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Biomass and Carbon Stock Assessment in Moist Deciduous Forests of Doon Valley, Western Himalaya, India.

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ABSTRACT: The study was conducted in the three forest ranges of Dehra Dun Forest Division of Doon Valley, Western Himalaya, India. Biomass and carbon status in the moist deciduous forest were estimated using volumetric equations. A total of 150 quadrats were laid in the study sites. The biomass ranged from 338.40 Mg ha^{-1} to 438.17 Mg ha^{-1} and carbon stocks from 169.20 Mg ha^{-1} to 219.08 Mg ha^{-1} in different study sites. The study concludes that moist deciduous forests of Doon Valley have the potential for carbon sequestration. The study sites are also experiencing lot of anthropogenic pressures from the villages at the forest fringes.

KEY WORDS: Biomass, Carbon, Moist Deciduous Forest, Uttarakhand, Wood Density.

INTRODUCTION

The contribution of biomass production to climate change mitigation is recognized by their ability to uptake CO_2 from atmosphere through photosynthesis as for the strong capacity in biotic and abiotic components (Laclau, 2003). By complex relationships with vegetation species and the environment, each growing tree is a control factor of carbon emissions the same as a reservoir that increases its storing capacity overtime until it reaches a steady state in late succession stage. The biomass productivity and distribution of trees is generally influenced by the climatic and geographical variations (Rawat and Singh, 1988; Wang, 2003).

Shorea robusta (Sal) forests are spread across 10 million hectare (m ha) in India. Sal is an important tree species with high timber value (Tewari, 1995). Globally, the natural range of Sal forests lies between 20–32°N lat. and 75–95°E long., where the distribution is primarily controlled by climate and edaphic factors (Gautam and Devoe, 2006). In India, the species is dominantly distributed on the plains and lower foothills of the Himalayas and also along the valleys (Gautam, 1990). Champion and Seth, (1968) have demarcated the spread of Sal forests ranging from Uttarakhand in the north up to Andhra Pradesh in the south and Tripura in the east; covering Himachal Pradesh, Haryana, Uttar Pradesh (UP), Bihar, West Bengal, Odisha, Madhya Pradesh, Chhattisgarh, Maharashtra, Jharkhand, Sikkim, Assam and Meghalaya.

Doon valley experiences a contradiction between ecological and economic priorities. The recent development in terms of burgeoning population density as well as high density of vehicular traffic because of very low road length per capita has generated high level of pollution on one hand and deteriorating soil and water quality on the other. The forests of the valley are interspersed and intersected by a large number of villages resulting in a number of isolated and sometimes narrow fingers like formations.

The objective of the study was to investigate the carbon storage in three forest ranges of Dehra Dun Forest Division in Doon valley of Uttarakhand, India and to analyze their differences with respect to various anthropogenic pressure faced by the forests of Doon Valley.

STUDY AREA

The word Doon represents the boulder valley that runs parallel to and between the lesser Himalayan range and the Shiwalik range. The Doon valley is located in the Shiwalik Himalayas, lying between latitudes 29°55'and 30°30' N and longitudes 77°35' and 78°24' E. It is about 20 km wide and 80 km long saucer-shaped valley with a geographical area of ca. 2100 km^2. The Doon valley falls under the sub-tropical to temperate climate due to its variable elevation. The average maximum temperature for the Doon valley was 27.65°C and the average minimum temperature was 13.8°C, with average maxima in June (40.00°C) and average minima in January (1.80°C) in year 2010-11. The area received an average annual rainfall of 2025.43 mm. The region receives most of the annual rainfall during June to September, the maximum rainfall occurring in July and August.

The study was conducted in the three ranges (Barkot Range, Lachchiwala Range and Thano Range) of Dehra Dun Forest Division in Doon Valley (Fig. 1). In the natural forests of Doon valley, *Shorea robusta* is the most common representatives of the native genera. Sal and its associates occur throughout the Shivaliks

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across large tracts of the valley and also along the lower foothills of the Himalayas. The associates of *Shorea robusta* are *Anogeissus latifolia*, *Terminalia tomentosa*, *Adina cordifolia*, *Terminalia bellirica*, *Lannea coromodelica*, *Garuga pinnata*, *Lagerstromia parviflora*, *Stereospermum suveolens*, *Albizia procera*, *Cederala toona* etc. The underwood consists of *Mallotus philippensis*, *Cassia fistula*, *Ougeinia dalbergiodes*, *Ficus religiosa*, *Ehretia laevis*, *Emblica officinalis*, *Bauhinia variegata*. The undergrowth consists of *Murraya koenigii*,*Colebrookia oppositifolia*, *Carissa opaca*, etc.

The site is a natural Sal forest and lopping of these trees for fuel and fodder, along with extraction of medicinal (*Zingiber roseum*) and ethanobotanical (*Pterospermum acerifolium*, *Calamus tenuis* etc.) plants are the major disturbances prevailing in the region. In addition to this, in the recent years, over mature Sal, and those infested by *Hoplocerambyx spinicornis* (Sal borers) were also removed/harvested by the forest department. All these disturbances have resulted in large canopy gaps and tampering of forest soils, which has made the forest floor vulnerable to runoff during rains. With the runoff of the top soil all the nutrients are washed away and the soil becomes oligotrophic.

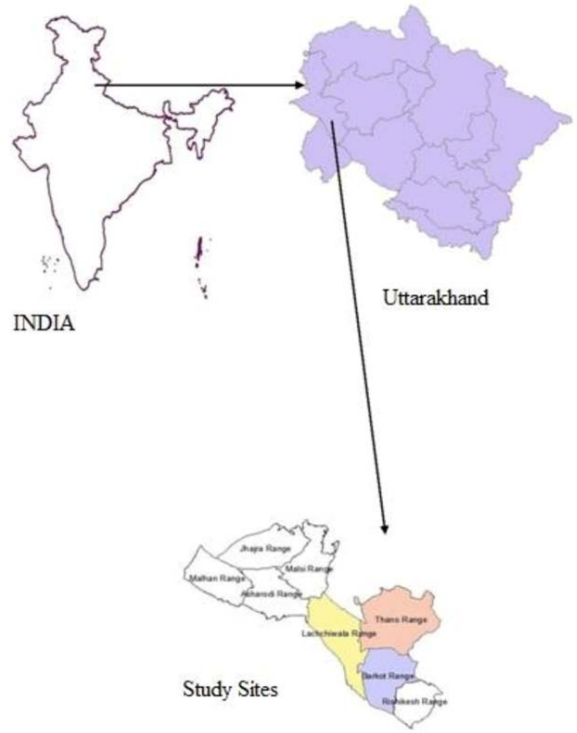


Fig. 1. Location map of the study sites

METHODOLOGY

A total 50 quadrats of 10 × 10 m^2 were laid down randomly in each range of the entire study area. The height and diameter at breast height (1.37 m above the ground) of all the trees within the sampling quadrat were measured. The volume of the individual trees was estimated using the species specific volume equations (FSI, 1996). The estimated volume of each tree was multiplied by its wood density to derive the stem biomass. Later, the bole biomass was multiplied by the biomass expansion factor (Haripriya, 2000) to derive individual tree aboveground biomass. Aboveground biomass was used to calculate the belowground biomass by multiplying the value of aboveground biomass with the constant factor 0.26 (IPCC 2006). Aboveground biomass and belowground biomass were added to get the individual tree total biomass. The carbon contents was calculated by the multiplying the individual tree total biomass with the conversion factor 0.5 (IPCC, 2006). The individual tree total biomass and carbon contents in a quadrat were summed to obtain total biomass and carbon storage in sampling quadrat. The mean total biomass and carbon were calculated by averaging the total biomass and carbon values in all sampling quadrats.

RESULTS

Barkot Range

The aboveground biomass ranged from 0.43 Mg ha^{-1} to 202.26 Mg ha^{-1}. *Shorea robusta* and *Mallotus philippensis* have the aboveground biomass of 202.26 Mg ha^{-1} and 28.24 Mg ha^{-1} respectively, being the dominant and co-dominant species. Aboveground biomass for the *Ehretia laevis* and *Anogeissus latifolia* was 9.24 Mg ha^{-1} and 7.67 Mg ha^{-1} respectively. The belowground biomass falls in the range of 0.11 Mg ha^{-1} to 52.59 Mg ha^{-1} for individual tree species. The total biomass of tree species in the moist deciduous forest ranged between 0.54 Mg ha^{-1} and 254.85 Mg ha^{-1}. The maximum contribution was by the *Shorea robusta.* A total of 169.20 Mg ha^{-1} carbon stock was recorded in the moist deciduous forest in Barkot Range (Table 1).

Lachchiwala Range

A total aboveground biomass (347.75 Mg ha^{-1}) was recorded in the moist deciduous forest of Lachchiwala Range. *Shorea robusta* had the contribution of 271.21 Mg ha^{-1} followed by *Mallotus philippensis* with the contribution of 25.20 Mg ha^{-1}. Belowground biomass ranges between 0.17 to 70.51 Mg ha^{-1}. A total of 90.42 Mg ha^{-1} belowground biomass was recorded in the moist deciduous forest of Lachchiwala Range. Total biomass of 438.17 Mg ha^{-1} has been recorded with the

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Table 1. Biomass and carbon stock of the moist deciduous forest in three study sites.

Location	Barkot Range				Lachchiwala Range				Thano Range			
Tree Species	AGB	BGB	TB	CS	AGB	BGB	TB	CS	AGB	BGB	TB	CS
Adina cordifolia	2.25	0.59	2.84	1.42	0.67	0.17	0.84	0.42				
Anogeissus latifolia	7.67	1.99	9.66	4.83	15.94	4.14	20.08	10.04				
Bauhinia variegata	1.24	0.32	1.56	0.78	2.65	0.69	3.34	1.67				
Caseaseria tomentosa	0.62	0.16	0.78	0.39	0.84	0.22	1.06	0.53				
Cassia fistula.	1.33	0.35	1.68	0.84	1.17	0.3	1.47	0.74				
Cordia dichotoma					0.28	0.07	0.35	0.18				
Ehretia laevis	9.24	2.4	11.64	5.82	8.46	2.2	10.66	5.33	2.19	0.57	2.76	1.38
Ficus benghalensis	2.94	0.76	3.7	1.85								
Flacourtia indica					0.9	0.23	1.13	0.57				
Litsea glutinosa	0.43	0.11	0.54	0.27								
Mallotus philippensis	28.24	7.34	35.58	17.79	25.2	6.55	31.75	15.88	19.87	5.17	25.04	12.52
Miliusa velutina	5.86	1.52	7.38	3.69	10.78	2.8	13.58	6.79				
Ougeinia oojeinensis	0.66	0.17	0.83	0.42								
Shorea robusta	202.26	52.59	254.85	127.42	271.21	70.51	341.72	170.86	240.46	62.52	302.98	151.49
Syzygium cumini	2.54	0.66	3.2	1.6	4.44	1.15	5.59	2.8	69.85	18.16	88.01	44.01
Tectona grandis									1.21	0.31	1.52	0.76
Terminalia alata	0.74	0.19	0.93	0.47	1.5	0.39	1.89	0.95	1.69	0.44	2.13	1.06
Terminalia bellirica	2.55	0.66	3.21	1.61	1.5	0.39	1.89	0.95				
Total	268.57	69.83	338.40	169.20	347.75	90.42	438.17	219.08	335.27	87.17	422.44	211.22

AGB=Above Ground Biomass (Mg ha^{-1}), BGB=Below Ground Biomass (Mg ha^{-1}), TB=Total Biomass (Mg ha^{-1}), CS=Carbon Stock (Mg ha^{-1})

maximum contribution 341.72 Mg ha^{-1} by *Shorea robusta*. 219.08 Mg ha^{-1} carbon stock has been reported from the moist deciduous forest in Lachchiwala Range (Table 1).

Thano Range

Total aboveground biomass recorded was 335.27 Mg ha^{-1} in moist deciduous forest of Thano Range. *Shorea robusta* had the contribution of 240.43 Mg ha^{-1} while the *Syzygium cumini* had the contribution of 69.85 Mg ha^{-1} in the aboveground biomass. *Mallotus philippensis* had the aboveground biomass of 19.87 Mg ha^{-1}. The total belowground biomass recorded was 87.17 Mg ha^{-1}. Total biomass and total carbon estimated in the moist deciduous forest of Thano Range was 422.44 Mg ha^{-1} and 211.22 Mg ha^{-1} respectively (Table 1).

The total biomass (438.17 Mg ha^{-1}) and carbon stocks (219.08 Mg ha^{-1}) were maximum in moist deciduous forest of Lachchiwala Range was followed by Thano Range with total biomass (422.44 Mg ha^{-1}) and carbon stocks (211.22 Mg ha^{-1}). Moist deciduous forest in Barkot Range has the 338.40 Mg ha^{-1} total biomass and 169.20 Mg ha^{-1} carbon stocks (Table 1).

Contribution of *Shorea robusta* in carbon storage of moist deciduous forest

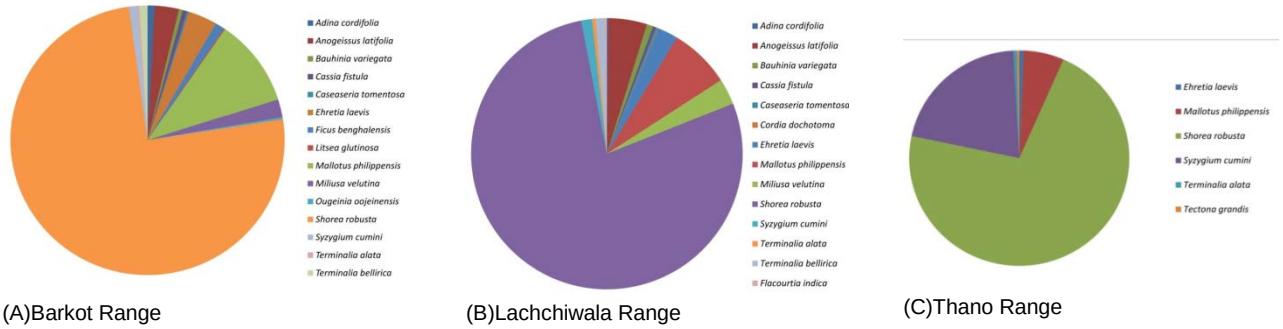
The moist deciduous forest of Barkot Range had the *Shorea robusta* contribution of 127.42 Mg ha^{-1}, 75 % of the total carbon (Fig. 2. (A)). The contribution of *Shorea robusta* in total carbon of moist deciduous forest of Lachchiwala Range was 78% (170.86 Mg ha^{-1}) (Fig. 2. (B)). In Thano Forest Range, the contribution of *Shorea robusta* in total carbon was 72% (151.49 Mg ha^{-1}) (Fig. 2. (C)).

DISCUSSION

The role of forests in harvesting atmospheric carbon has gained considerable importance & debate in recent year. Biomass is an important parameter to assess the atmospheric carbon that is harvested by trees. In recent times, biomass-related studies have become significant due to growing awareness of carbon credit systems the world over.

The Sal (*Shorea robusta*) forests occurring in the study areas are the natural forests. Forests were managed with an objective to enhance productivity of sal trees for harvesting maximum timber, usually on the principle of sustainable forest management. Various silvicultural systems were applied from time to time in order to improve the productivity of sal trees and their natural regeneration. However, these forests could not withstand against heavy biotic pressure of overgrazing,

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(A)Barkot Range (B)Lachchiwala Range (C)Thano Range

Fig. 2. Comparison of percentage contribution of carbon storage of *Shorea robusta* with other species in Moist Deciduous Forest in (A) Barkot Range. (B) Lachchiwala Range. (C) Thano Range.

lopping, overexploitation of non-wood forest products, urbanization etc., and resulting failure of natural regeneration.

Appendix 1 reveals the comparison of volume, biomass and carbon with the present study. Ramachandaran *et al*., (2007) had conducted study on the different forest types of Eastern Ghats. Carbon in deciduous forest of Eastern Ghats is 125.826 Mg ha^{-1} while in the secondary deciduous forest is 120.886 Mg ha^{-1}. Sal mixed forest in Chattisgarh has recorded with 33.27 Mg ha^{-1} while in the present study, the largest share of *Shorea robusta* is recorded with 271.21 Mg ha^{-1} in Lachchiwala Range. It might be due to the reason that the forest of Chattisgarh are not fully mature as compare to our present study that resulted in higher carbon storage.

Sharma *et al.*, 2010 has reported 159.40 Mg ha^{-1} in Moist Bhabhar *Shorea robusta* Forest while in present study, 219.08 Mg ha^{-1} of Carbon density is recorded in moist deciduous forest of Lachchiwala Range. Haripriya (2000) reported that above ground biomass had 48.30 Mg ha^{-1}C to 97.30 Mg ha^{-1}C (approximately 50% of the biomass) in tropical deciduous forests of India. The carbon storage in the present study is much similar to in range as compared to the estimates made in different tropical forests (Ajtay *et al.*, 1979; Brownand Lugo, 1982; Brown *et al.*, 1994). Brown *et al.*,(1982) estimated that the carbon storage was from 46 to 183 Mg ha^{-1}C for variety of tropical dry forests of the world.

Estimation of carbon content in forest woody biomass is important with regard to Greenhouse effect mitigation, and regarding mandatory reporting about carbon dioxide (CO_2) emissions and removals in forestry sector. Gorte (2009) reported that moist tropical forests are important for carbon sequestration, because they typically have high carbon contents. Roy and Ravan (1996) by using spectral response model estimated the biomass of tropical dry deciduous forest of Madhav National Park, Madhya Pradesh, India. Tiwari (1994) reported that average value of above ground biomass density in different forest types of Rajaji National Park, Dehra Dun, India ranged between 52.36 tha^{-1} (plantations) and 371.08 tha^{-1} (Sal forest).In the present study, moist deciduous forest has the mean aboveground biomass of 347.75 Mg ha^{-1} in Lachchiwala Range.

Climate also plays a vital role in biomass development of trees. Tree growth is actually controlled by a complicated mix of climate-related factors. The variation in biomass and carbon in various study sites may be due to the various plant community structure, species contribution or composition of forest. The forests of the study area are under highly anthropogenic threat, because the rural people are depended on these forests for their needs i.e. fuel, fodder, minor timber etc. The villager's demands have resulted in depletion of forests at much faster rate. Anthropogenic activities such as agricultural practices near to the forest periphery, burning of fossil fuels, construction of roads on these areas, which results in the variation of carbon stocks. Therefore, management practices need to be implemented to save these forests against various threats, so the carbon pools of these can be saved.

The forests have been suffering from grazing pressure and fuel wood collectors. The regeneration status has reduced to an all-time low because of high soil erosion level etc. The well-established natural forests need full protection for retaining the soil fertility and productivity in the valley. Development has to be planned on the basis of watershed management on a sustainable basis so that the valley can be kept alive with regenerating and well managed forest. Such a habitat can sustain healthy wildlife also. Human development strategies covering their settlement need should be synchronized with the conservation status of the valley because the interdependence of man and nature is of crucial reckoning of this fragile valley.

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Appendix1: Comparison of Biomass and Carbon of various forest types with present study.

Forest Type	Biomass (Mg ha^{-1})	Carbon (Mg ha^{-1})	Reference
Tropical DryForest, Varanasi	239.80	119.90	Singh, 1975
Sub Tropical Humid Forest	220.00	110.00	IPCC, 2006
Sub-Tropical Dry Forest	130.00	65.00	
EvergreenForest,Eastern Ghats	307.30	153.65	Ramachandaran *et al.*, 2007
Deciduous Forest, Eastern Ghats	251.65	125.82	
Secondary Deciduous Forest , Eastern Ghats	241.77	120.88	
Scrub , Eastern Ghats	57.50	28.75	
Semi Evergreen, Western Ghats	202.60	101.30	Kale *et al.*, 2009
Mixed Moist Deciduous, Western Ghats	209.30	104.65	
Tropical Semi Evergreen, Pauri Garhwal	324.0	162.00	Baishya *et al*., 2009
Mixed Forest, Chhattisgarh	78.31	39.11	Bijalwan *et al*., 2010
Teak Mixed Forest, Chhattisgarh	66.34	33.17	
Degraded Forest, Chhattisgarh	45.94	22.97	
Sal Mixed Forest, Chhattisgarh	66.54	33.27	
Dry Siwalik *Shorea robusta* Forest, Pauri Garhwal	180.80	83.20	Sharma *et al*., 2010
Dry Sub-deciduous *Shorea robusta* Forest , Pauri Garhwal	162.00	74.50	
Moist Bhabhar *Shorea robusta* Forest, Pauri Garhwal	346.50	159.40	
Pinus roxburghii, Pauri Garhwal	159.40	73.30	
Moist Deciduous Forest			Present Study
(i) Barkot Range	338.40	169.20	
(ii) Lachchiwala Range	438.17	219.08	
(iii) Thano Range	422.44	211.22	
Average	399.67	199.83	

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