maximum followed by banana farm and it was least in pearl millet farm. It must be due to nutrient allocation by roots to the deep soil layer because the distribution of roots was deepest in the amla orchard (having extensively penetrated the deep root system), moderately deep in the banana farm and shallow in the pearl millet farm. With time, more root biomass C has been added to the soil, resulting in increased C sequestration rates. SOC increases must be attributed to a significant increase in root growth and the absence of mechanical soil disturbance, according to Yang *et al.*, (2006) and Figueiredo *et al.*, (2013). Sheng *et al.*, (2015) and Indoria *et al.*, (2018) found that the principal sources of SOC (root biomass, root exudates, and dissolved organic carbon) are transported from the top soil to the deeper layers.

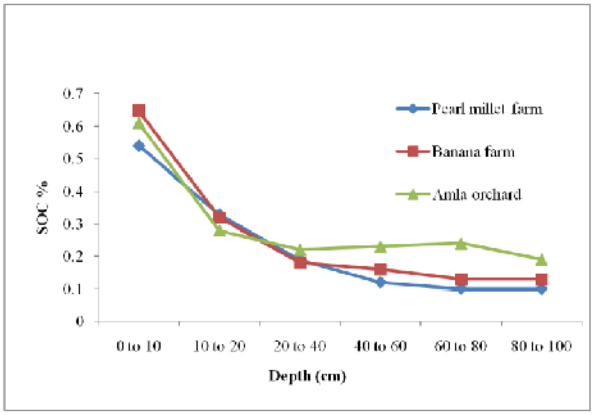

Fig. 1. Variation in SOC (%) with soil depth in three land use patterns.

Nutrient utilization by agricultural crops could also be a contributing factor to such a shift. In all three land use patterns, SOC (%) was highest in the upper 0-10 cm layer, but as we went down, a decreasing trend of SOC (%) was observed. The highest SOC content in the top layer (0-10 cm) in all three land use patterns must be due to carbon inputs from biomass residue and rapid decomposition of litter. Our results are also supported by Woods (1989), who concluded that soil organic carbon was concentrated in the upper layer and decreased with soil depth. Many previous study also found a gradual decrease in the percentage of soil organic carbon with an increase in soil depth (Gautam and Mandal 2013; Magar 2020). Song *et al.,* (2016) after their study in selected forests of China reported that reported that soil organic carbon contents dropped with depth, with the highest concentration in the 0–10 cm topsoil. According to Wells *et al.,* (2012), because the 0-30 cm layers are biologically the most active, the majority of the SOC is found there. VanStraaten, (2015) also reported that SOC is much higher in the top soil (0-15 cm) than in the subsurface layers (15-30 and 30-45 cm). According to Sahoo *et al.,* (2019), the distribution of soil organic carbon stock at various depth classes exhibited a decreasing tendency with increasing depth in all land use types. However, the decreasing tendency was found to be the lowest at amla orchards, followed by banana farms, and the highest at the pearl millet farm.

The values of N (%) ranged from 0.068 to 0.029, 0.085 to 0.016, 0.041 to 0.023 % for pearl millet farm, banana farm and amla orchard respectively. We found that among all the three land use patterns N (%) content was maximum at upper 0 to 20 cm in banana farm followed by pearl millet farm and minimum at amla orchard. It must be again due the influence of chemical fertilizers (mostly nitrogen based), less disturbance and residue replacement at banana farm as compared to that of pearl millet farm and amla orchard. After 20 cm depth highest TN (%) was found at pearl millet farm while banana farm and amla orchard had almost same quantity. More TN (%) at lower layers in pearl millet farm may be due to large levels of soluble organic nitrogen (N) fertiliser chemicals seeping into deeper strata, as anticipated by Diekow *et al.,* (2005) (as pearl millet farm experienced more fertilizers followed by banana wheat farm and least at amla orchard).When compared the trend of TN (%) in all the land use patterns with depth it is found that as we go down TN (%) first decreased up to certain depth and then become almost constant (Fig 2). Malo *et al.,* (2005) showed a drop in TN as we moved from top soil to subsoil layers, claiming that the decrease in total nitrogen with increasing depth was attributable to decreased humus with depth. The decreasing tendency of nitrogen content with increasing depth was also reported by many researchers (Tiwari *et al.,* 2013; Gautam and Mandal 2013; Pandey and Bhusal 2016; Kafle 2019). We observed that the TN (%) follows a nearly identical trend to the SOC (%) at all depths and in all three land use patterns, regardless of quantity (except from 10-20 to 20-40 cm of pearl millet farm of where N content increased). Parras-Alc´antara *et al.,* (2013) also discovered that TN concentration was higher in locations where SOC was high, indicating a positive C-N relationship. According to Xu, (2019) also TN content is substantially associated with SOC content. It was found that in all studied systems SOC was positively correlated with TN at all depths. Kafle (2019) also reported positive correlation between SOC and TN in the tropical community forest of Nepal.

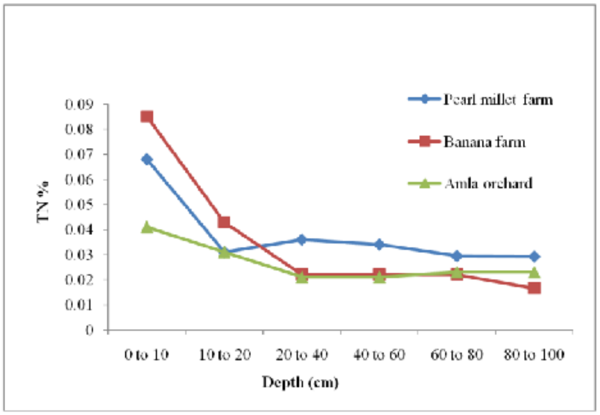

Fig. 2. Variation in TN (%) with soil depth in three land use patterns.

Because of the strong link with SOC and total nitrogen (TN), the soil C/N ratio is a useful predictor of soil fertility. Many factors influence it, including climate (Miller *et al.*, 2004), soil conditions (Ouedraogo *et al.,* 2006; Yamashita *et al.*, 2006), and vegetation varieties (Miller *et al.*, 2006). (Diekow *et al.*, 2005). According to studies, soils with a lower C/N ratio are more susceptible to N losses through leaching (Dise *et al.,* 1998; Gundersen *et al.,* 1998; Thomsen *et al*., 2008), whereas soils with a high C/N ratio can slow down the decomposition rate of organic matter (Zhang *et al.*, 2011). C/N ratio is a sensitive indication of soil quality, according to Shunfeng *et al.,* (2013). Its values are ranged from 3.4 to 7.9, 6.0 to 8.1, 8.4 to 14.9 for pearl millet farm, banana farm and amla orchard respectively (Fig. 3).

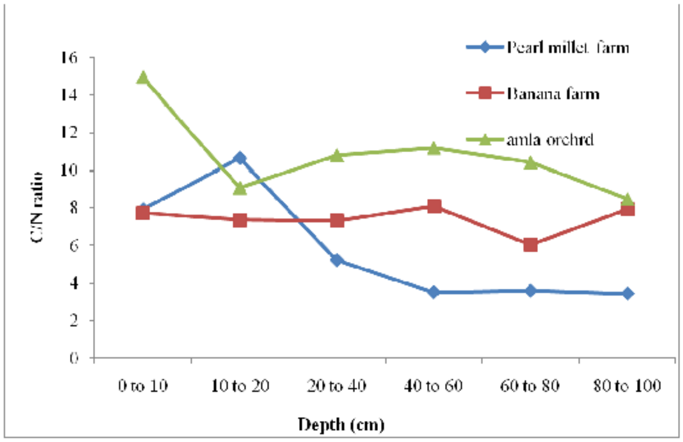

Fig. 3. Variation in C/N ratios with soil depth in three different land use patterns.

Brady and Weil (2008) found that C/N ratios in agricultural systems ranged from 8:1 to 15:1, with an average of 12:1. The highest C/N ratios were recorded in amla orchards, followed by banana farm and the lowest values were found at pearl millet farm at all depths. Lowest C/N ratio was observed at lower layer of pearl millet farm. It must be due to more use of N fertilizer at pearl millet farm followed by banana farm then least at amla orchard. We did not get any trend of C/N ratio depth wise in banana farm and amla orchard. While Kafle (2019) during his study in the tropical community forest of Nepal, found an increasing tendency of C/N ratio with increased soil depths. Irregularly it increased sometimes and decreased sometimes following no uniform trend with increasing depth of soil. Whereas at pearl millet farm it decreased with depth. Lowest values and decreasing trend of C/N ratio at pearl millet farm must be due to excessive use of nitrogen fertilizers. Sa *et al*., (2001) similarly found that the soil C/N ratio increased with depth, possibly due to high C/N soluble organic molecules leaking into deeper layers (Diekow *et al.,* 2005). To promote the steady expansion of the soil C/N ratio, greater emphasis should be paid to improving soil organic carbon. The change of soil C:N could lead to significant decline in carbon storage (Aitkenhead and McDowell, 2000).

CONCLUSION

The current study shows that composite interactions of combined soil management practices (e.g., degree of tillage, crop plant change, and fertilizer input) affect distinct qualitative and quantitative changes in SOC and TN availability in the soil profile. Relative distribution of SOC (%) at lower depth was highest in amla orchard, intermediate in banana farm, and it was lowest in pearl millet farm. These recorded data suggest that nutrient utilization by the agricultural crops; root distributions and frequency of disturbance affect the vertical distribution of SOC with depth. As a result of these findings, we can conclude that plant deep root distribution patterns leave distinct impressions on the distribution patterns of soil organic carbon and total nitrogen with depth due to changes in allocation. Thus, there is a great scope for better agricultural practices for efficient use of the whole soil profile such as use of cultivars with deeper and improved root systems. Management practices such as reduced or no tillage and a mix of agroforestry with crop fields may be an appropriate alternative for increasing C sequestration in the deeper layers of the soil profile. Results of our study highlight the need for appropriate and adequate agricultural management practices for building SOC and TN in agricultural soils. Accordingly we emphasize the necessity for additional research in this area.

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