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Biomass and Carbon Stock Assessment in Different Age Group Plantations of Teak (*Tectona grandis* Linn. F.) in Bhabar and Shivalik Regions of Uttarakhand

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Abstract

The available information on optimum rotation of teak is largely based on teak plantations. Age at which a tree stand is extracted decides the quality of the timber; biomass accumulation and carbon sink potential of the stand. The present study was based on non-destructive method to assess the total biomass, carbon stock and carbon dioxide (CO_2) content of different age group plantations of teak at five different compartments of Bhabar and Shivalik regions of Kotdwar Forest Division, Uttarakhand. Above ground biomass (AGB), below ground biomass (BGB) and total biomass (TB) significantly influenced by different sites and age group of teak plantations. The extent of increase in AGB (687.07 t ha^{-1}), BGB (171.77 t ha^{-1}) and TB (858.84 t ha^{-1}) in S_{26} (Sigaddi-18A) plantation site at the age of 48 was 70.10% over S_8 (Sigaddi-18B) in AGB (205.40 t ha^{-1}), BGB (51.35 t ha^{-1}) and TB (256.75 t ha^{-1}) at the age of 33 years. Further, the total carbon (TC) (429.42 t ha^{-1}) and CO_2 (1575.97 t ha^{-1}) was highest in Sigaddi-18A (S_{26}) plantation site at the age of 48 years. Whereas, the lowest TC (128.37 t ha^{-1}) and CO_2 (471.13 t ha^{-1}) at the age of 33 years was observed in S_8 (Sigaddi-18). The tree diameter (cm) showed highly significant positive correlation with volume (R^2=0.903), total biomass as well as with total carbon (R^2=0.859). The variation in diameter could explain nearly 85.9 % variation in total biomass and total carbon. Therefore, the diameter can be a good predictor of biomass and carbon sequestration in teak plantations.

Keywords: Age, carbon sink, forest, CO_2 assimilation, teak, biomass

1. Introduction

Carbon sequestration is a serious concern confronting the world today. Since the beginning of the industrial revolution, carbon dioxide concentration in the atmosphere has been rising alarmingly, i.e. from 270 ppm prior to the industrial revolution to about 394 ppm in December 2012 (Manua Loa observatory, 2013). In spite of increasing interest of ecologists in the production of organic matter in different ecosystems, work of this nature in forests of tropical region is scanty due to great biological richness and diversity of species.

The tree plantation plays an important role to remove the CO_2 from the atmosphere and stored in and on the surface of the each assuming the given amount of CO_2 will remain stored in and on the same stable way as reserve of the oil, natural gas or coal beneath the ground for centuries to come. They absorb CO_2 from atmosphere and store carbon in wood, leaves, litter, roots and soil by acting as "carbon sinks". Carbon is released back into the atmosphere when forests are cleared or burned. Forests are acting as carbon sinks to moderate the global climate. Overall, the world's forest ecosystems are estimated to store more carbon than the entire atmosphere (FAO, 2006).

A non-destructive method of determining total biomass, carbon sequestration and carbon dioxide content of tree species is mainly based on volumetric equations which are derived from measurable tree parameters like diameter at breast height (DBH), basal area and tree height. Non-destructive method is having advantages over destructive method such as for the routine estimation of volume, growing stock, total biomass, carbon sequestration and carbon dioxide content of tree species and mainly used for conservation purposes. Apart from this, it is also used for predicting the future yield and biomass of particular stand. *Tectona grandis* belonging to family the verbenaceae, is commercially important and growing throughout the greater part of the country. However, an extensive search of literature failed to reveal any useful information on total biomass, carbon sequestration and carbon dioxide content. The present paper deals with the biomass accumulation and carbon sequestration of different age groups of teak plantation for Bhabar and Shivalik regions of Kotdwar Forest Division, Uttarakhand on the basis of a non-destructive method.

2. Materials and Methods

2.1. Study area

The study was conducted in different age groups of teak plantations comprising of five compartments, *viz.,* Paniyali, Lalpani, Sigaddi and Sukhro of Kotdwara Range and Saneh of Kothari Range of Kotdwara Forest Division, Pauri Garhwal, Uttarakhand. The study site lies between 29°37”041’ -25°47”621’ N latitude and 078°24”577’-078°32”802’ E longitudes with an elevation ranging from 248 to 546 msl. Kotdwara situated at the bank of river ‘Khoh’ in the ‘Bhabar’ region and another part touch to the bank of river ‘Saneh’ in the ‘Shivalik’ region of Himalayan foothills. The mean monthly temperature ranges between 25 °C and 35 °C and the average annual rainfall is 218 cm. Relative humidity varies between 54 and 63%, respectively. During the monsoon season, there is often heavy and prolonged rainfall occurs.

The present investigation was carried out in a total of 27 plantations at sites in five different compartments of Kotdwara Forest Division, namely Paniyali, Lalpani, Saneh, Sigaddi and Sukhro. A total of 81 (27×3=81) sample plots were laid out in all five compartments during 2014–2015. The sample plot with an area of 0.1 ha and a square shape was used in the field. After laying out the sample plot, measurements were made on the individual tree basis. The height and girth were measured by using Ravi’s multimeter and measuring tape.

2.2. Estimation of biomass accumulation

The above ground biomass was intended by multiplying estimated total growing stock with wood density (Reyes et al., 1992, Pearson and Brown, 1932) of *Tectona grandis* and biomass expension factor (BEF) of 1.5 as prescribed by Brown and Lugo (1992). The above ground biomass was expressed in tonne per hectare (t ha^{-1}) and was calculated by the formula:

Above ground biomass (AGB)=GS×Wood density×BEF

Whereas AGB=Above ground biomass, GS=Growing stock, Wood density=(0.56), BEF=Biomass expansion factor (1.5)

Biomass Expansion Factor (BEF) is the expansion of merchantable volume to the total above ground biomass volume to account for non-merchantable components of the tree, stand and forest. BEF is dimensionless (IPCC, 2006).

Below ground biomass was calculated by using simple default value of 25% (for hardwood species) of the above ground biomass as recommended by IPCC, 2006.

2.3. Estimation of carbon stock and CO_2

The carbon stock was estimated as 50% of total biomass as per IPCC (2006) and finally exhalation of carbon dioxide (CO_2) was multiplied by carbon fraction 3.67 (44/12) for computation of CO_2.

Carbon content (t ha^{-1})=Total biomass (t ha^{-1})×Carbon fraction %

CO_2=Carbon content (t ha^{-1})×3.67 (44/12)

2.4. Statistical analysis

The statistical analyses were conducted using STPR3 software package. The correlation was observed among the different variables, *viz*., total biomass and carbon content as well as, basal area v/s total biomass and basal area v/s total carbon.

3. Results and Discussion

The amount of biomass in different sites varied due to age group of teak plantations. Above ground biomass (AGB), below ground biomass (BGB) and total biomass (TB) are significantly influenced by different sites and age group of teak plantations (Table 1). In the present study, TB ranged from 858.84 to 256.75 t ha^{-1} (Table 1). Values of AGB ranged from 687.07 to 205.40 t ha^{-1}, whereas BGB varied between 171.77 to 51.35 t ha^{-1} in S_{26} (Sigaddi-18A) plantation site at the age of 48 was 70.10 % over S_8 (Sigaddi-18B) at the age of 33 years. Sharma et al. (2010) was also found that the total biomass density 346.48±45.46 Mg ha^{-1} in *Shorea robusta* for Moist Bhaber region and 180.81±9.05 Mg ha^{-1} for Shivalik region. Similar results were reported by Banerjee and Prakasham (2013) in teak, where they recorded highest (269.97 t ha^{-1}) total biomass at the age of 47, which is much lower than the present study.

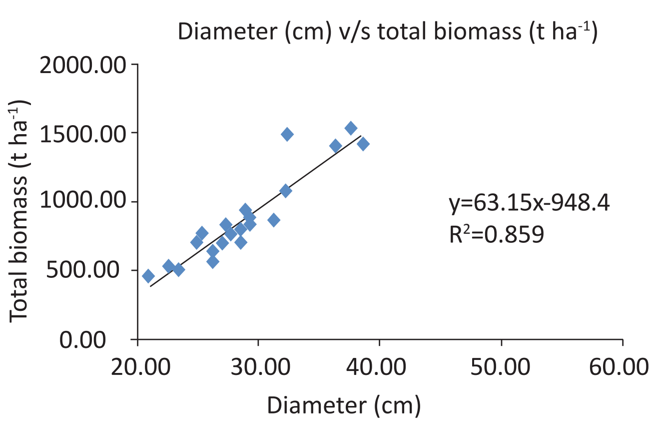
Total carbon sequestered (TC) and CO_2 also significantly influenced by different sites and age groups of teak plantation. The extent of increase in TC (429.42 t ha^{-1}) and CO_2 (1575.97 t ha^{-1}) in Sigaddi-18A (S_{26}) plantation site at the age of 48 was 70.10 % over Sigaddi-18B (S_8) in TC (128.37 t ha^{-1}) and CO_2 (471.13 t ha^{-1}) at the age of 33 years. Giri et al. (2014) reported 69.71 t ha^{-1} in *Tectona grandis* plantation in Dehradun Forest Division, Uttarakhand. Similar findings has been reported by Sharma et al. (2010), where they found the total carbon density 83.17±4.16 Mg ha^{-1} for in *Shorea robusta* for Shivalik region. Iqbal et al. (2014), observed the highest (81.27±4.82 Mg ha^{-1}) total carbon in *Bischofia javanica* for same region. Bohre et al. (2013), assessed the highest (1,295.14 t ha^{-1}) CO_2 in 19 years old teak plantation.

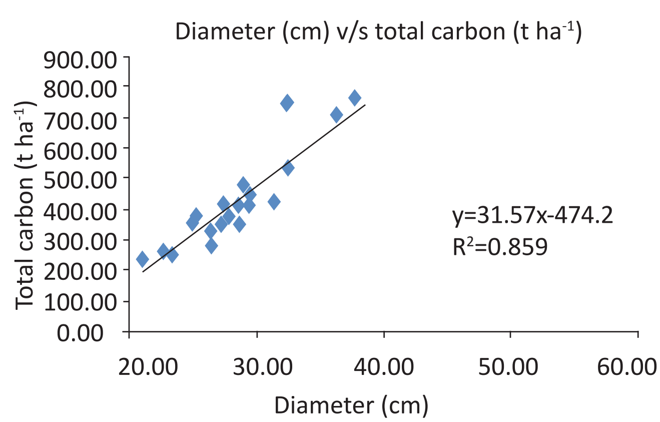
Among the different sites and age groups of teak plantations, the relationship between different parameters such as diameter v/s total biomass and carbon content showed highly significant positive correlation with total biomass and with total carbon (R^2= 0.859) and basal area v/s total biomass and basal area v/s total carbon also showed highly significant positive correlation with total biomass and with total carbon (R^2=0.882) in Figure 1. The variation in diameter could explain nearly 85.9% variation in total biomass and total carbon. Therefore, the diameter can be a good predictor of biomass and carbon sequestration in teak plantations. These results were substantiated by Bohre et al. (2013), reported highly significant correlation (0.912) of total biomass with Basal area (BA) at five different age groups in *Tectona grandis*.

Table 1: Biomass and carbon accumulation in different Age group plantations of Teak in Bhabar and Shivalik regions of Uttarakhand

Site No.	Plantation sites	Age (year)	AGB (t ha^{-1})	BGB (t ha^{-1})	TB (t ha^{-1})	TC (t ha^{-1})	CO_2 (t ha^{-1})
S_1	Sigaddi-17	28	366.65	91.66	458.31	229.16	841.01
S_2	Sigaddi-18A	29	360.91	90.23	451.14	225.57	827.85
S_3	Saneh-15B	29	208.19	52.05	260.24	130.12	477.54
S_4	Sukhro-2	31	252.77	63.19	315.97	157.98	579.80
S_5	Lalpani-2	31	353.28	88.32	441.60	220.80	810.33
S_6	Sukhro-1	32	287.88	71.97	359.85	179.92	660.32
S_7	Paniyali-2A	33	225.06	56.27	281.33	140.66	516.23
S_8	Sigaddi-18B	33	205.40	51.35	256.75	128.37	471.13
S_9	Saneh-12B	33	316.60	79.15	395.75	197.87	726.19
S_{10}	Paniyali-4	34	231.46	57.87	289.33	144.66	530.92
S_{11}	Sigaddi-18A	34	314.30	78.58	392.88	196.44	720.93
S_{12}	Lalpani-2	34	668.78	167.20	835.98	417.99	1534.02
S_{13}	Saneh-1A	34	358.60	89.65	448.25	224.12	822.53
S_{14}	Paniyali-1	35	350.20	87.55	437.75	218.87	803.26
S_{15}	Paniyali-3	38	382.36	95.59	477.95	238.97	877.04
S_{16}	Saneh-9A	38	421.82	105.46	527.28	263.64	967.56
S_{17}	Paniyali-2A	39	406.96	101.74	508.70	254.35	933.47
S_{18}	Paniyali-3A	39	375.04	93.76	468.80	234.40	860.26
S_{19}	Paniyali-2	40	373.44	93.36	466.80	233.40	856.58
S_{20}	Sukhro-2	42	339.23	84.81	424.03	212.02	778.10
S_{21}	Saneh-2	43	368.92	92.23	461.15	230.57	846.21
S_{22}	Sukhro-1	44	484.17	121.04	605.21	302.60	1110.56
S_{23}	Sukhro-2	45	406.07	101.52	507.59	253.80	931.43
S_{24}	SuKhro-2	47	631.41	157.85	789.26	394.63	1448.30
S_{25}	Saneh-2	47	501.34	125.33	626.67	313.34	1149.94
S_{26}	Sigaddi-18A	48	687.07	171.77	858.84	429.42	1575.97
S_{27}	Saneh-15	48	628.18	157.04	785.22	392.61	1440.88
SEm±		95.83	23.96	119.79	59.96	219.82	

SEm: Standard error of mean; AGB: Above ground biomass; BGB: Below ground biomass; TB: Total biomass; TC: Total carbon





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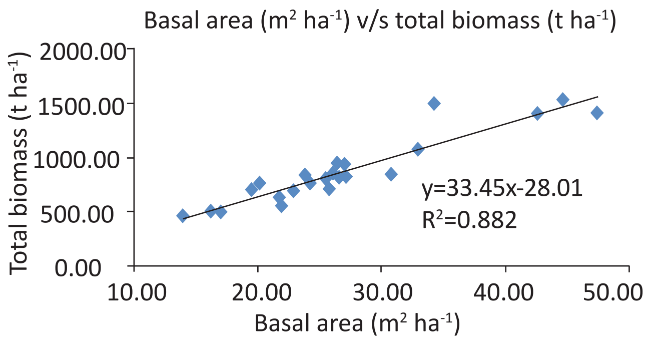

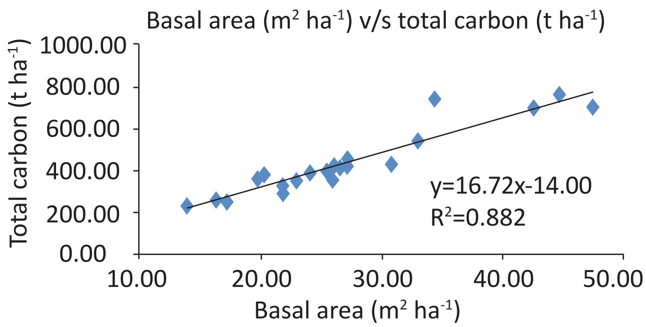

Figure 1: Relationship between a) diameter (cm) v/s total biomass (t ha^{-1}) and total carbon (t ha^{-1}) b) basal area (m^2 ha^{-1}) v/s total biomass (t ha^{-1}) and total carbon (t ha^{-1}) among different

Similarly findings receive support from Krenzel et al. (2003), also observed high correlation (0.978) between biomass and DBH in 20 years old teak plantations.

4. Conclusion

TB (858.84 t ha^{-1}), TC (429.42 t ha^{-1}) and CO_2 (1575.97 t ha^{-1}) in Sigaddi-18A (S_{26}) plantation site at the age of 48 was 70.10 % over Sigaddi-18B (S_8) in TB (256.75 t ha^{-1}), TC (128.37 t ha^{-1}) and CO_2 (471.13 t ha^{-1}) at the age of 33 years. The variation in total biomass and carbon among the plantations may be due to age structure, stand density and storage potential.

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