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RESEARCH ARTICLE

SOIL ORGANIC CARBON STOCK AND SINK POTENTIAL IN HIGH MOUNTAIN TEMPERATE HIMALAYAN FORESTS OF INDIA

Jahangeer A. Bhat, *Munesh Kumar, Ajeet K. Negi, Nazir A. Pala and N. P. Todaria

Department of Forestry and Natural Resources, H. N. B Garhwal University, Srinagar Garhwal, Uttarakhand, India

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ABSTRACT

The estimation of soil organic carbon stock along altitudinal gradient was carried out in Kedarnath Wildlife Sanctuary of Garhwal Himalaya in different vegetation types. The moisture content in the soil increased with increasing altitude and the highest moisture was recorded in *Betula utilis* forest at an elevation of 3550 m amsl followed by Grassland (3050 m), *Rhododendron arboreum* forest, (2550 m), mixed forest (*Quercus* and *Rhododendron* species, 2050 m) and *Pinus roxburghii* forest (1550 m). The bulk density also followed similar trend as moisture, which increased with increasing altitude. The soil carbon stock also increased with altitude and the highest carbon stock (35.4±1.8 Mg C ha^{-1}) was in *Betula utilis* forest soils and the lowest (19.2±2.7 Mg C ha^{-1}) in *Pinus roxburghii* forest soils. Thus moisture showed positive correlation with carbon stocks, higher the moisture, higher was carbon stock. Thus high precipitation and low temperature is associated with increasing altitude which enhances soil carbon stock at higher altitudes.

INTRODUCTION

Organic carbon can be regarded as a repository for carbon dioxide fixed via photosynthesis, and is part of the solid and liquid phase in the soil and soils are regarded as a potential sink for CO_2 and serve as both sources and sinks of the major GHGs-both naturally and under the influence of anthropogenic activities (Leifeld, 2006). Carbon stored in soil is among the most important C pools on the global scale, exceeding that in vegetation and the atmosphere by a factor of two (Bolin and Sukumar, 2000). Soil is the largest pool of organic carbon in the terrestrial biosphere, and minor changes in soil organic carbon (SOC) storage can impact atmospheric carbon dioxide concentrations (Johnston *et al*., 2004, Xu *et al*., 2011). Estimates of SOC stock are required to assess the role of soil in the global carbon cycle (Yang *et al*., 2007). Soil C is one of the key variables for estimating terrestrial C dynamics, since it is a major determinant of the amount of CO_2 released to the atmosphere through decomposition of organic matter in the soils. Improved knowledge of the amount and spatial distribution of the C stock in soils is crucial to estimating changes in the terrestrial C dynamics (Bhatti *et al*., 2002). Soil C storage is determined by the balance of C input from plant primary production and C release through decomposition. Disturbance, land-use history, climate, soil texture, topography, and hydrology are the primary variables that influence both production and decomposition processes and, therefore, the total amount of soil C stocks. Soil moisture controls the amount of C assimilated by vegetation, rate of photosynthesis and C decomposed in soils and, therefore, is a key controller of soil C stocks (Parton *et al*., 1993, Trumbore and Harden, 1997). Although the importance of soil C sequestration as a tool to mitigate global warming should not be neglected, the attainable capacity of the soil as a C sink is most likely to be smaller than the historical losses induced by human activity (Lal, 2004b).

***Corresponding author:** muneshmzu@yahoo.com

MATERIALS AND METHODS

The study was carried out in the Madhmaheshwar area which is located inside Kedarnath Wildlife Sanctuary, Uttarakhand, India and geographically sanctuary is situated between 30°25'-30°41' N, 78°55'-79°22' E in the Garhwal region of Greater Himalayas. The sanctuary takes its name from the famous Hindu Shrine “Kedarnath” and the area falls under the IUCN management Category IV (Managed Nature Reserve) in the Biogeographical Province 2.38.12 of Himalayan highlands. The sanctuary lies in the upper catchment of the Alaknanda and Mandakini Rivers, which are major tributaries of River Ganges. The area also encloses many important Hindu shrines, including Madhamaheshwar (3200 m), Rudranath, (3500 m), Trijuginarayan (2200m) and Tungnath (3750 m), while Kedarnath (3400 m) is almost on its northern boundary. It is estimated that about 44.4% to 48.8% of the sanctuary is forested, 7.7% comprises alpine meadows and scrub, 42.1% is rocky or under permanent snow and 1.5% represents formerly forested areas (Prabhakar *et al*., 2001). In this article, we report carbon stocks along an altitudinal gradient in the interior part of wildlife sanctuary. The present study was conducted between the coordinates (30° 35' 42"- 30° 38' 12"

N, 79° 10' 00"-79° 13' 00" E) in the Madhmaheshwer area which is the interior part of Kedarnath Wildlife Sanctuary. The sanctuary covers a wide altitudinal range from 1160 m to 7068 m amsl, covering an area about 975 kms^2 (Quasin and Uniyal, 2010) and has sizeable areas with limited human pressure. This area has unique physiognomic, climatic and topographic conditions. The area receives 300cm of annual precipitation of which the rainy months (June-August) contribute approximately 60%. The relative humidity varies from 35 to 85% annually. There is moderate to heavy snowfall during December-February, even in low-altitude areas. The mean maximum temperature varied between 4 °C (January) and 33.5 °C (June). The sanctuary has dense forests of Chir pine (*Pinus roxburghii*), Oak (*Quercus leucotrichophora*) and (*Quercus semicarpifolia*) and *Rhododendron* species. Thus, is very diverse in both flora and fauna, and is characterized by undulating topography, wide variation in the altitude, rainfall, temperature and soil conditions.

The site selection was based on observations and reconnaissance survey. Five different sites were identified along an altitudinal gradient and were named on the basis of dominant vegetation cover i.e., *Pinus roxburghii* (1550 m), mixed forest (*Quercus* and *Rhododendron* species 2050 m), *Rhododendron arboreum* (2550 m), Grassland (3050 m) and *Betula utilis* 3550 m (Table 1). The soil sampling was done by nested plot design method. At every site, a plot of 40 x 5 m size was laid, and six sampling points were identified in each plot (Hairiah *et al*., 2001). A total of 30 soil samples (6 from each site) were collected. All soil samples were collected in the year of 2010, typically during the month of June. The soil samples were air dried and sieved (< 2 mm) before analysis. Soil organic carbon (SOC) percent was determined by partial oxidation method (Walkley and Black, 1934). The total SOC stock was estimated by multiplying the values of SOC g kg^{-1} by a factor of 4 million, using general assumption that 30 cm layer of 1 ha soil weighs 4 million kg (Jha *et al*., 2003). The data was statistically analysed through Minitab Software using Duncan's Multiple Range Test 'DMRT' (Minitab Inc., 2007).

Table 1. Site characteristics of the study area

Dominant Vegetation	Elevation (m amsl)	Aspect	Slope (%)
Pinus roxburghii	1550	South 169.90°	23.30°
Quercus & *Rhododendron* species	2050	North West 316.31°	36.89° 20.89°
Rhododendron arboreum	2550	South West 222.40°	17.40°
Grass land *'Bogyal'*	3050	South East 147.34°	32.02° 19.02°
Betula utilis	3550	East 79.78°	4.78°

Table 2. Soil carbon stock at different altitudes

Dominant Vegetation	BD (g/cm^3)	Moisture (%)	Carbon Stock Mg C h^{-1}
Pinus roxburghii	1.41^a±0.01	8.12^a±1.01	19.2^a±2.7
Quercus & *Rhododendron* species	1.47^b±0.03	25.83^b±2.12	23.2^b±2.2
Rhododendron arboreum	1.48^b±1.01	29.59^c±4.26	31.8^d±3.5
Grassland *'Bogyal'*	1.53^c±0.08	33.21^d±5.32	25.0^c±2.1
Betula utilis	1.59^d±0.02	39.71^e±1.50	35.4^e±1.8

* Values are mean± S.D of replications. Values having same superscript in a column do not differ significantly from each other.

RESULTS AND DISCUSSION

We observed that, the highest amount of moisture was found in *Betula utilis* forest soils (3550 m) followed by Grassland (*Bogyals*) at 3050 m altitude, *Rhododendron arboreum* forest soils (2550 m), mixed forest (*Quercus* and *Rhododendron* species) forest soils (2050m) and the lowest moisture percent was recorded in *Pinus roxburghii* forest soils at lowest (1550 m) altitude (Table-2). The values of bulk density have also followed similar trend as moisture and increased with increase in altitude, ranged from 1.41±0.01 (1550 m) to 1.59±0.02 (3550 m). Soil organic carbon (Table 2) was found increasing with increase in altitude. The highest carbon stock was in the *Betula utilis* forest soil (35.4±1.8 Mg C ha^{-1}) at 3550 m altitude followed by *Rhododendron arboreum* (31.8±3.5 Mg C ha^{-1}) at 2550 m, grassland (25.0±2.1 Mg C ha^{-1}) at 3050 m altitude, mixed forest (*Quercus* and *Rhododendron* species) forest soils (23.2±2.2 Mg C ha^{-1}) at 2050 m altitude and the lowest carbon stock (19.2±2.7 Mg C ha^{-1}) was recorded at 1550 m altitude in *Pinus roxburghii* forest soils. The moisture of soils at different altitudes showed positive correlation ($p \leq 0.05$) with carbon stocks, higher the moisture percent higher was the carbon stock of soils and vice versa.

Igwe (2005) reported that soils with highest SOC had highest average soil moisture at 0-20 cm. As per Bauer and Black (1992) in the soils a unit increase in SOC concentration caused a relatively larger increase in available water content. Soil organic carbon is the component of soil organic matter, and soil organic matter increases with precipitation and decreases with temperature (Jenny, 1980; Burke *et al.*, 1989, Lemenih and Itanna, 2004). Alvarez and Lavado (1998) reported that SOM content in the top 0-50 cm soil layer is positively correlated with the precipitation/temperature ratio in the pampa and Chaco soils in Argentina. Similar to moisture percent the values of bulk density also followed similar trend as in moisture, which increased with increase in altitude. Jiao *et al*., (2010) described in their study that soil bulk density vary significantly within sites, forming an important cause of variation in SOC density, which relates differences in SOC density and total SOC stocks to differences in land use and land cover area in fact describing the combined effects of these factors on both SOC concentration and soil bulk density. The bulk density depends on several factors such as compaction, consolidation and amount of SOC present in the soil but it is highly correlated to the organic carbon content (Morisada *et al.*, 2004; Leifeld *et al.*, 2004). This may be probably as a result of lower organic matter contents, less aggregation, fewer roots and other soil-dwelling organisms, and compaction caused by the weight of the overlying layers (Brady and Weil, 2002). Variation in SOC with elevation is more difficult to interpret because there are compounding factors such as the impact of elevation with associated climate changes (Elmore and Asner, 2006). However, in undisturbed ecosystems, SOC variation with climate is explained by the climatic control of vegetation type and productivity and therefore carbon supply to soils and its influence on microbial processes that regulate SOC accumulation and loss (Davidson *et al*., 2000; Jobaggy and Jackson, 2000).

As high altitudes experience the cool temperatures it may be the reason for highest carbon stocks at higher altitudes. The same reason has also been reported by Schlesinger (1997), the stock of soil organic carbon accumulation was highest in cool, wet conditions and lowest in deserts. The moisture of soils at different altitudes showed positive correlation ($p \leq 0.05$) with carbon stocks, higher the moisture percent, probably higher the carbon stock of soils and vice versa. The increasing SOC with altitudes having cool temperature and lower annual average temperature retarding the decomposition rate might also have resulted in greater amount of SOC stock at higher elevation. Some of the workers have suggested that soil respiration rates are generally more responsive to working than productivity in cool, high latitude ecosystem (Scheerser, 1982; Kirschbaum, 1995). The cooler upper elevations plots were consistently characterized by slower C turnover, indicated by lower litter decomposition rates, lower soil respiration rates and higher mean residence times of forest floor C. Laboratory incubations further indicated that organic and mineral horizons in the upper elevation band contained more labile C than lower and mid-elevation sites (Tewksbury, 2005). In alpine region, the temperature is very low (seldom above 10^0 C) which retard the microbial activity.

Due to less microbial activity, there is less degradation and released of nutrients required for plant growth. And due to lack of required nutrients, plant growth will be less and can't use the carbon stock present in soil. SOC in the alpine region is greater than other regions which are viable sink of atmospheric carbon in the absence of forest (Maharjan, 2010). Schimel *et al*., (2000) reported that SOC increased with elevation in semi-arid environment due to increase in precipitation, decrease in temperature and production of greater amount of plant biomass at higher elevations. But due to steep slopes which accelerate soil erosion there is always possibility of reduction in SOC at higher altitudes. There was strong correlation between SOC content and slopes showing the steeper the slopes lower the carbon content. The study demonstrated that slope position and aspect also played important role in SOC sequestration (Awasthi, 2004). SOC become high when there is high amount of biomass present. But it is not only one factor that affects SOC sequestration. There are other factors like temperature which also influence SOC sequestration, lower the temperature of the place, higher is the SOC.

Conclusion

The findings of the paper concludes that altitude plays an important role in soil organic carbon stocks. Increasing altitude is associated with high amount of precipitation and low temperature, resulting in high moisture content in soils which ultimately helps in enhancing soil organic carbon stock.

REFERENCES

Alvarez, R., and Lavado, R. (1998). Climate, organic matter and clay content relationships in the Pampa and Chaco soils, Argentina. *Geoderma,* 83: 127–141.

Awasthi, K.D. (2004). Land use change effect on soil degradation, carbon and nutrient stocks and greenhouse gas emission in mountain watersheds. Agricultural university of Norway.

Bauer, A. and Black, A.L. (1992). Organic carbon effects on available water capacity three soil textural groups. *Soil Science Society of America Journal,* 56: 248-254

Bhatti, J.S., Apps, M. J. and Tarnocai, C. (2002). Estimates of soil organic carbon stocks in central Canada using three different approaches. *Canadian Journal of Forest Research,* 32: 805–812.

Bolin, B. and Sukumar, R. (2000). Global perspective. In: Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo, D.J. & Dokken, D.J. (eds) *Land Use, Land-use Change, and Forestry. A Special Report of the IPCC,* Cambridge University Press, Cambridge, UK, 23-51

Brady, N. C., and Weil, R. R. (2002). The Nature and Properties of Soil. pp139.

Burke, I.C., Yonker, C.M., Parton, W.J., Cole, C.V., Flach K. and Schimel, D.S. (1989). Texture, climate, and cultivation effects on soil organic matter content in U.S. grassland soils. *Soil Science Society of America Journal,* 53:800–5.

Davidson, E. A., Trumbore, S. E. and Amundson, R. (2000). Soil warming and organic carbon content. *Nature*, 408(14): 789–790.

Elmore, A. J. and Asner, G. P. (2006). Effects of grazing intensity on soil carbon stocks following deforestation of a Hawaiian dry tropical forest. *Global Change Biology*, 12: 1761–1772, doi: 10.1111/j.1365-2486.2006.01198.

Hairiah, K., Sitompul,V.S., Noordwijk, M. and Palm, C. (2001). Methodology for sampling carbon stocks above and below ground. ASB Lecture Notes 4B. *International Centre for Research in Agroforestry, Indonesia, Published in Dec.*http://www.icraf.cgiar.org/sea.

Igwe. C. A. (2005). Soil physical properties under different management systems and organic matter effects on soil moisture along soil catena in southeastern Nigeria. *Tropical and Subtropical Agroecosystem*s, 5: 57 – 66.

Jenny, H. (1980). The Soil Resource, Origin and Behavior. Springer-Verlag, New York.

Jha, M.N., Gupta, M.K., Saxena, A. and Kumar, R. (2003). Soil organic carbon store in different forests of India. *Indian Forester* June, 129(6): 714-723.

Jiao, Jia-Guo., Yang, Lin-Zhang., Wu, Jun-Xi., Wang, Hong-Qing., Li, Hui-Xin. and Ellis, E. C. (2010). Land Use and Soil Organic Carbon in China's Village Landscapes. *Pedosphere* 20(1): 1–14,

Jobbagy, E. G. and Jackson, R. B. (2000). The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological Application,* 10: 423–436.

Johnston, C.A., Groffman, P., Breshears, D.D., Gcardon, Z.G., Currie, W., Emanuel, W., Gaudinski, J., Jackson, R.B., Lajtha, K., Nadelhoffer, K., Nelson, Jr, D., Post, W.M., Retallack, G. and Wielopolski, L. (2004). Carbon cycling in soil. *Frontiers in Ecology and the Environment,* 2: 522–528.

Kirschbaum, M.U.F. (1995). The temperature dependence of soil organic matter decomposition, and the effect of global warming on soil organic storage. *Soil Biology Biochemistry*, 27: 753-760

Lal, R. (2004b). Soil carbon sequestration impacts on global climate change and food security. *Science,* 304: 1623-1627.

Lemenih, M. and Itanna, F.2004. Soil carbon stocks and turnovers in various vegetation type and arable lands along an elevation gradient in southern Ethiopia. *Geoderma*, 123:177-188.

Liefeld, J. (2006). Soils as sources and sinks of greenhouse gases. In: Frossard, E., Blum, W.E.H. & Warkentin, B.P. (eds) *Function of Soils for Human Societies and the Environment*. Geological Society, London, Special Publications, 266, 23-44.

Liefeld, J., Bassin, S. and Fuhrer, J. (2004).Carbon stock in Swiss agriculture soils predicted by land use soil characteristics, and altitude. *Agriculture, ecosystem and environment*.

Maharjan, M. (2010). Soil carbon and nutrient status of rangeland in upper mustang. Masters thesis submitted to Tribhuvan University Institute of Forestry Pokhara, Nepal

Minitab Inc. (2007), “Specifying models for some specialized designs”, Minitab Help, Version 15.1.

Morisada K., Ono, K., Ramspott, B. L. and Price, K. P. (2004). Organic Carbon stock in forest soils in japan. *Geoderma*,119 (1-2): 21-32.

Parton, W.J., Scurlock, J. M., Ojima, D. S., Gilmanov, T. J., Scholes, R. J., Schimel, D. S., Kirchner, T., Menaut, J. C., Seastedt, T., Moya, E.G., Kamnalrut, A. and Kinyamario, J. I (1993). Observation and modeling of biomass and soil organic matter dynamics for the grassland and biome worldwide. *Global Biogeochemical Cycles,* **7**(4): 785–809.

Prabhakar, B., Sharma, S. S. and Singh, R. L. (2001). Management plan of Kedarnath musk deer Sanctuary (from 2000-2001 to 2009-2010) Part I and II, Wildlife preservation organization, Forest department, U.P

Quasin, S. and Uniyal, V. P. (2010). Preliminary investigation of spider diversity in Kedarnath Wildlife Sanctuary, Uttarakhand, India. *Indian Forester*, Oct. 1340-1345

Schimel D., Melillo, J., Tian, H., McGuire, A. D., Kicklighter, D., Kittel, T., Rosenbloom, N., Running, S., Thornton, P., Ojima, D., Parton, W., Kelly, R., Sykes, M., Neilson, R. and Rizzo, B. (2000). Contribution of increasing CO_2 and climate to carbon storage by ecosystems in the United States. Science 287: 2004–2006.

Schleser, G. H. (1982). The response of CO_2 evolution form soil to global temperature changes. Z. Naturforsch. 37: 287-291.

Schlesinger, W.H. (1997). Biogeochemistry. An analysis of global change. Academic Press: San Diego. 588pp

Tewksbury, C.E. (2005). Soil organic carbon dynamics along a climate gradient in a souther Appalachian spruce-fir forest. M. Sc. Thesis, Utah State University, Logan, Utah.

Trumbore S.E. and Harden, J. W. (1997). Accumulation and turn over of C in organic and mineral soils of BOREAS northern study area. *Journal of Geophysical Research* 102(D4): 28 817–28 830.

Walkley, A. and Black, I. A. (1934). An examination of determining method for determining organic soil matter and a proposed modification of the chromic acid titration method. *Soil Science,* 37: 29–37.

Xu, X., Liu, W. and Kiely, G. (2011). Modeling the change in soil organic carbon of grassland in response to climate change: effects of measured versus modelled carbon pools for initializing the Rothamsted Carbon model. *Agriculture, Ecosystems and Environment*, 140, 372–381.

Yang, Y., Mohammat, A., Feng, J., Zhou, R. and Fang, J. (2007). Storage, patterns and environmental controls of soil organic carbon in China. *Biogeochemistry*, 84: 131–141.

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