

Research Article

Comparative assessment of profile storage of soil organic carbon and total nitrogen in forest and grassland in Jajarkot, Nepal

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ABSTRACT

Understanding distribution of soil organic carbon and nitrogen in soil profile is important for assessing soil fertility and soil carbon dynamics. However, little is known about their distribution in soil depth below 30cm in Nepal. In this context, this research was carried out in 2019 to determine the Soil Organic Carbon (SOC) and Total Nitrogen (TN) in 0-10 cm, 11-30 cm and 31-60 cm depths of soil profile at forest and grassland in Kotila community forest, Jajarkot, Nepal. Overall field measurement was based on national standard protocols. Three replicates of soil pit from forest and grassland were dug for soil sample collection. Approximately 100 g soil sample from each soil layer was collected and taken to laboratory for SOC analysis. Separate soil samples, one sample from each soil layer were collected with the help of a metal soil corer having volume 245.22cm³ to quantify bulk density. Forest has 25.42 ton/ha SOC stock and 3.28 ton/ha TN stock up to 60 cm soil depth. Likewise, Grassland has 21.19 ton/ha SOC stock and 3.14 ton/ha TN stock up to 60cm soil depth. However, these values are not significantly different at 5 % level of significance. The SOC and TN were decreased with increased soil depths, though not significantly different at 5 % level of significance. The C:N ratio was found higher in forest than grassland. It is concluded that SOC and TN do not vary significantly between forest and grassland. Topsoil contains more SOC, TN, and C:N ratio, so the management practices should focus on maintaining inputs of soil organic matter in the forest and grassland.

Keywords: Organic carbon, Soil depth, Total nitrogen

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INTRODUCTION

Soil Organic Matter (SOM) is a complex and varied mixture of organic substances that has great influence on the behavior, functions and properties of the soil ecosystem. There is an enormous amount of carbon stored in SOM (Brady & Weil, 1996) Grasslands and forests may be preferable systems in terms of organic matter compared to agricultural lands, because they are characterised by permanent vegetation cover (Conant, 2010). Although grassland is usually characterised by permanent vegetation cover, management differences such as mowing versus pasture and grazing intensity may influence the carbon and nitrogen input and dynamics (Lemaire et al., 2011).

Total Nitrogen (TN) is frequently the limiting element in terrestrial ecosystems (Vitousek et al., 1997). Nitrogen availability is often a determinant of ecosystem composition and productivity (Schlesinger, 1997). Carbon accumulation in soil and vegetation is partially dependent upon nitrogen availability (Marshall & Porter, 1991). Soil organic carbon (SOC) and TN have long been identified as factors that are important to soil fertility in both managed and natural ecosystems (Knops & Tilman, 2000).

Plant litter is mainly deposited in the surface soil, thereby contributing to SOM in the upper soil horizons. However, root litter and the translocation of particulate organic matter and decomposed organic matter may also affect the composition of the subsoil carbon and nitrogen (Kaiser & Guggenberger, 2000). Vertical patterns of SOC can contribute as an input or as an independent validation for biogeochemical models and thus provide valuable information for examining the responses of terrestrial ecosystems to global change (Mi et al., 2008).

SOC represents a significant pool of carbon within the biosphere (Grace and Hennessy, 2006). Improved knowledge of distribution of SOC across different soil depth is essential to determine whether carbon in deep soil layers will react to global change and accelerate the increase in atmospheric carbon dioxide (CO₂) concentration. Difficulties in comparing results obtained by various authors arise due to SOM being assessed in layers varying in thickness amount concluded different by different authors in both forest and grassland. Vertical distribution of SOC in relation to vegetation and land use is less understood (Jabbagy and Jackson, 2000). Moreover, no prior information regarding the selected variables such as SOC and TN was available from the study sites (own literature review). In this context, this research was carried out to analyze SOC and TN up to 60 cm depth in different soil layers, so that the stock and variation was determined in the soil profile in forest and grassland and also in between them.

METHODOLOGY

The research was carried out in Kotila Community forest located in Chhedagad Municipality ward number one, Jajarkot district and grassland within it (Figure 1). Both sites are located in sub-tropical climatic zone with an elevation of 1500m from mean sea level. Community forest covers an area of 493.47 ha. There are 187 households in the user's group. The forest was handed to local community in 2057 B.S. It is an important forest from biodiversity conservation point of view. This forest is dominated by Khote salla (*Pinus roxburghii*) associated with Sal (*Shorea robusta*), Asna (*Terminalia tomentosa*), Valayo (*Semicarpus anacardium*), Botdhayaro (*Lagerstroemia parviflora*), Lampaate (*Neolitsea cuipala*), Mahuwa (*Madhuca indica*), Tuni (*Toona ciliata*), Chilaune (*Schima wallichii*) etc. (own observation). Likewise, grassland is with Khar (*Cymbopogon microtheca*), Siru (*Imperita cylindrica*), Babiyo (*Eulaliopsis binata*) etc. (own observation).

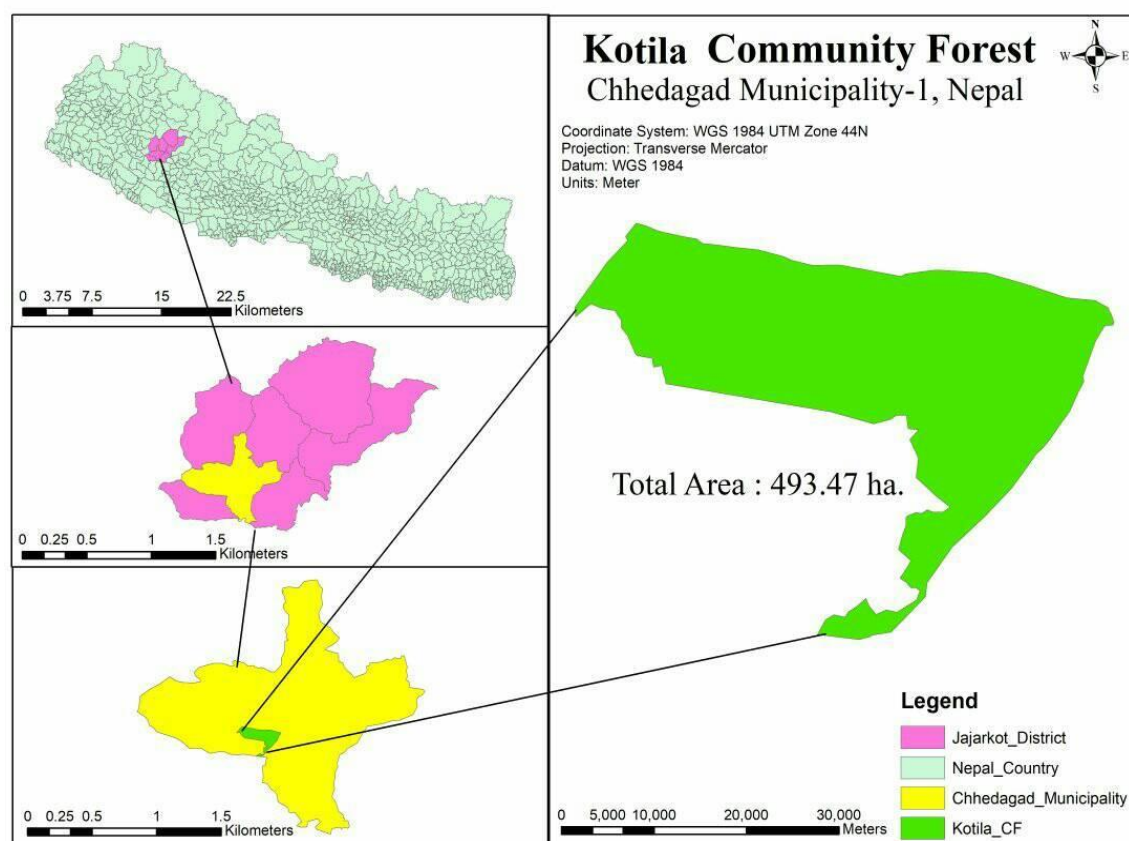


Figure 1: Map of study area

Stratified random sampling method was used to layout the sample plots and to collect the soil samples. Three sample plots were selected randomly from each from forest and grassland for estimating profile storage of SOC and TN in a forest and grassland. Three replicates of soil pits from forest and grassland were dug for soil sample collection.

For the purpose of estimating bulk density, one soil sample from each 0-10, 11-30, 31-60 cm depth were collected with the help of a metal soil corer having volume 245.22 cm³ from each land use in 2019. For the purpose of estimating SOC and TN, soil samples of approximately 100 g, each from 0-10, 11-30, 31-60 cm were collected from each land use. According to Penman et al. (2003), roughly half of the SOC of the top 100 cm of mineral soil is held in the upper 30 cm layer. We aimed to quantify SOC and TN in deep layers, so doubled the soil depth in this study.

Soil samples taken from each depth was placed in sample bags after labeling and that was transported to the laboratory for further analysis. The overall field measurements methods were based on guidelines of MoFSC (2011).

Relevant publications, journals, reports of different line agencies including other relevant literatures were reviewed for better understanding and discussion.

Soil bulk density was quantified following Blake & Harte (1986). Soil sample was transported to the laboratory for oven drying and measuring the oven dry weight after drying 24 hours at constant temperature of 105°C.

Bulk density of soil = (Oven dry weight of soil in gram) / (Volume of the soil in cm³)

The SOC concentration was determined by Walkey-Black method (McLean, 1982).

Samples from each of the three soil depths were prepared for carbon measurement by removing stones and plant residue > 2 mm as well as by grinding. Total SOC was calculated by using the formula given by Pearson et al. (2007). SOC (ton/ha) = Organic carbon content % × soil bulk density (g/cm³) × soil layer depth (cm).

TN was determined by the semi Kjeldahl digestion–distillation method (Bremner & Mulvaney, 1982). TN (ton/ha) = Nitrogen content % × soil bulk density (g/cm³) × soil layer depth (cm) (Pearson et al., 2007).

The data were analyzed using MS-Excel and SPSS. Both descriptive and analytical methods were used. One way ANOVA was used to test the significance difference in variables such as land use types, soil depths, SOC, bulk density of the soil and TN. The results were presented on texts and tables as required.

RESULTS AND DISCUSSION

RESULTS

Distribution of percentages of organic carbon and total nitrogen in soil profile at different soil depths

The percentage of SOC and TN in soil profile of forest and grassland at different depths is presented in Table 1. Accordingly, the value was 0.78 for 0-10 cm, 0.31 for 11-30 cm and 0.13 for 31-60 cm. with 0.78 as maximum value in the top layer of soil. Similarly, the percentage of TN was 0.09 for 0-10 cm, 0.038 for 11-30 cm and 0.02 for 31-60 cm.

The percentage of SOC for grassland was 0.60 at 0-10 cm, 0.20 for 11-30 cm and 0.11 at 31-60 cm as 0.60 as a maximum value in upper layer. Percentage of TN in this case was 0.07 at 0-10 cm, 0.03 at 11-30 cm 0.01 for 31-60 cm. Percentages of both SOC and TN were found decreasing with increasing depths in both forest and grassland.

Table 1. SOC and TN percentages up to 60 cm soil depth

Soil depth (cm)	SOC (%)		TN (%)	
	Forest	Grassland	Forest	Grassland
0-10	0.78	0.60	0.09	0.07
11-30	0.31	0.20	0.03	0.03
31-60	0.13	0.11	0.02	0.01

Stocks of SOC and TN in soil profile at different soil depths

Forest

Mean stocks of SOC in soil profile at 0-10 cm, 11-30 cm and 31-60 cm depths of forest were 10.38 ton/ha, 9.05 ton/ha and 5.97 ton/ha, indicating share of 40.86 %, 35.63 % and 23.51 % respectively (Table 2). ANOVA test at 5 % level of significance shows $p= 0.478$ that means stocks of SOC do not differ significantly at soil depths 0-10 cm, 11-30 cm and 31-60 cm.

Mean stocks of TN in soil profile at 0-10 cm, 11-30 cm and 31-60 cm depths of forest were 1.22 ton/ha, 1.10 ton/ha and 0.95 ton/ha, indicating share of 37.38 %, 33.55 % and 29.08 % respectively (Table 2). ANOVA test at 5 % level of significance shows $p=0.097$ that mean stocks of TN do not differ significantly at soil depths 0-10 cm, 11-30 cm and 31-60 cm.

Table 2. Stocks of SOC and TN up to 60 cm soil depth in forest

Depth(cm)	SOC (ton/ha)	TN(ton/ha)	SOC share in total	TN share in total
0-10	10.38	1.22	40.86	37.38
11-30	9.05	1.10	35.63	33.55
31-60	5.97	0.95	23.51	29.08

Grassland

Mean stocks of SOC in soil profile at 0-10 cm, 11-30 cm and 31-60 cm depths of grassland were 8.98 ton/ha, 6.52 ton/ha and 5.68 ton/ha, indicating share of 42.41 %, 30.77 % and 26.82 % respectively (Table 3). ANOVA test at 5 % level of significance shows $p=0.158$ that means stocks of SOC do not differ significantly at soil depths 0-10 cm, 11-30 cm and 31-60 cm.

Mean stocks of TN in soil profile at 0-10 cm, 11-30 cm and 31-60 cm depths of grassland were 1.13 ton/ha, 1.09 ton/ha and 0.91 ton/ha, indicating share of 36.18 %, 34.78 % and 29.04 % respectively (Table 3). ANOVA test at 5 % level of significance shows $p=0.364$ that means stocks of TN do not differ significantly at soil depths 0-10 cm, 11-30 cm and 31-60 cm.

Table 3. Stocks of SOC and TN up to 60 cm soil depth in grassland

Depth(cm)	SOC(ton/ha)	TN(ton/ha)	SOC share in total	TN share in total
0-10	8.98	1.13	42.41	36.18
11-30	6.52	1.09	30.77	34.78
31-60	5.68	0.91	26.82	29.04

Although the mean stock of SOC and TN is seen higher in all depths in forest than grassland, ANOVA test at 5% level of significance for SOC stock shows $p=0.460$ and for TN $p=0.695$ that means they do not differ significantly with land use types.

Total SOC and TN in soil profile up to 60cm depth

Total stocks of SOC in soil profile up to 60 cm depth of forest and grassland were 25.42 ton/ha and 21.19 ton/ha respectively (Table 4). Total stocks of TN in soil profile up to 60 cm depth of forest and grassland were 3.28 ton/ha and 3.14 ton/ha respectively (Table 4).

Table 4. Stocks of SOC and TN up to 60 cm soil depth in forest and grassland

Land use type	SOC (ton/ha)		TN (ton/ha)	
	Total	Std	Total	Std
Forest	25.42	2.26	3.28	0.13
Grassland	21.19	1.55	3.14	0.11

Carbon:nitrogen ratio in soil profile up to 60 cm depth

The Carbon:Nitrogen (C:N) ratio in soil profile of forest at different depths is presented in Table 5. Accordingly, the value was 8.48 for 0-10 cm, 8.21 for 11-30 cm and 6.27 for 31-60 cm depth. Similarly, C:N ratio for grassland was 7.89 at 0-10 cm depth, 5.97 for 11-30 cm

and 6.23 for 31-60 cm depth. ANOVA test at 5 % level of significance shows $p=0.0759$ that means C:N ratio does not differ significantly at soil depth 0-10 cm, 11-30 cm, 31-60 cm in both forest and grassland. ANOVA test at 5 % level of significance shows $p=0.120$ that means C:N ratio does not differ significantly between two land use types.

Table 5. Distribution of C:N ratio up to 60 cm soil depth

Depth	C:N ratio	
	Forest	Grassland
0-10	8.45	7.91
11-30	8.21	5.97
31-60	6.25	6.23

DISCUSSION

The percentages and stocks of SOC and TN were seen higher in upper layer in both forest and grassland in 0-10 cm. It may be due to the higher inputs of organic matter in top soils compared to other two soil depths. Mendham et al. (2003) reported that the proportion of total soil carbon in the 0 to 10 cm depth was higher than in the 10 to 30 cm depth for forest and grassland. Our findings are similar to that. Gautam and Mandal (2013) reported a decreasing trend of SOC and nitrogen with increased depths of soil in a tropical moist forest in eastern Nepal. Similar findings on the decline of stocks of SOC with the increase in soil depth were reported by Pandey and Bhusal (2016) in *S. robusta*-dominated forests of hills and Terai regions of Nepal and Song et al. (2016) who reported that the concentrations of SOC and nitrogen decreased with depth, and the greatest concentration was in the 0–10 cm topsoil in selected forests of China. The result of the present study is also consistent with the findings of many other previous studies (Malo et al., 2005; Heluf and Wakene, 2006; Kafle, 2019; Kafle et al., 2019; Shrestha and Kafle, 2020). According to Malo et al. (2005) the decrease in total nitrogen with increasing depth was due to declining humus with depth. Increase in organic carbon status under tree species with addition of organic matter through litter fall has been reported by Gill et al. (1987) and Kumar et al. (1998).

Because of differences in management practices between the two-land use systems, forest is with fewer disturbances than grassland. Grassland was poorly managed, heavily overgrazed and mostly they were susceptible to surface erosion. Abera and Belachew (2011) reported higher concentration of carbon and nitrogen in forest than grassland in all soil depths 0-5 cm, 5-15 cm, 15-30 cm and 30-60 cm. Our results are similar to that. The lower level of total nitrogen in the grassland than the forest might be due to the sparse vegetation due to human and livestock disturbance.

Data presented by Ostrowska and Porębska (2015) indicated that the mean C:N ratio for humus was 12.7, the mean C/N ratio in the arable soils examined by the authors was 13.6, and the mean C/N ratio for an international soil amounted to 11.6, close to the values reported in this research (5.97 – 8.45). The C:N ratio shows the relationship between organic matter and nitrogen of soils. In both forest and grassland, its value was found decreasing with increasing soil depth. In this study, the C:N ratio varied with land use systems. Moreover, the ratio was slightly narrower in soils of grassland as compared to forest; it might be due to higher mineralization and oxidation of organic matter in grassland in comparison to forest land (Abera & Belachew, 2011). The TN content was strongly associated with total SOC and decreased consistently with increasing soil depth under two land use systems. Puget and Lal

(2005) reported higher C:N ratio in forest soil as compared to soils under pasture. Such differences in C:N ratios among land use systems may also reflect variations in qualities of organic residues entering the soil organic matter pool and could be attributed to contrasting vegetation covers.

Total stocks of SOC in both forest and grassland are small despite the fact that both forest and grassland possess high capacity of sequestration of SOC. Sparse vegetation cover, forest fire, lesser soil depth and presence of small pebbles in some plots including others were observed in the forest and those might be the reasons behind it. Likewise, heavy grazing, presence of small pebbles and excessive cutting of grasses for stall feeding reduce the grass from the area and lead barren and these might be the reasons behind it for the grassland.

CONCLUSION

Forest was found with 25.421 ton/ha organic carbon stock and 3.288 ton/ha total nitrogen stock up to 60 cm soil depth. Grassland was found with 21.191ton/ha organic carbon stock and 3.140 ton/ha total nitrogen stock up to 60 cm soil depth. A comparison of the soil organic carbon stock, total nitrogen and C:N ratio of forest and grassland shows no significant difference. There is a declining trend of soil organic carbon and total nitrogen with increasing soil depths; however the variation is not statistically significant. The C:N ratio was found decreasing with soil depths in both forest and grassland but it do not differ significantly at depth wise as well as land use wise. It is recommended to maintain continuous inputs of organic matter on the soil surface for enhancing stocks of soil organic carbon and total nitrogen.

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Authors' Contributions

M. Sharma and G. Kafle wrote the whole paper and M. Sharma collected information from fields and both authors extracted information from literatures. G. Kafle finalizes the initial draft of this manuscript.

Conflict of interest

The authors declare that there is no conflict of interest regarding publication of this manuscript.

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