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Preliminary Assessment of Vegetation Structure, Biomass and Carbon Stock in *Shorea robusta, Tectona grandis* and *Quercus leucotrichophora* Stand in Dehradun District, Uttarakhand, India

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ABSTRACT

A preliminary study was conducted to assess the vegetation structure (density, frequency, abundance, basal area and IVI) biomass and carbon content in *Shorea robusta, Tectona grandis* and *Quercus leucotrichophora* forests. In sal forest site,the total tree density (4.3 ind/ha) are lower but the value of basal area (1418.55) in these forests are higher. In contrast, value of biomass and carbon was recorded 4.62 t/ha and 1.92 t/ha respectively in present study which reveals that production of biomass is comparatively less than reported in other sal forests. For Teak forest, total tree density (4.6 ind/ha), TBA (523.83), total biomass (0.0276 t/ha) and carbon (0.022 t/ha) were also found in lower quantity as compare to earlier studies of Teak forests. Similarly total density (7.2 ind/ha), TBA (1102.397), total biomass (4.068 t/ha) and total carbon stock (1.921 t/ha) in Oak forest site were at lower side. Our findings with respect to vegetation structure analysis, biomass and carbon stock are not similar to earlier result of forests studied in the region, this is might be due to preliminary assessment of biomass and carbon stock of trees in these forest sites, hence, it is concluded that the studied forests were not affected much from nearby humans pressure and variation in climate.

Keywords Vegetation structure, Biomass, Carbon stock, *Shorea robusta, Tectona grandis.*

INTRODUCTION

Carbon storage is a growing research topic that addresses one important aspect of an overall strategy for carbon management to help mitigate the increasing emission of carbon dioxide, into the atmosphere. Currently, emission of carbon dioxide are increasing globally and are projected to double over the next century. This excess carbon dioxide, enters the global carbon cycle where part remain in the atmosphere, part is taken up by oceans and the terrestrial biosphere. Carbon sequestration in the terrestrial ecosystem can be defined as the net removal of carbon dioxide from the atmosphere into long lived pools

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of carbon. Sal (*Shorea robusta*) at 400-1200 m, Pine *(Pinus roxburghii)* at 1200-1800 m and Oak (*Quercus leucotrichophora)* at 1400- 2700 m elevational ranges comprises the dominant forests in Uttarakhand, it reveals that forest composition, forest area (64.79%) and forest cover (45.82%) (FSI 2013) changes with altitude and climate in this region (Lodhiyal 2011, Lal and Lodhiyal 2016).

The carbon cycle in the forest is threatened as a result of human activities (Bohra et al. 2018). The increase of carbon in the atmosphere has drawn global attention. It has already been proposed in the Kyoto Protocol in relation to the increase of carbon caused by global warming (rana et al. 1989, Pandey and Lodhiyal 2015, Ullah and Al-Amin 2012).

The United Framework Convention on Climate Change (UNFCCC) defines carbon sequestration as the process of removing carbon from the atmosphere and depositing it in a reservoir. It entails the transfer of atmospheric carbon dioxide and its secure storage in long-lived pools (UNFCCC 2007, Ravindranath and Ostwald 2008, Nair et al. 2010). It occurs in two major segments of the AFS: Above ground and below ground. On average the above ground part and the soil (including roots and other living biomass) are estimated to hold roughly one-third and two-third, respectively, of the total C stored in tree-based land use system (Sheikh and Kumar 2010, Lal 2010). Above ground biomass of trees is mainly the largest carbon pool, being directly affected by deforestation and degradation. The conversion of forested land for other activities has in consequence affected the carbon cycle in the forest (Ratnasingam et al.2015).

Biomass equation can be used to estimate the weight of the tree based on the measured DBH and height of each tree in the sample plots. Allometric equation that relate tree diameter at breast height (DBH) to other attributes such as standing carbon stock, leaf area and basal area are an important and often used tool in ecological research as well as for commercial purpose. Such tools represent the primary method for estimating above ground forest dry matter or carbon stocks (Hamburg 2000).

Sal (*Shorea robusta*) forests cover over 11 million ha in India, Nepal and Bangladesh and these forests are conventionally managed for timber. Recently, interested in producing multiple products from Sal forests has increased; accordingly, a silviculture regime for managing Sal forest for multiple products is a central concern. Information on edaphic factors, phenology and stand development processes is important for designing scientific forest management of Sal forest. Community based forestry in this region emerged in responses and local people initiated protection practices and demonstrated the success of Sal forest from coppice (Gautam and Devoe 2006).

Teak (*Tectona grandis*) is one of the most valuable timber tree species of the world. The total area of natural Teak forest in India has been estimated to be 9.77 m ha, which is about 13% of the total forest area of the country (Keswani 2001). Teak *(Tectona grandis),* a tropical timber species. This multipurpose timber has favorable strength properties besides having resistance to termite and fungal attack by the presence of the polyphenols. On a global basis, the total area under teak plantation extend to 2,253,540 ha, of which 44% is grown in India. Teak plantation in India cover an areas of about 1,330,090 ha (Chundamannil 1998, Pandey and Brown 2000, George and Verghese 1992).

The Himalayan evergreen Oak (*Quercus leucotrichophora)* is an endangered tree in Northern India. The reasons for its decline are varied, the population explosion and probably global warming, deforestation and losses due to natural calamities, play role in its decline. Another reason is the wide spread aggressive pruning as cattle feed and firewood by the local population (Lodhiyal and Lodhiyal 2012, Singh et al. 2014, Lodhiyal et al. 2015). This results in the Oaks not bearing any acorns hence there are no new trees coming up in these areas. Both in Kathwar (HP) and Mussoorie, the trees seem to grow only at higher altitudes (1400-2300 m range) (in Mussoorie upwards of Landour Cantonment) (Rover 2013).

The present study was undertaken to calculate the above ground biomass and carbon stock of *Shorea robusta, Tectona grandis* and *Quercus leucotrichophora* and their major associated species in different sites in Dehradun forest division.

Table 1. Geographic variables of study area (s).

Forest site	Latitude ^{0}N	Longitude ^{0}E	Altitude (m asl)
1. Sal forest - Manduwala (Dehradun)	$30^0 23'$	$77^0 56'$	648
2. Teak forest - Lachhiwala (Dehradun)	$30^0 13'$	$78^0 4'$	484
3. Oak forest - Lal Tibba - Mussoorie (Dehradun)	$30^0 26'$	$78^0 4'$	2275

MATERIALS AND METHODS

Study area

Dehradun, the capital city of Uttarakhand State of India is in the Doon Valley on the foothills of Himalayas, lies between $29^0 58'$N to $31^0 2'$N latitudes and $77^0 34'$E to $78^0 18'$E longitudes at an elevational range of 410 to 700 m asl with summer temperature upto 44^0C and winter temperature between 1 to 20^0C, experiences severe rain showers with 2200 mm of rainfall approximately between June and September months (Table 1).

Vegetation structure

Vegetation studies were carried out during February-March 2019, using random sampling technique method (Mishra 1968). Ten quadrates of 10×10 m size were laid randomly in each forest site. In each quadrate, all the tree species were measured at 1.37 m (circumference at breast height) from ground level. Tree density, abundance, basal area and IVI were measured in each forest site following the methods given by Mishra (1968), Curtis and Mclntosh (1950), Cottam and Curtis (1956).

Biomass estimation

Reliable estimation of total biomass for standing trees and forests or their components such as stem wood, stem bark, living and dead branches, foliage, stump and roots are very essential part of forest carbon. Destructive harvesting of forest trees is not always possible because it is time-consuming and there is high risk of uncertainty when the obtained results are extrapolated to large areas (Mc–William et al.1993). Undoubtedly, the most common approach is to obtain biomass estimates at standing level.

The biomass of forest tree species was estimated by using allometric equation as developed by (Chaturvedi and Singh 1987, 1982, Chaturvedi et al. 2011, 2012, Lodhiyal et al. 2014). The total biomass determine by summing up the respective component values of each tree species occurred in each site. The regression equation was used in the form- Y = a+b Inx, Where, Y = Dry weight of component (kg), x = GBH (cm), a = Intercept, b = Slope or regression coefficient, In = Log natural.

Carbon estimation

Carbon was estimated using the method as given by (Magnussen and Reed 2004, Singh and Lodhiyal 2009). The total carbon was estimated by summing up of carbon values of all tree components in each forest. Carbon = B ×0.475, where B = Biomass.

RESULTS AND DISCUSSION

Vegetation structure

In the first forest study site, two tree species were present i.e. *Shorea robusta* and *Tectona grandis.* The total tree density was 4.3 ind/ha, of which, sal accounted for 83%. Total basal area and IVI of this forest site was 1418.55 m^2/ha and 299.9 respectively, of this, basal area and IVI of *Shorea robusta* shared 1405.9 m^2/ha and 249.44 respectively at forest site-1 (Table 2).

Table 2. Vegetation analysis of trees in Sal forest in site-1.TBA = Total Basal Area, IVI = Important Value Index.

Species composition	Density ind/ha	Frequency (%)	Abundance	TBA (m^2/ha)	IVI
S. robusta	3.6	100	3.6	1405.9	249.44
T. grandis	0.7	50	1.4	50.89	50.49
Total	4.3	150	5.0	1418.55	299.9

Table 3. Vegetation analysis of trees in Teak forest in site-2. TBA = Total Basal Area, IVI = Important Value Index.

Species composition	Density ind/ha	Frequency (%)	Abundance	TBA (m^2/ha)	IVI
T. grandis	2.5	100	2.5	407.47	170.62
Terminalia spp.	0.7	50	1.16	42.77	46.45
S. robusta	0.8	50	1.6	50.365	46.24
Syzygium spp.	0.6	60	1.2	23.230	36.45
Total	4.6	260	6.46	523.83	300.02

Table 4. Vegetation analysis of trees in Oak forest in site-3.

Species composition	Density ind/ha	Frequency (%)	Abundance	TBA (m^2/ha)	IVI
Q. leucotrichophora	2.8	100	2.8	601.366	120.465
C. deodara	1.0	70	1.428	126.572	44.284
P. roxburghii	0.7	50	1.4	45.031	27.319
C. torulosa	1.1	60	1.833	145.620	44.702
R. arboreum	1.6	90	2	183.808	63.153
Total	7.2	370	9.461	1102.397	299.923

At forest site-2, total four tree species i.e. *Tectona grandis, Terminalia* spp., *Shorea robusta* and *Syzygium* spp. were occurred in Teak forest study site. Total density of this forest was 4.6 ind/ha, of this, Teak *(Tectona grandis)* accounted for 54.3% density. Total basal area of Teak forest was 523.83 m^2/ha of this, Teak shared 407.47 m^2/ha basal area and IVI value of 170.62 (Table 3).

At forest site-3, five tree species i.e. *Quercus leucotrichophora, Cedrus deodara, Pinus roxburghii, Cupressus torulosa* and *Rhododendron arboreum* were present in this Oak forest site. The density of forest was 7.2 ind/ha of this, Oak *(Quercus leucotrichophora)* accounted for 38.8% density. Total basal area of Oak forest was 1102.397 m^2/ha. Of this, basal area and IVI of *Quercus leucotrichophora* was 601.366 m^2/ha and 120.465 respectively (Table 4).

Biomass

The total forest biomass was 4.621 t/ha in Sal forest site, of this, *Shorea robusta* accounted for 99.97%. The bole component biomass was 73.53% while twig biomass account for 6.65% at forest site-1 (Table 5).

Total biomass of tree species was 0.0997 t/ha in Teak forest site, of the total biomass, *Tectona grandis* accounted 50.55%. Among the various tree component, biomass of bark component shared 3.51% while stump root contributed 29.08% respectively at forest site-2 (Table 6).

In Oak forest, total forest biomass was 4.068 t/ha, of this, *Quercus leucotrichophora* accounted for 85%. Of the total biomass, bole component shared 20.74% followed by branch in the above ground biomass while the stump root contributed 11.72% which is followed by lateral root 2.8% in below ground part at forest site-3 (Table 7).

Carbon content

The total carbon content of Sal forest site was 2.195 t/ha. Of this, *Shorea robusta* accounted for 2.19 t/ha. Of the total carbon, bole wood component accounted for 75.33% followed by branch 15.45% in the above ground part at the forest site-1 (Table 8).

In Teak forest, the total carbon content of Teak forest site was 0.0505 t/ha. Of this, *Tectona grandis* accounted for 0.027 t/ha. Of the total carbon, bole wood component form maximum 23.36% followed

Table 5. Component-wise biomass (t/ha) of Sal forest site-1 (value in parenthesis is percent contribution).

Tree species	Bole	Bark	Branch	Twig	Leaves	Stump	Total
S. robusta	3.397 (73.52)	—	0.714 (15.45)	0.307 (6.64)	0.202 (4.37)	—	4.62 (99.97)
T. grandis	—	0.0003 (16.66)	0.0002 (11.11)	0.0005 (27.77)	0.0007 (38.88)	0.0006 (33.33)	0.0018 (0.038)
Total	3.397 (73.53)	0.0003 (0.006)	0.7142 (15.45)	0.3075 (6.65)	0.2027 (4.37)	0.0006 (0.012)	4.621 (100)

Table 6. Component-wise biomass (t/ha) of Teak forest in site-2 (value in parenthesis is percent contribution).

Tree species	Bark	Bole	Branch	Twig	Leaves	Above ground	Stump root	Below ground	Total
T. grandis	0.005 (9.92)	–	0.0022 (4.36)	0.0045 (8.92)	0.0053 (10.51)	0.0033 (6.54)	0.029 (57.53)	0.0026 (5.15)	0.0504 (50.55)
S. robusta	-	0.0256 (51.92)	0.0122 (24.74)	0.0056 (11.35)	0.0059 (11.96)	–	–	–	0.0493 (49.44)
Total	0.0035 (3.51)	0.0256 (25.67)	0.0144 (14.44)	0.0101 (10.30)	0.0112 (11.23)	0.0033 (3.30)	0.029 (29.08)	0.0026 (26.07)	0.0997 (100)

Table 7. Component-wise biomass (t/ha) of Oak forest in site-3 (value in parenthesis is percent contribution).

Name of tree species	Bole	Branch	Twig	Foliage	TAG	Stump root	Lateral root	Fine root	TBG	Total
Q. leucotrichophora	0.705 (20.33)	0.435 (12.5)	0.157 (4.53)	0.072 (2.08)	1.421 (41.06)	0.408 (11.7)	0.073 (2.10)	0.009 (0.26)	0.187 (5.40)	3.467 (85.2)
C. deodara	0.019 (27.9)	0.013 (19.11)	0.010 (14.7)	0.007 (10.2)	–	0.010 (14.7)	0.008 (11.7)	0.001 (1.47)	–	0.068 (1.67)
P. roxburghii	0.004 (65.5)	0.0004 (6.55)	–	0.0005 (8.19)	–	0.001 (16.39)	0.0002 (3.27)	.00005 (0.81)	–	0.0061 (0.14)
C. torulosa	0.042 (28.57)	0.041 (27.89)	0.004 (2.72)	0.016 (10.88)	–	0.018 (55.10)	0.022 (14.96)	0.0040 (2.72)	–	0.147 (3.61)
R. arborum	0.074 (19.47)	0.051 (13.42)	0.021 (5.52)	0.010 (2.63)	0.141 (37.10)	0.040 (10.52)	0.012 (3.15)	0.002 (0.52)	0.029 (7.63)	0.38 (9.34)
Total	0.844 (20.74)	0.540 (13.27)	0.192 (4.71)	0.105 (2.58)	1.562 (38.39)	0.477 (11.72)	0.115 (2.82)	0.016 (0.39)	0.216 (5.30)	4.068 (100)

by branch 13.26% component in the above ground part at the forest site-2 (Table 9).

In Oak forest, the total carbon content of forest was 1.921 t/ha. Of this, *Quercus leucotrichophora* accounted for 1.643 t/ha. Of the total biomass bole component shared 20.87% followed by branch in the above ground biomass while the stump root contributed 11.76% in followed by lateral roots 2.70% in below ground part, while the fine roots accounted for about 1% at forest site-3 (Table 10).

Forest play a significance role in the development,livelihood and climate they provide timber, non-timber products agriculture implements to hill people and also improve fertility of the agriculture soil and control erosion and forests composition in the hill region, vary from place because of altitude, climate, slope, aspect and soil characteristic. The objectives of study were to assess the vegetation structure (density, frequency, abundance, basal area and IVI) biomass and carbon content in *Shorea robusta, Tectona grandis* and *Quercus leucotrichophora* forests.

Table 8. Component-wise carbon content (t/ha) of Sal forest site-1 (value in parenthesis is percent contribution).

Tree species	Bole	Bark	Branch	Twig	Leaves	Stump root	Total
Shorea robusta	1.613 (73.58)	–	0.339 (15.46)	0.145 (6.61)	0.095 (4.33)	–	2.195 (99.90)
Tectona grandis		0.0001 (10)	0.00009 (9)	0.0002 (20)	0.0003 (30)	0.0002 (20)	0.0010 (0.045)
Total	1.613 (75.33)	0.0001 (0.0045)	0.339 (15.45)	0.1452 (6.62)	0.0953 (4.34)	0.0002 (0.0009)	2.195 (100)

Table 9. Component-wise carbon content (t/ha) of Teak forest site-2 (value in parenthesis is percent contribution).

Name of tree species	Bark	Bole	Branch	Twig	Leaves	Above ground	Stump root	Below ground	Total
Tectona grandis	0.0016 (5.79)	–	0.0010 (3.62)	0.0021 (7.60)	0.0025 (9.0)	0.013 (47.10)	0.0015 (5.43)	0.0012 (4.34)	0.0276 (54.65)
Shorea robusta	–	0.0118 (51.52)	0.0057 (24.89)	0.0026 (11.35)	0.0028 (12.22)	–	` –	–	0.0229 (45.34)
Total	0.0016 (3.16)	0.0118 (23.36)	0.0067 (13.26)	0.0045 (8.91)	0.0053 (10.49)	0.013 (25.74)	0.0015 (2.97)	0.0012 (2.37)	0.0505 (100)

Table 10. Component-wise carbon content (t/ha) of Oak forest site-3 (value in parenthesis is percent contribution).

Tree species	Bole	Branch	Twig	Foliage	TAG	Stump root	Lateral root	Fine root	TBG	Total
Q. leucotrichophora	0.335 (20.38)	0.206 (12.53)	0.074 (4.50)	0.034 (2.06)	0.674 (41.02)	0.194 (11.80)	0.034 (2.06)	0.004 (0.24)	0.088 (5.35)	1.644 (85.52)
C. deodara	0.009 (30)	0.006 (20)	0.004 (13.33)	0.003 (10)	–	0.005 (16.66)	0.003 (10)	0.0005 (1.66)	–	0.030 (1.56)
P. roxburghii	0.002 (66.66)	0.0002 (6.66)	–	0.0002 (6.66)	–	0.0005 (16.66)	0.0001 (3.33)	0.0002 (0.66)	–	0.003 (0.156)
C. torulosa	0.020 (29.85)	0.019 (28.35)	0.002 (2.98)	0.007 (10.44)	–	0.008 (11.94)	0.010 (14.9)	0.001 (1.49)	–	0.067 (3.48)
R. arborum	0.035 (19.66)	0.024 (13.48)	0.010 (5.61)	0.004 (0.22)	0.067 (37.64)	0.019 (51.12)	0.005 (2.80)	0.001 (0.56)	0.013 (7.30)	0.178 (9.26)
Total	0.401 (20.87)	0.255 (13.27)	0.09 (4.68)	0.048 (2.49)	0.741 (38.57)	0.226 (11.76)	0.052 (2.70)	0.006 (0.31)	0.101 (5.25)	1.921 100

In Sal forest site, the total value of density were lower but total basal area was higher than the value obtained by Bandhu (1969) for *S. robusta* forest in their findings. He reported the density and basal area to be 200 stems/ha and 9.5 m^2/ha respectively. Similarly the value of basal cover is higher than the value (33.5 m^2/ha) obtained by Rana et al. (1988) in new growth *S. robusta* forest of India and also greater than the value (51.2 m^2/ha) obtained in old growth forest. However, the value of density (4.3 ind/ha) and basal area (1,418.5 m^2/ha) as estimated in Sal forest in Dehradun were comparatively higher. Sejuwal (1994) reported 1038.16 t/ha above ground biomass in the Sal forest of Royal Chitwan National park, Central Nepal, in which sal covered 96.7% of the total species. Likewise, Rana et al. (1988) reported 460-717 t/ha average above ground biomass in Sal forest of India. The present value of biomass and carbon 4.62 t/ha and 1.92 t/ha reveales that production of biomass is less than other Sal forests.

The total density of Teak (*Tectona grandis*) 4.6 ind/ha in the tree-studied forest are lower than the value 280-620 stems/ha in Teak stand of Mizoram, India obtained by Khanduri et al. (2008). The basal area of Teak forest 523.83. The present value of biomass and carbon of tree species 0.0276 t/ha and 0.022 t/ha.

The density of Oak *(Quercus leucotrichophora)* is 7.2 t/ha are lower than the value 980-1100 ind/ha obtained by Lal and Lodhiyal (2016) and 420-1640 ind/ha in temperate forests of Western Himalaya studied by Saxena and Singh (1982) and 920-1245 ind/ha for natural forests of Kumaun Himalaya reported by Lodhiyal et al. (2014) and 570-760 ind/ha for Oak forest obtained by Rawat and Singh (1988). Present estimates of basal area (1102.39 m^2/ha) are higher than 33.9-36.8 m^2/ha reported for Oak forest by Singh and Singh (1992).

Present biomass estimates 4.068 t/ha are lower than 458 t/ha reported for Oak forests by Rawat and Singh (1988), 236-400 t/ha for Oak dominated forests of high altitude obtained by Adhikari et al. (1995) and 285-651-718 t/ha of natural forests in Kumaun Himalaya examined by Lodhiyal et al. (2014) and 590 t/ha of Kharsu Oak forests site in Kumaun Himalaya reported by Rana et al. (1989). The carbon stock was 1.921 t/ha, which falls within the range 229-270 t/ha of Oak dominated forests of Kumaun Himalaya studied by Lal and Lodhiyal (2016) and 240-290 t/ha of Oak and Pine forests in non-degraded forest sites in Kumaun Himalaya estimated by Jeena et al. (2008).

CONCLUSION

Present finding on different forest sites viz. Sal, Teak and Oak forest in Dehradun are not at higher side, than earlier result of forests studied in the region, this is might be due to lesser age of studied forest sites for biomass and carbon assessment of trees in these forest sites, hence, it is concluded that the studied forests were not affected much from nearby humans pressure and variation in climate. This is because of mainly two reasons : These forests were judiciously cared and managed by forest department using better conservation practices as well as implementation of strict rules and regulation and Adequate support and timely co-operation of community people residing in nearby areas.

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