Assessment of Soil Organic Carbon Stock of Churia Broad Leaved Forest of Nawalpur District, Nepal

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Abstract
The present article is based on the study carried out to quantify aspect wise variation in Soil Organic Carbon (SOC) stock of Churia broad leaved forest in Bhedawari Community Forest of Nawalpur district, Nepal. The total amount of SOC stock in upto 30 cm soil depth in Bhedawari Community Forest was found to be 33.91 t/ha. Aspect had made significant difference upon SOC stock with p value of 0.002 (p<0.05). The total SOC was higher in the northern aspect (36.83 ± 1.34 t/ha) than in the southern aspect (30.98 ± 1.22 t/ha). Hence, soil carbon sequestration through community managed forest is a good strategy to mitigate the increasing concentration of atmospheric CO₂.

Keywords
Soil Organic Carbon; Community Forest; Aspect
Introduction

The interaction between climate change and the global carbon cycle is an important aspect of the global environmental changes (Parry et al., 2007). Soil is the largest pool of terrestrial organic carbon in biosphere, storing more carbon. Therefore, the Soil Organic Carbon (SOC) stock has an irreplaceable function in mitigating climate change as a key component of the biosphere carbon cycle. Meaning that changes in Soil Organic Carbon (SOC) content significantly influence climate change, and a slight change in the SOC stocks can have a considerable effect on atmospheric carbon dioxide concentration, contributing to climate change (Jobbágy and Jackson, 2000).

Soil, being the largest carbon reservoir of the terrestrial carbon cycle, has three times more carbon than in the world’s vegetation. The soils hold double the amount of carbon that is present in the atmosphere (Sheikh, Kumar and Bussmann, 2009). The amount of stored SOC is the net balance between carbon inputs from plant production and losses through decomposition and leaching. Hence, depending upon carbon fluxes, the soil can either be a source or sink for atmospheric CO₂ (Schrumpf et al., 2011). The stability and distribution of SOC in the soil profile is influenced by biotic controls such as the abundance and vigor of faunal, microbial and plant species, as well as environmental controls like temperature, moisture and soil texture (Lorenz and Lal, 2005).

Carbon emissions from deforestation account for an estimated 20% of global carbon emissions (Parry et al., 2007), second only to that produced by fossil fuel combustion (Campbell et al., 2008).

Nepal ranked 4th most vulnerable country in the world in terms of climate change (Maplecroft, 2010 cited in MoEnv, 2012), and the main issue is to mitigate the climate change for the betterment of the environment and sustainable development. Nepal’s Department of Forest Research and Survey (DFRS) in 2015 reported that Nepal’s average organic carbon in soil, litter and debris, and tree component (≥10 cm DBH) are 67.14 t/ha, 1.19 t/ha and 108.88 t/ha, respectively. The highest soil organic carbon stock (114.03 t/ha) was estimated in High¹ Mountain and High Himal² regions. SOC was the lowest in Churia region with an average of 31.44 t/ha. The results from Middle Mountains³ region showed an average SOC stock of 54.33 t/ha. SOC stock in the forests of the Terai⁴ was found to be slightly higher than in Churia⁵. To successfully reduce greenhouse gas emissions from land cover change, effective strategies for protecting natural habitats are needed. Thus, assessment of SOC is important for carbon budgeting, designing appropriate carbon sequestration strategies and enhancing our understanding of biogeochemical cycles. The aim of this article is, therefore, to investigate how SOC in the profiles varied under different aspect in community managed Churia broad-leaved forest.

¹ High Mountains: The region is characterized by the rugged landscape and very steep slopes and elevation varies from 543 m in the river valley floor to 4951 m above mean sea level.
² High Himal: This region includes the highest Himalayan massifs and elevation ranges from 1,960 m to 8,848 m above mean sea level.
³ Middle Mountains: This region lies north of Churia along the southern flanks of the Himalayas and elevation varies from 110 m in the lower river valleys to 3,300 m above mean sea level.
⁴ Terai: It consists of gently sloping recent and post-Pleistocene alluvial deposits, which form a piedmont plain south of the Himalayas. Its elevation varies from 63 m to 330 m above mean sea level.
⁵ Churia: Churia region is the youngest mountain range in the Himalayas. Just north of the Terai, it runs the entire length of southern Nepal, from east to west, skirting the southern flanks of the Himalayas. The elevation of Churia varies from 93 to 1,955 m above mean sea level.
Materials and Methods

Study Area

The research was carried out in Bhedawari Community Forest of Churia region. It is situated in Gindakot Municipality ward number 11 and 12, an eastern part of Nawalpur district in the Gandaki Province of Nepal. It lies between 27° 42' N latitude and 84° 18' E longitude. It is about 14 kilometers west from Narayangadh, Chitwan district. The study area experiences tropical climate with altitudinal range from 200 to 750 m from mean sea level (Figure 1). Soil is of reddish-brown type. It is the area having a natural broad-leaved forest dominated by *Shorea robusta* (Sal) with other associates such as *Terminalia tomentosa* (Saj), *Adina cordifolia* (Karma), *Semecarpus anacardum* (Valayo), etc.

![Map of Study Area](image)

Figure 1: Map of the Study Area

Soil Sample Collection

The stratified random sampling method was adopted for this study. Two aspect classes (north and south) were the strata for the study. Soil samples were collected from 10 replicated sites of each aspect within the study area. In each sampling site, a pit of 30 cm x 100 cm pit was dug, and undisturbed soil core samples were taken by a cylindrical core sampler (5.5 cm diameter and 10 cm height) from the 0-10 cm, 10-20 cm, and 20-30 cm soil depths for the determination of bulk density. The bulk soil samples were dried in oven, sieved through a 2 mm sieve and carefully stored before basic considerations. The samples were collected during March 2018.

Bulk Density Analysis

Soil bulk density was determined using core sampling method (Blake and Hartge, 1986). Oven dried (at 105 °C) soil samples were used for moisture correction. Bulk density was calculated by the following formula:
Bulk density (g.cm\(^{-3}\)) = \frac{(Oven dry weight of soil in 'g')}{(Volume of the soil in 'cm^3')} \\
Where, \\
Volume of the soil = Volume of core – Volume of the stone

Estimation of Soil Organic Carbon

Soil organic carbon percent was determined by the titration method developed by Walkley and Black (1934). The Soil Organic Carbon content percent was calculated as per following:

\[
\text{Carbon} \, (\%) = 3.951/\text{g} \times [1 - T/S] \\
\text{Where,} \\
g = \text{Weight of sample in gram,} \\
T = \text{Volume of ferrous solution consumed in sample titration (ml),} \\
S = \text{Volume of ferrous solution consumed in blank titration (ml)}. \\
\]

Total soil organic carbon was then calculated (Chhabra, Palria and Dadhwal, 2003)
SOC = \rho \times d \times \%C \\
Whereas,
SOC = soil organic carbon stock per unit area (ton ha\(^{-1}\)), \\
\rho = \text{soil bulk density (Kg/m}^3\), \\
d = \text{soil depth (m), and} \\
\%C = \text{carbon concentration (%)}

Results and Discussion

Bulk Density

Bulk density (BD) varies with respect to depths in the soil. The range of BD in northern and southern aspects upto 30 cm depth of Bhedawari Community Forest is given in Table 1. The minimum BD (1.35 ± 0.06 g.cm\(^{-3}\)) was found at the topsoil (0-10 cm) while maximum BD (1.59 ± 0.07 g.cm\(^{-3}\)) was at 20-30 cm in the southern aspect. The finding is similar with Shrestha (2009) who reported that there was a gradual increase in BD with increase in depths in both broad leaved (Shorea and Schima-Castanopsis) forests. Ghimire, Kafle and Bhatta (2018) also reported that BD value of soil also increases with increase in depths of soil layers in different land uses in Churia range, Nepal. BD at 10-20 cm profile in the north aspect differs slightly than other depths; this may be due to presence of tree root zone.

### Table 1: Average Bulk density (g.cm\(^{-3}\)) at various depths

| Depth (cm) | Northern Aspect | Southern Aspect |
|------------|----------------|-----------------|
|            | Mean | S.D. | S.E.  | Mean | S.D. | S.E.  |
| 0-10       | 1.43 | 0.32 | 0.10  | 1.35 | 0.19 | 0.06  |
| 10-20      | 1.37 | 0.33 | 0.11  | 1.55 | 0.23 | 0.07  |
| 20-30      | 1.51 | 0.31 | 0.10  | 1.59 | 0.23 | 0.07  |
Soil Organic Carbon Percentage (SOC %)

The SOC percentage was higher at the upper layers and gradually decreased in the soil depth. Table 2 shows the depth wise distribution of SOC stock in different aspects. The maximum SOC % (1.20 ± 0.14) was found at the topsoil (0-10 cm) in the northern aspect and minimum SOC % (0.47 ± 0.08) at the depth of 20-30 cm in the southern aspect (Table-2). The soil organic carbon in the forest depends upon forest types, climate, moisture, temperature, soil organic matter and types of soil. Higher SOC percent in upper layer is due to high soil organic matter content and less degraded organic matter. Top layer of most of the soils contains carbon between 0.3% and 11.5% in the 20 cm surface mineral soil (Perry, 1994 cited in Lal, 2005). Neupane (2017) recorded maximum SOC % being 1.09% in 0-10 cm and minimum being 0.65% in 20-30 cm depth in Kalika Community Forest of Chitwan district which is also a Churia broad leaved forest. This supports the result that with increase in the depths soil organic carbon percentage decreases.

Figure 2: Average Soil Organic Carbon Percentage at various depths

Table 2: Average Soil Organic Carbon Percentage at various depths

| Depth (cm) | Northern Aspect | Southern Aspect |
|------------|-----------------|-----------------|
|            | Mean | S.D. | S.E. | Mean | S.D. | S.E. |
| 0-10       | 1.20 | 0.43 | 0.14 | 1.01 | 0.35 | 0.11 |
| 10-20      | 0.73 | 0.43 | 0.14 | 0.66 | 0.25 | 0.08 |
| 20-30      | 0.64 | 0.49 | 0.15 | 0.47 | 0.26 | 0.08 |

Soil Organic Carbon Stock

It was found that with increase in the soil depth, SOC stock gradually decreases. Distribution of SOC stock in different soil profile is shown in Table 3. The maximum SOC (16.94 ± 1.86 t/ha) was found at the topsoil (0-10 cm) in the northern aspect and minimum SOC (7.48 ± 1.34 t/ha) at the depth of 20-30 cm in the southern aspect. The total SOC stock of Bhedawari Community Forest was found to be 33.91 t/ha. This finding is similar to the SOC stock of Churia region of Nepal as reported by DFRS (2015). SOC diminishes with the depth of the soil (Shrestha, 2009). Higher rate of deposition of forest leaf, litters, etc. may results to higher organic carbon stock in the top layer.
Pandey and Bhusal (2016) reported that the SOC decreased with the increase in soil depth in *Shorea robusta* forests of hills and Terai regions of Nepal. Also, Ghimire *et al.* (2018) reported higher SOC in top layer and decreased SOC with increased depth in *Shorea robusta* forests of Banaskhandi Community Forest, Makwanpur district. Thus, it is established that the results of this study were justified with previous findings that SOC decreases with increasing soil depths. The amount of SOC was higher in the northern aspect (36.83 ± 1.34 t/ha) than in the southern aspect (30.98 ± 1.22 t/ha), which was justified with studies that have reported higher SOC content on the north as compared to south-facing slope (Egli *et al*., 2009; Sharma *et al*., 2010). Similarly, Parjapati (2015) reported higher SOC in North-East aspect than in South-West aspect in Phulchoki Community Forest, Bhaktapur district.

Table 3: Average Soil Organic Carbon Stock at various depths

| Depth (cm) | North |       | South |       |
|------------|-------|-------|-------|-------|
|            | Mean  | S.D.  | S.E.  | Mean  | S.D.  | S.E.  |
| 0-10       | 16.94 | 5.88  | 1.86  | 13.74 | 4.87  | 1.54  |
| 10-20      | 10.16 | 6.28  | 1.99  | 9.76  | 2.62  | 0.83  |
| 20-30      | 9.73  | 7.46  | 2.36  | 7.48  | 4.24  | 1.34  |
| Total      | 36.83 |       |       | 30.98 |       |       |

The total soil carbon stock in Bhedawari Community Forest differs significantly in both Northern and Southern aspects with p value of 0.002 (p<0.05). This correlates to Begum *et al.* (2010) who found significant difference in average SOC, which was higher on the northern aspect than the southern aspect.

**Conclusion**

The total SOC stock was 33.91 t/ha, which is decreasing with increasing depths. The total SOC stock was found to be higher in Northern (36.83 t/ha) aspect than that of Southern aspect (30.98 t/ha). Despite similarity in vegetation, low light intensity (temperature) may be contributed in higher SOC storage in north. North-facing sites are usually cool and moist and contain higher amounts of organic carbon and organic matter, higher abundance and diversity of soil fauna, whereas south-facing slopes are usually hot and dry, prone to erosion and are depleted in SOC. Hence, soil carbon sequestration through enhanced community managed forest is a good strategy to mitigate the increasing concentration of atmospheric CO$_2$.

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