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Biomass and carbon stock in *Tectona grandis* (Teak) plantation in tropical environment

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Abstract

The present study on "Biomass and carbon stock in *Tectona grandis* (Teak) plantation in tropical environment" was carried out at State Forest Research and Training Institute Raipur (Chhattisgarh), during the year 2020-2021. The total tree density in *T. grandis* plantation was 280 stems ha^{-1}. The total basal area of tree layer in *T. grandis* plantation site was 13. 77 m^2 ha^{-1}. Total sapling and seedling density in *T. grandis* plantation site was 47. 5 stems ha^{-1} and 157. 5 stems ha^{-1} respectively. Total abundance for sapling and seedling layer in *T. grandis* plantation site was 4. 33 and 15. 78 respectively. The Shannon index in *T. grandis* plantation site for the tree, sapling and seedling layer was 0. 54, 0. 93 and 0. 96, respectively. The simpson's index for tree, sapling and seedling layer were 0. 21, 0. 49 and 0. 49, respectively. The evenness in *T. grandis* plantation site for tree, sapling and seedling layer was 0. 78, 1. 34 and 1. 39, respectively. Species richness for tree, sapling and seedling layer was 0. 17, 0. 25 and 0. 19, respectively. Beta diversity in *T. grandis* plantation site for tree, sapling and seedling layer was 2. 3, 3. 33 and 2. 72, respectively. Total biomass, litter mass and carbon stock in *T. grandis* plantation site was 73. 71, 9. 4 t ha^{-1}, 31. 62 t ha^{-1} respectively. Soil pH, EC, total available nitrogen, available phosphorous, total available potassium and organic carbon in upper soil layer (0-10 cm) of *T. grandis* plantation site was 6. 18, 48. 5 ds/m, 313. 6 kg/ha, 5. 78 kg/ha 217. 16 kg/ha and 0. 95%, respectively. Soil pH, EC, total available nitrogen, available phosphorous, total available potassium and organic carbon in lower soil layer (10-20 cm) of *T. grandis* plantation site was 6. 36, 69. 3 ds/m, 288. 5 kg/ha, 5. 7 kg/ha, 141. 3 kg/ha and 0. 86%, respectively. Study revealed the potential of *T. grandis* in biomass production and carbon storage.

Keywords: *T. grandis*, tropical environment, carbon stock

1. Introduction

Tropical deciduous forests grow in a variety of climates, mostly with alternate wet and dry periods. The structure, content, and functioning of deciduous forests, on the other hand, fluctuate with the duration of the wet season, quantity of rainfall, latitude and altitude (Shankar, 2001), and the effects of human and animal activities. Tropical forests are disappearing at an alarming rate of 0. 8-2. 0 percent per year (May and stumpf, 2000) [18] as a result of excessive cutting of timber and other forest produce (Raghubanshi and Tripathi, 2009), and it has been declared that continuous biomass extraction activities may prevent the goal of conserving biodiversity from being achieved (Schaik *et al.* , 1997). Habitat degradation, over exploitation, pollution, and species introduction has all been cited as important causes of biodiversity loss in India (UNEP, 2001). Teak (*T. grandis* Linn. f.) is a member of the Verbenaceae family with a tropical or subtropical range. Teak genetic diversity is highest in the country, with a spread of 8. 9 million hectares. Biomass is a key for understanding a variety of biological processes in forest ecosystems, including energy flow, water movement, and nutrient cycling (Chaturvedi and Singh, 1987; Tiwari, 1994) [5]. One of the most pressing global carbon concerns now is the fast rising quantity of CO_2 in the atmosphere at (2 ppm yr^{-1}) and its potential to alter global climate. CO_2 and other greenhouse gases in the atmosphere have elevated the global average surface temperature by 0. 6 to 0. 2 degrees Celsius (IPCC, 1999). CO_2 levels are growing, which has serious consequences for the world's physical and biological systems. To address this issue, the IPCC (1996) [15] called for expanding the C pool by extensive afforestation and reforestation, as well as conserving the present C pool in the terrestrial environment. Rapid land use and land cover change has resulted in large-scale carbon degradation in tropical ecosystems during the last several decades. As a result, an appropriate land use strategy that improves carbon storage is critical for preserving the region's carbon balance.

2. Materials and methods

2. 1 Study site

The present study was carried out at the State Forest Research and Training Institute in Raipur, Chhattisgarh. The research area is located at the height of 292 metres above mean sea level and is located between 21°14'08. 09"North and 81°42' 32. 69"East. It is located 12 kilometres from Raipur to Baloda Bazar Road. Figure 1 depict the research area's location. The average annual rainfall is about 1401 mm. The average annual temperature is 35. 1°c. The average relative humidity of Raipur is around 62% although it varies from around 40% during summer (May) to 80% during the monsoon (September). Soils of study area are red lateritic soil.

2. 2 Method

For vegetation characterization, a stratified random sample technique was used. The plantation site was studied for vegetation analysis by randomly placing 20m × 20m quadrates. Tree vegetation was studied by placing, ten quadrates of 20m x 20m randomly. A 2 m x 2 m quadrates was placed in the middle of each 20 m x 20 m quadrates for enumeration of saplings and seedlings. At 1. 37 m above ground level, the adult individual's girth was measured. As a result, all individuals were counted by species and their girths were measured. The vegetational data were used to calculate density, frequency and dominance (Curtis and Mclntosh, 1950) [8]. The IVI was measured as the sum of relative density, relative frequency and relative dominance (Phillips, 1959). Species diversity were calculated using density values from Shannon-Weiner information function (Shannon and Weaver, 1963). Concentration of dominance was calculated using Simpson’s index (Simpson, 1949). Species richness following Margalef (1958) [17], equitability following pielou (1966) and beta diversity following Whittaker (1972).

2. 3 Biomass estimation

For the measurement of biomass, allometric equations relating tree circumference to biomass developed earlier by Singh and Mishra (1979) for dry deciduous forest species were used (Apendix). Computation protocol as described by Chaturvedi and Singh (1989) and Singh and Singh (1991) were followed.

2. 4 Litter mass

By using 50 cm x 50 cm randomly placed quadrates, forest floor litter was collected and then categorized into fresh leaf litter, wood litter and partially decayed litter. The collected litter was brought to the laboratory and oven dry weights were determined.

2. 5 Carbon estimation

For the estimation of carbon stock, carbon concentrations reported by Singh (2010) were used. The carbon storage for the vegetation components were computed as the sum of the products obtained by multiplying dry weights of components with their mean carbon concentrations. The values for carbon stock in different components were summed to get the total carbon stock by the vegetations.

2. 6 Soil analysis

Soil samples were collected from 0-10 cm and 10-20 cm soil depth on each sites and were analyzed for pH, EC, available nitrogen, available phosphorous, available potassium and% organic carbon of soil was determined by the Walkley and Black method following Jackson, (1958) [16]. All the results were expressed on oven dry weight basis.

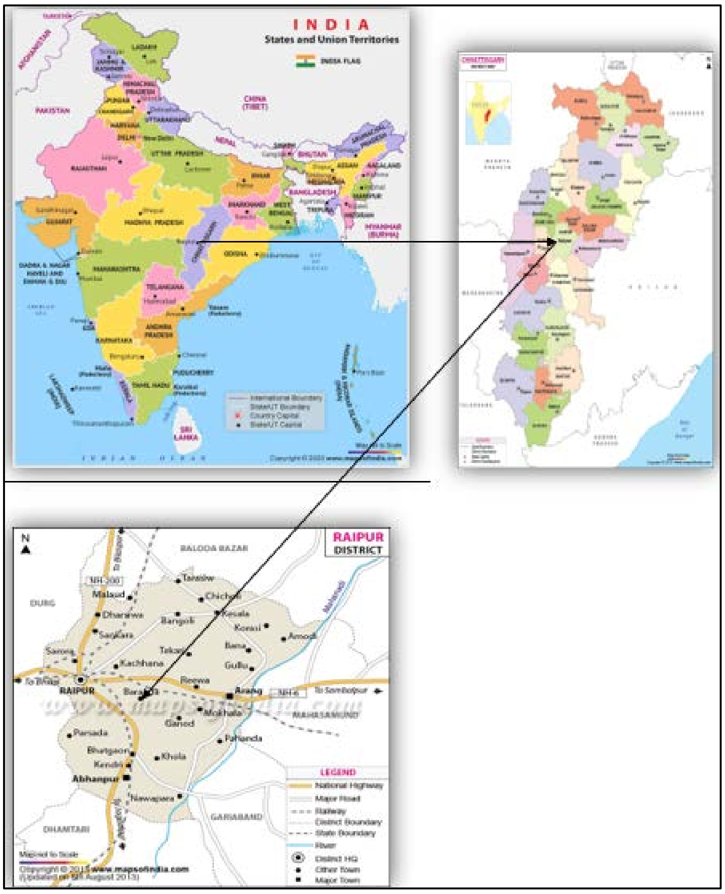

Fig 1: Location map of the study area

3. Results

3. 1 Species structure of *T. grandis* plantation site

In the tree layer of *T. grandis* plantation site *T. grandis* was dominant followed by *L. leucocephala*. Maximum density was measured for *T. grandis* (245 stems ha^{-1}) followed by *L. leucocephala* (35 stems ha^{-1}). Maximum basal area was observed for *T. grandis* (13. 32 m^2 ha^{-1}) followed by *L. leucocephala* (0. 45 m^2 ha^{-1}). Highest IVI was calculated for *T. grandis* (261. 12) followed by *L. leucocephala* (38. 86). The total density and basal area for tree layer in *T. grandis* plantation site were 280 stems ha^{-1} and 13. 77 m^2 ha^{-1}, respectively. In sapling layer *T. grandis* was dominant species followed by *L. leucocephala*. Maximum density was estimated for *T. grandis* (30 stems ha^{-1}) followed by *L. leucocephala* (17. 5 stems ha^{-1}). Maximum abundance was observed for *L. leucocephala* (2. 33) followed by *T. grandis* (2). Highest IVI was calculated for *T. grandis* (175. 99) followed by *L. leucocephala* (123. 98). The total density and abundance for sapling layer in *T. grandis* plantation site was (47. 5 stems ha^{-1}) and 4. 33, respectively. In seedling layer *L. leucocephala* was dominant species followed by *T. grandis*. Maximum density was measured for *L. leucocephala* (95 stems ha^{-1}) followed by *T. grandis* (62. 5 stems ha^{-1}). Maximum abundance was measured for *L. leucocephala* (12. 66) followed by *T. grandis* (3. 12). Highest IVI was calculated for *L. leucocephala* (167. 8) followed by *T. grandis* (132. 17). The total density and abundance for seedling layer was 157. 5 stems ha^{-1} and 15. 78, respectively.

Table 3. 1: Species structure of tree layer of *T. grandis* plantation sites

***T. grandis* plantation**					
Sr. no.	Species	F%	D (Stems ha^{-1})	BA (m^2 ha^{-1})	IVI
1	*T. grandis*	100	245	13. 32	261. 12
2	*L. leucocephala*	30	35	0. 45	38. 86
Total		130	280	13. 77	299. 98

*F=Frequency, D=Density, BA=Basal area, IVI=Importance value Index

Table 3. 2: Species structure of sapling layer of *T. grandis* plantation site:

***T. grandis* Plantation**					
Sr. no.	Species	F%	D (Stems ha^{-1})	Abund.	IVI
1	*T. grandis*	60	30	2	175. 99
2	*L. leucocephala*	30	17. 5	2. 33	123. 98
Total		90	47. 5	4. 33	299. 97

Table 3. 3: Species structure of seedling layer of *T. grandis* plantation site

***T. grandis* Plantation**					
Sr. no.	Species	F%	D (Stems ha^{-1})	Abund.	IVI
1	*T. grandis*	80	62. 5	3. 12	132. 17
2	*L. leucocephala*	30	95	12. 66	167. 8
Total		110	157. 5	15. 78	299. 97

3. 2 Species diversity of *T. grandis* plantation site:

The Shannon index values calculated in *T. grandis* plantation site for the tree, sapling and seedling layer was 0. 54, 0. 93 and 0. 96, respectively. The Simpson's index values calculated for tree, sapling and seedling layer was 0. 21, 0. 49 and 0. 49, respectively. The evenness measured in *T. grandis* plantation site for tree, sapling and seedling layer was 0. 78, 1. 34 and 1. 39, respectively. Species richness measured for tree, sapling and seedling layer was 0. 17, 0. 25 and 0. 19, respectively. Beta diversity calculated in *T. grandis* plantation site for tree, sapling and seedling layer was 2. 3, 3. 33 and 2. 72, respectively.

Table 3. 4: Diversity Parameter of *T. grandis* plantation site

***T. grandis* plantation**				
S. no.	**Parameter**	**Tree layer**	**sapling layer**	**seedling layer**
1	Shannon index (H')	0. 544	0. 93	0. 96
2	Simpson index (cd)	0. 2188	0. 49	0. 49
3	Equitability (e)	0. 78	1. 34	1. 39
4	Richness (d)	0. 17	0. 25	0. 19
5	Beta diversity (βd)	2. 3	3. 33	2. 72

3.3 Biomass (t ha^{-1}) in *T. grandis* plantation site

The total biomass in *T. grandis* plantation site was 73. 71 t ha^{-1} of which 61. 69 t ha^{-1} was in above ground parts and (12. 0 t ha^{-1}) below ground parts. *T. grandis* had the highest biomass (70. 11 t ha^{-1}) followed by *L. leucocephala* (3. 6 t ha^{-1}). The allocation of biomass in the various components was 36. 66 t ha^{-1} in bole, 17. 38 t ha^{-1} in branch, 7. 65 t ha^{-1} in leaf and 12. 02 t ha^{-1} in root. The share of bole, branch, leaf, and root was 49. 73%, 23. 57%, 10. 37% and 16. 30%, respectively of the total biomass.

Table 3. 5: Biomass (t ha^{-1}) of different components in *T. grandis* plantation site

***T. grandis* plantation**						
Sr. no.	Species	Bole	Branch	Leaf	Root	Total (t ha^{-1})
1	*T. grandis*	35. 57	16. 42	7. 52	10. 6	70. 11
2	*L. leucocephala*	1. 09	0. 96	0. 13	1. 42	3. 6
Total		36. 66	17. 38	7. 65	12. 02	73. 71

3. 4 Litter mass (t ha^{-1}) in *T. grandis* plantation site

The total litter mass was 9. 4 t ha^{-1} in *T. grandis* plantation site. Of the total litter mass 2. 9 t ha^{-1} was leaf litter, 1. 8 t ha^{-1} was wood litter and 4. 7 t ha^{-1} was partially decomposed litter. The leaf litter, wood litter and partially decomposed litter constituted 30. 85%, 19. 14%, 50% of the total litter mass.

Table 3. 6: Litter mass (t ha^{-1}) in the *T. grandis* plantation study area

Litter mass	*T. grandis* Plantation
Leaf litter	2. 9
Wood litter	1. 8
Partially decomposed Litter	4. 7
Total (t ha^{-1})	9. 4

3. 5 Carbon Stock (t ha^{-1}) in *T. grandis* plantation site

The total carbon stock in *T. grandis* plantation site was 31. 62 t ha^{-1}. *T. grandis* had the highest carbon stock of 30. 16 t ha^{-1} followed by *L. leucocephala* 1. 46 t ha^{-1}. The allocation of carbon stock in various components was 15. 94 t ha^{-1} in bole, 7. 92 t ha^{-1} in branch, 3. 56 t ha^{-1} in leaf and 4. 2 t ha^{-1} in root. The share of bole, branch, leaf and root was 50. 41%, 25. 04%, 11. 25% and 13. 28%, respectively of the total carbon stock.

Table 3. 7: Carbon stock (t ha^{-1}) in *T. grandis* plantation sites

T. grandis plantation						
Sr. no.	Species	Bole	Branch	Leaf	Root	Total (t ha^{-1})
1	*T. grandis*	15. 47	7. 49	3. 5	3. 7	30. 16
2	*L. leucocephala*	0. 47	0. 43	0. 06	0. 5	1. 46
Total		15. 94	7. 92	3. 56	4. 2	31. 62

3. 6 Physico-Chemical properties for upper and lower soil layer in *T. grandis* plantation site

Soil pH, EC, total available nitrogen, available phosphorous, total available potassium and organic carbon in *T. grandis* was 6. 18, 48. 5 ds/m, 313. 6 kg/ha, 5. 78 kg/ha, 217. 16 kg/ha and 0. 95%, respectively. Soil pH, EC, total available nitrogen, available phosphorous, total available potassium and organic carbon in *T. grandis* plantation was 6. 36, 69. 3 ds/m, 288. 5 kg/ha, 5. 7 kg/ha, 141. 3 kg/ha and 0. 86%, respectively.

Table 3. 8: Physico-chemical properties of soil in *T. grandis* plantation sites

Particular	Soil depths	
	0-10	**10-20**
Ph	6. 18	6. 36
EC	48. 5	69. 3
% Organic carbon	0. 95%	0. 86%
Available N (kg/ha)	313. 6	288. 5
Available P (kg/ha)	5. 78	5. 7
Available K (kg/ha)	217. 16	141. 34

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