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Sequestered Organic Carbon Status in the Soils under Grassland in Uttarakhand State, India

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Abstract Vegetative growth serves as an important means to capture and store atmospheric carbon dioxide in biomass and soil. Grassland soils are high in soil organic carbon and contain an extensive fibrous root system that creates an environment ideal for soil microbial activity. Accurate quantification of SOC pool is needed to generate benchmark information for the present and to determine the changes in future. No systematic study has been undertaken to estimate the soil organic carbon pool in grasslands of Uttarakhand state of India. This study therefore, was conducted to estimate SOC pool in the grasslands occurring between the wide altitudinal range of 500m to 4200m above msl. Maximum SOC pool, 142.14 t ha^{-1}, was observed in the altitudinal range of 2501 to 4200m, followed by 105.28 t ha^{-1} between 2001-2500 m, 97.80 t ha^{-1} between 1501–2000 m, 41.15 t ha^{-1} between 1001-1500m and the least was 37.09 t ha^{-1} at 501–1000 m altitude. The grasslands in Uttarakhand extend over an area of 2,28,900 hectare at different altitudes and contain 26.77 million tons of soil organic carbon pool. Correlation between altitudes and SOC pool revealed that altitude was significantly positively correlated with SOC pool under the grassland with correlation coefficient 0.955* (Significant at $P < 0.05$ level). Results of one - way ANOVA indicates that SOC pools at different altitude ranges were significantly different at 0.05 level.

Keywords: *altitudes, grasslands, soil organic carbon, Uttarakhand*

1. Introduction

Global warming and emission of carbon are of worldwide concern because of environmental imbalance in the atmosphere and consequent environmental problems in all parts of the world. Vegetation growth serves as an important means to capture and store atmospheric carbon dioxide in soils and biomass products [1]. Soil contains an important pool of active carbon that plays a major role in the global carbon cycle [2,3]. Soil carbon has much longer residence mean times than the carbon in the vegetation that the soils support. Storage of organic carbon in this long residence time pool is referred to as carbon sequestration. Intergovernmental Panel on Climate Change (IPCC) has recognized soil organic carbon pool as one of the five major carbon pools for the Land Use, Land Use Change in Forestry sector.

Grasslands cover approximately one-third of the earth's terrestrial surface area and play an important role in global carbon cycling as they store between 10% and 30% of the world's soil carbon [4,5] .Grassland soils are high in organic carbon and contain an extensive fibrous root system that creates an environment ideal for soil microbial activity [6]. Although some evidence suggests that temperate grassland soils can sequester relatively large amounts of carbon, there is still uncertainty as to how long this can remain and whether there is an upper limit to carbon storage [7].

Accurate quantification of SOC pool is required to generate benchmark information for the current period and to detect the changes in its amount in the future. Laboratory analysis indicate carbon concentration in soils, but the soil layer thickness, bulk density and percent of fragments > 2mm must be known in order to estimate SOC storage accurately and precisely. Ideally, measurements of SOC concentration are performed on the same soil samples used to determine bulk density and percent of fragments > 2mm, but this is frequently not possible [8]. No systematic study has been undertaken to estimate the soil organic carbon pool in grasslands of Uttarakhand state of India. This study, therefore, was conducted to estimate SOC pool in the grasslands which are spread between 500m and 4200m altitude in Uttarakhand. Information generated from this study will serve as a benchmark to estimate the changes in SOC pool in this land use in future.

2. Materials and Methods

This study was conducted in whole of Uttarakhand state which is located between 28 ° 43'- 31 ° 27' N latitudes and 77 ° 34'- 81 ° 02' E longitudes. The state borders Uttar Pradesh to the south, Haryana to the west and Himachal Pradesh in the north-west and has international border with the Tibet autonomous region on the north and Nepal on the east. The total geographical area of the state is 53483km^2 out of which only 7448km^2 are the plain and

the remaining 46035km^2 are the hills and mountains. The average annual rainfall of the state is 1606 mm. The mean minimum and maximum temperature are -1.7 ℃ and 42 ℃ respectively due to large variation in altitude i.e. 173m to 7280m. SOC pool was estimated in grasslands from low altitudes of 500m above m s l to alpine pasture up to the altitude of 420m. Grasslands were mainly found in Rudrapryag, Chamoli, Uttarkashi, Dehra Dun and Nainital districts.

Sampling sites were selected randomly in different districts of Uttarakhand on the basis of occurrence of grasslands. Five soil samples were collected for soil organic carbon estimation and two separate samples were collected for bulk density and coarse fragment estimation at each sampling site. It was ensured that sampling points typically represent the study area. In all, 112 soil samples were collected from 17 locations (Figure 1). Variation in the number of samples at different sites was due to difference in the extent of grasslands.

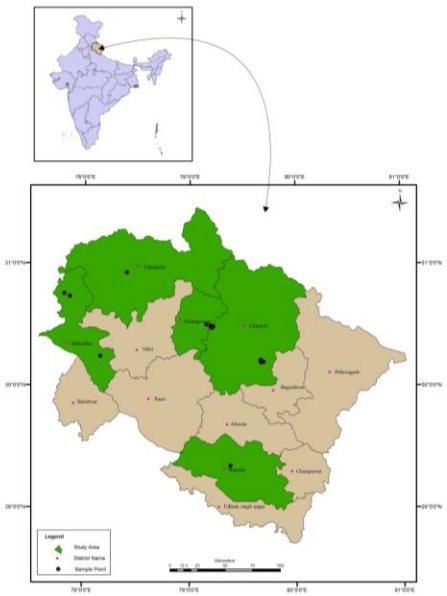

Figure 1. Location of sampling sites

2.1. Estimation of Organic Carbon, Bulk Density and Coarse Fragments

Soil organic carbon was estimated by Walkley and Black method [9]. Amount of coarse fragments was estimated in each sample and deducted from the soil weight to get an accurate soil weight for calculating soil organic carbon on hectare basis. Bulk density of every site was estimated by standard core method [10]. All the methods used in this study are in accordance to Ravindranath and Ostwald [11]. Latitude, Longitude and altitude of each sampling site were recorded by GPS (Garmin 72).

Because the input of organic matter is largely from aboveground litter, forest soil organic matter tends to concentrate in the upper soil horizons, with roughly half of the soil organic carbon (SOC) of the top 100cm of mineral soil being held in the upper 30cm layer. The carbon held in the upper profile is often the most chemically decomposable, and the most directly exposed to natural and anthropogenic disturbances [12]. Therefore, soil organic carbon pool was estimated up to the depth of 30 cm in this study.

2.3. Equation for SOC Calculation

The data for SOC pool was calculated by using the following equation as suggested by IPCC Good Practice Guidance for LULUCF [12]:

$$SOC = \sum_{Horizon=1}^{Horizon=n} SOC_{Horizon}$$

$$= \sum_{Horizon=1}^{Horizon=n} \left([SOC] * \text{Bulk density} * \text{depth} * (1 - \text{C frag}) * 10\right)_{horizon}$$

Where,

SOC = Representative soil organic carbon content for the forest type and soil of interest, tones C ha^{-1}.

$SOC_{horizon}$ = Soil organic carbon content for a constituent soil horizon, tones C ha $^{-1}$.

[SOC] = Concentration of SOC in a given soil mass obtained from analysis, g C (kg soil)$^{-1}$.

Bulk density = Soil mass per sample volume, tones soil m^{-3} (equivalent to Mg m^{-3}).

Depth = Horizon depth or thickness of soil layer, m

C Fragment = % volume of coarse fragments / 100, dimensionless.

3. Results and Discussion

SOC pool in the grassland at different altitudes was estimated and data has been presented in Table 1. Maximum SOC pool, 142.14 t ha^{-1} was found above 2500m altitude followed by 105.28 t ha^{-1} between 2001-2500m, 97.80 t ha^{-1} between 1501-2000m, 41.15 t ha^{-1} between 1001-1500m altitude and the minimum amount of 37.09 t ha^{-1} was found between 501-1000m altitude. The higher temperature and restricted moisture availability up to 1500m altitude, as compared to high altitude grasslands, may be responsible for lower SOC pool between 501 and 1500m altitude. Temperate climate favours organic carbon accumulation in the soil [new 13], [14]. Grassland above 1501m altitude had reasonably higher SOC pool. Rawat [15] reported that soil organic carbon and potassium were positively correlated with the altitudinal gradient while working on soil characteristics along an altitudinal gradient from 1,700 to 2,100m above m s l in a mountain flank of Garhwal Himalayas. The Subset for $\alpha = 0.05$ indicated that the SOC of grassland between 501-1000m altitude and 1001-1500m altitude form one group (a), and those between 1501-2000m, 2000-2500m and > 2501m altitude form another group (b) (Table 1).

Table 1. Altitude wise SOC pool in Uttarakhand under Grassland, up to 30 cm depth

Sl. No.	Altitude Range (m)	SOC pool (t ha^{-1})	SD	SE
1	501 – 1000	37.09^a	± 19.8742	6.28
2	1001 – 1500	41.15^a	± 21.1634	9.46
3	1501 – 2000	97.80^b	± 27.1226	19.17
4	2001 – 2500	105.28^b	± 51.9809	16.43
5	> 2501	142.14^b	± 38.8683	5.33

Same alphabets represent statistically at par group.

SOC pool has been found to increase with increasing altitude. Correlation between altitude and SOC pool (Figure 2) revealed that altitude was significantly positively correlated with SOC pool under the grassland

with correlation coefficient 0.955* (Significant at P < 0.05 level).

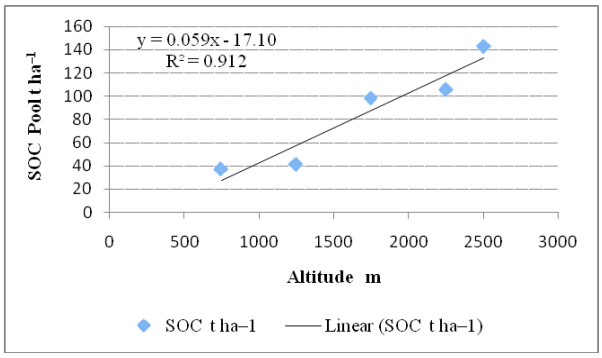

Figure 2. Relationship between Altitude and SOC pool

Soil organic carbon content was also found to be strongly correlated with elevation in the grasslands of mountainous French region [16]. Study conducted by spatially-explicit version of the CENTURY soil model to characterize the storage and flux of soil organic carbon (SOC, 0-30cm depth) in the Luquillo Experimental Forest (LEF), indicated that differences in elevation affect decomposition and content of SOC primarily by changing micro-climate [17]. A projected warming of 2.0℃ is likely to result in losses of SOC in the lower and higher elevation.

Results of one - way ANOVA indicated that SOC pool between the altitudinal groups was significantly different at 0.05 level (Variance ratio, F = 22.064; p < 0.05). SOC pool in the grasslands at the altitudes of 501-1000m and 1001–1500 m do not differ significantly and similarly the SOC of grasslands between 1501-2000m and 2001-2500m and > 2501m altitude are statistically at par. However, the SOC between 501-1000m and 1001-1500m altitude is significantly different from SOC of other altitudes (Table 2).

Table 2. Statistically significant mean differences on the basis of CD (LSD)

Sl No.	Vegetation	Mean Difference	p value
1	> 2501 Vs 501 – 1000 m	105.0465*	0.000
2	> 2501 Vs 1001 - 1500 m	100.9815*	0.000
3	2000 – 2500 m Vs 501 – 1000 m	68.1865*	0.000
4	2001 - 2000 m Vs 1001 – 1500 m	64.1215*	0.003
5	1501 – 2000 m Vs 501 – 1000 m	60.7098*	0.043

* Mean difference is significant at the 0.05 level.

The average SOC pool in the grasslands of Uttarakhand is 116.98 t ha^{-1} and the permanent pastures extend over an area of 2,28,900 ha [18]. The total SOC pool contained by the grasslands of Uttarakhand state is therefore, 26.77 million tons.

The temperate climate favors accumulation of SOC pools and a major concern for such regions is the change that may take place in the large SOC stock if temperature would rise. Change in the carbon stocks in the grassland soils in response to land use change will increase atmospheric CO_2 and consequently affect the climate change. Results of this study [19] indicate that the SOC stock in upper 30 cm layer decreased and approximately 10 and 25 % of original SOC of the grasslands has been emitted over 28 and 42 years respectively after doing cropping on the grasslands.

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