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TREE AND SOIL CARBON STOCK BY COMMUNITY MANAGED FORESTS IN GARHWAL HIMALAYA

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Abstract

The present study highlights the significance of community managed forests in relation to regulating service as well as local community benefitted from the REDD + mechanism by controlling the rate of forest degradation.

Tree carbon and soil organic carbon stock estimation was conducted in a Ghotla van Panchayat forest in district Pauri of Garhwal Himalaya, Uttarakhand, India. This forest is managed by Ghotla villagers and is dominated by tree species: *Quercus leucortichophora*. The highest values for above ground biomass density 78.20±17.41 t ha^{-1} was found in *Quercus leucotrichophora*, which was followed by *Pinus roxburghii.* Overall calculated values of total biomass density and total carbon density were 132.74 Mg ha^{-1} and 66.36 Mg ha^{-1} respectively. As far as Soil Organic carbon (%) (SOC) was concerned; the mean value of organic carbon was 1.28%, while the highest SOC percentage was found in depth 0 - 10 cm (2.29±0.42%). The per hectare mean SOC stock for van Panchayat was 218.57t.

The finding indicates that the van Panchayat forests may act as role model on mitigating climate changes. It is neccesary to add in climate change concern in forest sector, especially Van Panchayat forests for long-term planning process.

Key words : Regulating services, tree biomass, soil organic carbon, Van Panchayat, Garhwal Himalaya.

Introduction

The concept of ecosystem services, meaning the benefits people obtain from ecosystems, has gained widespread acceptance among scientists, managers and politicians since its use in the Millenium Ecosystem Assessment (MEA, 2005). Regulating services such as carbon and water regulation often tend to change over much longer timescales than do provisioning services. Regulating services contribute and enhance provisioning services by providing conditions for the flow of provisioning services (such as fuel & fodder). For example, regulating services reduce soil erosion and modulate micro-climatic conditions that are beneficial to crop production, the biomass of a tree, indirectly enhancing productivity (nutrient leaching).

Earliyer study indicates that many indigenous communities recognize the importance of regulating services provided by different ecosystems. Among all the terrestrial ecosystems, forests contain the largest store of carbon (IPCC, 2001). The main carbon pools in forests are plant biomass (above and below-ground), coarse woody debris, litter and soil (IPCC, 2003). The quantity of carbon stocked in tree biomass corresponds to approximately 77% of the carbon contained in the global vegetation, while forest soil stores 42% of the global 1m top soil carbon (Bolin *et al*., 2000). Rodger (1993) estimated that about 86% of the terrestrial aboveground carbon and 73% of the earth's soil carbon are stored in the forests. Forest play a imporant role in reducing CO^2, according to Brown and Pearce (1994) the forest sequesters 20 to 100 times more carbon per unit area than croplands.

The carbon cycle connects forests to climate change as total carbon stored in forests has a very important role in determining the climate stabilization paths. The Van Panchayats was formed under the Panchayat Forest Rules, 1931 and have been incorporated under Section 28(2) of the Indian Forest Act, 1927. In Uttarakhand, 65% geographical area is under the forest area, of which about 12% forest area is under Van Panchayat which is the second large vegetation area after reserve forest, with 12,089 number VP are present in the state (Hussain *et al*., 2015).

Forests of the Himalayan mountains comprise an important component of the ecosystem, serving as strong carbon sinks and conserving soil, water and biodiversity and building up a specific micro-climate. In the same way, Oak forests are major carbon sinks and their capacity to sequester carbon and therefore to mitigate the effects of climate change. Oak (*Quercus leucotrichophora*) forests are the major climax vegetation of the mid-altitude Himalayas, and also a major source of livelihoods of the inhabiting communities (Singh & Singh, 1992). Oak forests, are rich repository of carbon both in vegetation biomass and soils. Oak forest regulates the quality of air and water and contributes to soil formation, carbon sequestration and protection from erosion, etc. So, the present study deals with regulating services (as a carbon stock) stock by the Oak dominated van Panchayat.

Materials and Methods

Ghotla van Panchayat is situated near the village Ghotla in the Rikhnikhal block of Pauri district of Garhwal Himalaya (N 29°492 59.43 " E 78°472 17.93) an elevation of 1800-2300m asl. The area of van Panchayat is 50 hectares. Geographycally the VP situated mainly in southern aspect. There are three distinct seasons in a year as, summer, rainy and winter, in winter the snowfall are also observed. The mean minimum temperature is observed in January (3.6°C) and maximum in may (29.3°C), with average rainfall of 138.75mm. (http://www.worldclim.org/bioclim).

One percent sampling was carried out to enumerate trees using nested quadrate design. Quadrat size of 20m × 20m (400m^2) was to enumerate all the trees. The height and dbh (diameter at breast height) of all the trees (≥ 10 cm dbh at 1.37 m) falling within the sample plots were measured (Knight, 1963) and considered for estimation of carbon density.

Above ground biomass estimation was calculated based on total growing stock density (GSVD), GSVD was estimated using volume tables or volume equations based on the Forest Research Institute (FRI) and Forest Survey of India (FSI) publications for the respective species (FSI, 1996; Chaturvedi, 1973). The estimated GSVD (m^3 ha^{-1}) was then converted into above ground biomass density (AGBD), which was calculated by multiplying GSVD of the forest with appropriate biomass expansion factor (BEF) (Brown *et al*., 1999).

Below-ground biomass density was calculated using regression equations developed by Cairns *et al*. (1997), the BGBD (from fine and coarse roots) was estimated for different tree species using below given equation

$$BGBD = \exp[-1.059 + 0.884 \times \ln(AGBD) + 0.284]$$

Total biomass density was calculated by adding AGBD and BGBD

$$TBD = ABGD + BGBD$$

The total carbon density (TCD) was computed by using the following formula (IPCC, 2000):

$$\text{Carbon (Mg ha}^{-1}) = \text{Biomass (Mg ha}^{-1}) \times (0.5)$$

Soil sampling was carried out in March (2013) and samples were collected randomly from five plots. Soil samples were collected at five different depths *viz*., 0-10, 10.01 – 20, 20.01 – 40, 40.01 – 60 and 60.01 – 100 cm after clearing forest litter. The soil was packed in zip lock poly bags and brought to the laboratory for physical and chemical analysis. Layer wise estimation was used to derive the average soil property of the respective site. For determining soil bulk density, soil samples were collected by means of a special metal core-sampling cylinder of known volume (119.39cc). The weight of oven dried soil samples was divided by its volume to estimate bulk density (Mishra, 1968). Soil texture was determined by using different sieves of different pore sizes (Mishra, 1968). Percentage of soil separates were determined using the triangular diagram by U.S.D.A. system. Absorbed water content in saturated condition was calculated (Black, 1965; Jackson, 1967) as water holding a capacity of soil. The moisture content was determined on a fresh weight basis method given by Mishra (1968).

The pH of soil was then measured directly with the help of control dynamics digital pH meter (model Ap+ 175E/C). The soil organic carbon was estimated through Walkly and Black (1934).

Total soil organic carbon (tones)

$$= \frac{SOC\%}{100} \times BD\left(t/m^3\right) \times \text{are } (m^2) \times \text{Depth of soil (m)}$$

Results

Above and belowground tree biomass and carbon

The value of density is provided in table 1, with highest values of density observed for *Quercus leucotrichophora* (257.14) followed by *Pinus roxburghii* (35.71) while lowest values (1.79) was observed for both *Quercus floribunda* and *Toona ciliata* respectively (table 1). The highest total above ground tree biomass was 78.20±17.41 t ha^{-1} in *Quercus leucotrichophora*, which was followed by *Pinus roxburghii*, *Lyonia ovalifolia*, *Myrica esculenta*, *Toona ciliata* and *Quercus floribunda* with total biomass values 20.27±12.65, 1.99±1.64, 1.83±1.02, 0.29 and 0.86 t ha^{-1} respectively (table 2). The below ground biomass density values ranged between 0.40 t ha^{-1} to 20.89 t ha^{-1}

for *Toona ciliata* and *Quercus leucotrichophora*, total biomass density (both above and below) was highest for *Quercus leucotrichophora* (99.09 t ha^{-1}) followed by *Pinus roxburghii* (25.75 t ha^{-1}) and the lowest values were recorded for *Quercus floribunda* (table 2). In this site, 74.64% of the total biomass was present in *Quercus leucotrichophora,* which was followed by *Pinus roxburghii* (19.39%) and the lowest was recorded in *Quercus floribunda* (0.86%).

Physico-chemical property of soil

In five different depths of each site, the moisture content varied from 11.29±1.68 to 18.28±1.67 (table 3), while the average moisture content was 14.39±1.85%, which showed a decreasing trend with an increase in depth (table 4). Average WHC in VP was 24.17±4.32%, and the highest value (33.20±7.29%) of water-holding capacity (WHC) was recorded in the upper layer (0-10 cm), which decreased with increase in depth up to 18.77±6.34 in (60-100 cm depth) (table 4). Bulk density varied from 1.20±0.37 g cm^{-3} to 1.39±0.17 g cm^{-3} (table 3), which was higher at 40 - 60 cm depth (1.44±0.21 g cm^{-3}) and the lowest 1.04±0.29 g cm^{-3} at (0-10cm) (table 4). The percentage of sand, silt, and clay varied from 75.85±8.65 to 80.27±3.75, 10.60±2.73 to 18.35±6.26 and 4.21±1.21 to 10.27±6.40, respectively (table 3), while the overall soil was loamy sand in texture (table 3).

The pH was acidic, which varied from 5.74±0.04 to 6.04±0.34 (table 3), the highest pH was observed at 60 – 100 cm depth (6.12±0.24) and lower values 5.77±0.27 at 0-10 cm depth (table 4). As far as Soil Organic carbon (%) (SOC) was concerned, the values of organic carbon ranged between 1.01±0.82 to 1.60±1.01 (table 3). The highest SOC percentage was found in the depth of 0-10 cm (2.29±0.42%) followed by 10-20, 20-40, 40-60 and 60-100 cm depth, which showed decreased trend with increasing depth (table 4), while mean SOC stock per hectare was 218.57±22.31 ton (table 3).

Discussion

In the present study, the tree density value was 308.93 N ha^{-1}. Similar result was recorded for Van panchayat forest by Rawat and Rawat (2010), 349 individuals ha^{-1} for Western Himalaya forest by Saxena and Singh (1984). These value were lower than the 460-970 individuals ha^{-1} in protected forests of Nainital catchment (Bargali *et al*., 2013) and 920-1345 individuals ha^{-1} in natural Oak dominated forest (Lodhiyal *et al*., 2013). These value was higher than the values reported for Garhwal Himalayan van Panchyat by Negi *et al*. (2008).

Biomass is one of the important quantitative characters for forest ecosystems. Tree biomass in forest ecosystems vary with forest type, species composition, stand age, size class of trees, site conditions, rainfall pattern, edaphic factors, and altitude (Peichl and Arain, 2006; Terakunpisut *et al*., 2007; Gairola *et al*., 2011; Cao *et al*., 2012; Zhao *et al*., 2014). The values of tree biomass density obtained in the present study were 132.74Mg ha^{-1}, which is well within or near the range of the tree biomass density in temperate forests of India (Tiwari and Singh, 1987; Singh *et al*., 1994; Chhabra *et al*., 2002; Sharma *et al*., 2010) and other part of the world (Wang *et al*., 2008; Ponce and Galicia, 2010; Zhang *et al*., 2013; Zhao *et al*., 2014). Our results were also within the range of the results reported by Mohanraj *et al*. (2011) from Kolli hills of Eastern Ghats of India.

Total aboveground and belowground biomass in Indian forests contributes 79% and 21%, respectively of the total biomass (Chhabra *et al.,* 2002). The contribution of above and belowground biomass to the total biomass in the present study was 78.84 and 21.16%, respectively. Similarly, Gairola *et al*. (2011) have also reported the relative contribution to total biomass was 80.8% (AGB) and 19.2% (BGB) from Garhwal Himalaya, India. The ratio of above and below ground biomass is more or less similar to the present study. Average soil moisture content for the present study were between 11.29-18.28%. The values for the present study were comparable with the values reported by different authors from different parts of the Garhwal Himalaya for *Quercus* and other forest types (Khera *et al*., 2001; Srivastava *et al*., 2005; Semwal, 2006; Nazir, 2009; Sharma *et al*., 2010a; Sheikh and Kumar, 2010; Sharma *et al*., 2010b and Mehta and Bhatt, 2014). But the values are lower than the values reported by Usman *et al.* (2000); Pande *et al*. (2001); and Arya (2014) and higher than the values reported by Khera *et al*. (2001) for the mixed broadleaf forest of Nainital, Uttarakhand.

The water holding capacity is an index of a number of physical properties of soil. Good water holding capacity shows the good physical condition of soil. Average Water holding capacity for the present study varied between 19.20-28.14%.

The values of the present study were well within the values reported by Khera *et al*. (2001) for the mixed broadleaf forest of Nainital. Metha and Bhatt (2014); while working in Oak mixed coniferous forests of Garhwal has also supported the results. The values for the present study were lower than the values reported by different authors in Uttarakhand Himalayan forest (Sharma *et al*., 2010b; Pande *et al*., 2001; Mehta and Bhatt, 2014).

Table 1 : Species-wise (Mean and standard division) diameter at breast height (DBH), height, total basal cover (TBC), density for Van Panchyat.

Name of tree species	DBH (m)	Height (m)	Total Basal Cover (m^{-2} ha^{-1})	Density (N ha^{-1})
Lyonia ovalifolia	0.192±0.128	5.5± 2.12	0.127	3.57
Myrica esculenta	0.163±0.036	3.8± 0.90	0.193	8.93
Pinus roxburghii	0.271±0.165	8.5± 5.66	2.796	35.71
Quercus floribunda	0.121	2.5	0.020	1.79
Quercus leucotrichophora	0.566±0.236	10.0±7.85	13.072	257.14
Toona ciliate	0.159	6	0.035	1.79

Table 2 : Species wise (Mean ± SE) Growing stock Volume Density (GSVD), Above Ground Biomass Density (AGBD), Below Ground Biomass Density (BGBD), Total Biomass Density (TBD)and Total Carbon Density (TCD) for Van Panchyat.

Name of tree species	GSVD (m^3 ha^{-1})	AGBD (Mg ha^{-1})	BGBD (Mg ha^{-1})	TBD (Mg ha^{-1})	TCD (Mg ha^{-1})
Lyonia ovalifolia	0.50±0.45	1.99±1.64	0.66±0.53	2.65±2.17	1.32±1.09
Myrica esculenta	0.32±0.19	1.83±1.02	0.66±0.36	2.49±1.38	1.24±0.69
Pinus roxburghii	24.32±15.66	20.27±12.65	5.47±3.28	25.75±15.93	12.87±7.96
Quercus floribunda	0.17	0.86	0.30	1.15	0.58
Quercus leucotrichophora	52.86±16.56	78.20±17.41	20.89±4.30	99.09±21.70	49.54±10.85
Toona ciliata	0.29	1.21	0.40	1.61	0.81

Table 3 : Plot wise soil physico- chemical properties (mean ± SD) for Ghotla van Panchayat.

Plot	Moisture (%)	WHC (%)	BD (g cm^{-3})	Sand (%)	Silt (%)	Clay (%)	pH	SOC (%)	Total SOC (ton/Ha)
1	18.28±1.67	28.14±6.81	1.20±0.37	77.2±7.54	12.6±4.94	10.07±6.94	5.99±0.08	1.17±0.45	190.16
2	14.08±0.44	27.55±7.66	1.39±0.17	80.2±3.75	10.6±2.73	9.13±2.57	5.74±0.04	1.01±0.82	252.48
3	11.29±1.68	19.84±5.81	1.30±0.06	78.1±7.36	11.5±3.56	10.27±6.40	5.86±0.30	1.60±1.01	219.80
4	12.91±1.65	19.20±6.02	1.29±0.24	78.1±4.38	17.6±5.37	4.21±1.21	5.87±0.34	1.41±0.61	217.59
5	15.42±3.85	26.13±6.78	1.27±0.22	75.8±8.65	18.3±6.26	5.80±2.61	6.04±0.34	1.47±0.79	212.83
Average	**14.39±1.85**	**24.17±4.32**	**1.29±0.06**	**77.9±1.60**	**14.1±3.85**	**7.90±2.72**	**5.90±0.12**	**1.28±0.25**	**218.57±22.31**

Texture difference can affect many other physical and chemical properties and are therefore important in measures such as soil productivity. Natural soils are comprised of soil particles of varying sizes. Sand, silt and clay percentage for the present study recorded between 75.85-80.27, 10.60-18.35, 5.80-2.61, respectively. The variations in soil particles are evident between the different forest types. Tiwari *et al*. (2013) have reported that the variation in soil particles is due to heterogeneous soil conditions prior to the forest community establishment. The temperate forest soils of Himalayas are generally considered as sandy loam, which is also verified from the present study. The results of the present study of higher values of sand and silt are also supported by different authors of Garhwal Himalaya, *viz*., Semwal *et al*. (2009), Kumar *et al*. (2009) for *Quercus leucotricophora* forest of Garhwal Himalaya (Sheikh and Kumar, 2010; Arya, 2014). Soil pH, which refers to the soils acidity or alkalinity. Types of decomposition matter, inorganic and organic chemical reaction influence soil chemical properties. Soil fertility is directly influenced by pH through the solubility of many nutrients. The soil pH of the present study was found slightly acidic (5.90). The similar result for soil pH was also shown by different authors (Harpal *et al*., 2009; Srivastava *et al*., 2005; Sharma, 2010a and Arya, 2014) for the forest of Garhwal Himalaya.

Soil carbon is the fundamental building block of soil organic matter and as such, it is the primary determinant of many soil chemical and physical properties including nutrients availability, soil structure and water holding capacity (Lal, 1997; 1999). Soil organic carbon, being the largest terrestrial carbon pool, plays a very significant role in the carbon balance of global terrestrial ecosystems (Chhabra and Dadhwal, 2005). The primary source of soil organic carbon is plant tissues. Under natural

Table 4 : Depth wise soil physico-chemical properties (mean ± SD) of Ghotla van Panchayat.

Depth (cm)	Moisture (%)	WHC (%)	BD (g cm^{-3})	Sand (%)	Silt (%)	Clay (%)	pH	SOC %
0-10	20.46±6.85	33.20±7.29	1.04±0.29	77.72±5.43	16.69±6.40	8.59±6.80	5.77±0.27	2.29±0.42
10 – 20	15.13±5.40	25.67±3.71	1.30±0.07	78.62±2.29	14.78±1.82	6.61±1.74	5.94±0.32	1.69±0.42
20 – 40	15.09±5.40	24.09±3.50	1.24±0.13	78.28±7.77	10.83±3.24	10.89±8.10	5.73±0.15	1.17±0.31
40 – 60	13.40±3.83	19.14±4.71	1.44±0.21	81.32±7.48	12.83±7.09	5.85±1.37	5.93±0.13	0.82±0.22
60 - 100	13.01±6.03	18.77±6.34	1.42±0.12	76.75±7.16	15.70±6.67	7.55±2.26	6.12±0.24	0.43±0.20

conditions, the tops and roots of trees, shrubs, grasses and other plant parts annually supplement large quantities of organic residue. The soil organic carbon for the present study ranged between 1.01-1.60%.

The values for the present study are well comparable with the studies carried by different authors of Garhwal Himalaya. Nazir (2009) while working on *Quercus* mixed forest of Kewars forest reported value of 1.09-2.09, which is comparable with the values reported in present study.

The Ghotla VP committee is allowed a few day in a year for collection the provisioning services. The Ghotla VP forest is conserved by local communities for sustainable resource utilization. This study estimated the physicochemical property of soil and standing tree carbon stock in VP forest, this result can be served as a baseline for the implementation of project activities. Community based forest management, to avoid deforestation and encroachment by locals. The people of this area depends on forest provisioning services to fulfill their daily needs, like fuel, fodder, non-timber forest products, etc. The conservation of Ghotla VP forest will lead to improved unprotected forest and VP where conservation management practice and strategy are not implemented in Garhwal Himalaya. The Ghotla VP can provide model to sustainable provisioning service utilization and conserve the regulating service as a form of carbon.

Conclusion

Our study quantified the variation in carbon stock storage by species. From a carbon storage point of view, *Quercus leucotricophora* is not suitable species for plantation. But to fulfill provisioning service needs such as supply of fuelwood, fodder and grasses, *Quercus leucotricophora* forest is important. If aforestation is needed, the local management system should be involved in aforestation design. These types of community conserved forests will play a major role in long-term mitigation of GHG emissions due to conversion of natural forest. The REDD policy must be built upon the existing Community forest management policy where communities are recognized with their forest use rights. Successful participation can bring ecological and economic benefits to the community as well as the country.

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