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Biomass and carbon stock in *Acacia catechu* (Khair) plantation in tropical environment

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Abstract

The present study on “Biomass and carbon stock in *Acacia catechu* 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 *A. catechu* plantation site was 575 stems ha⁻¹. The total basal area of tree layer in *A. catechu* plantation site was 18.6 m² ha⁻¹. Total sapling and seedling density in *A. catechu* plantation site was 50 stems ha⁻¹ and 200 stems ha⁻¹ respectively. Total abundance for sapling and seedling layer in *A. catechu* plantation site was 4.83 and 12.22 respectively. The Shannon index in *A. catechu* plantation site for the tree, sapling and seedling layer was 0.43, 1.46 and 0.93, respectively. The Simpson's index for tree, sapling and seedling layer were 0.13, 0.62 and 0.42, respectively. The evenness in *A. catechu* plantation site for tree, sapling and seedling were 0.39, 1.33 and 1.34, respectively. Species richness for tree, sapling and seedling layer was 0.31, 0.51 and 0.18, respectively. Beta diversity in *A. catechu* plantation site for tree, sapling and seedling layer was 1.76, 2.5 and 2.3, respectively. Total biomass, litter mass and carbon stock in *A. catechu* plantation site was 177.42, 8.49 t ha⁻¹, 77.38 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 *A. catechu* plantation site was 6.02, 114.7 ds/m, 288.51 kg/ha, 6.68 kg/ha, 123.42 kg/ha and 0.76%, respectively. Soil pH, EC, total available nitrogen, available phosphorous, total available potassium and organic carbon in lower soil layer (10-20 cm) of *A. catechu* plantation site was 6.5, 115.8 ds/m, 163.07 kg/ha, 6.38 kg/ha, 122.3 kg/ha and 0.70%, respectively. Study revealed the potential of *A. catechu* in biomass production and carbon storage and may contribute to climate mitigation process.

Keywords: *A. catechu*, plantation, Soil pH, EC

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% 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). The tropical forest is one of the most diverse and complex terrestrial ecosystems, accounting for almost half of the world's live terrestrial carbon sinks. (*Acacia catechu*) is a deciduous tree with a light feathery crown and dark brown, glabrous, slender, thorny, shining branchlets, usually crooked. Bark dark brown or dark grey, brown or red inside, nearly 12-15 mm in thickness, rough, exfoliating in long narrow rectangular flakes which often remain hanging. 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 CO₂ in the atmosphere at (2 ppm yr⁻¹) and its potential to alter global climate. CO₂ and other greenhouse gases in the atmosphere have elevated the global average surface temperature by 0.6 to 0.2 degrees Celsius (IPCC, 1999). 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 meter above mean sea level and is located between 21°14'08.09"North and 81°42'32.69"East. It is 12 km from Raipur to Baloda Bazar Road. Figures 1 depict the research area's location. The average annual rainfall is about 1401 mm (55.2 inch) per year. 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 quadrats 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 McIntosh, 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 (Appendix). 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 different viz., 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 and were analyzed for pH, EC, available nitrogen, available phosphorous, available potassium following Jackson, (1958) [16]. % 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.

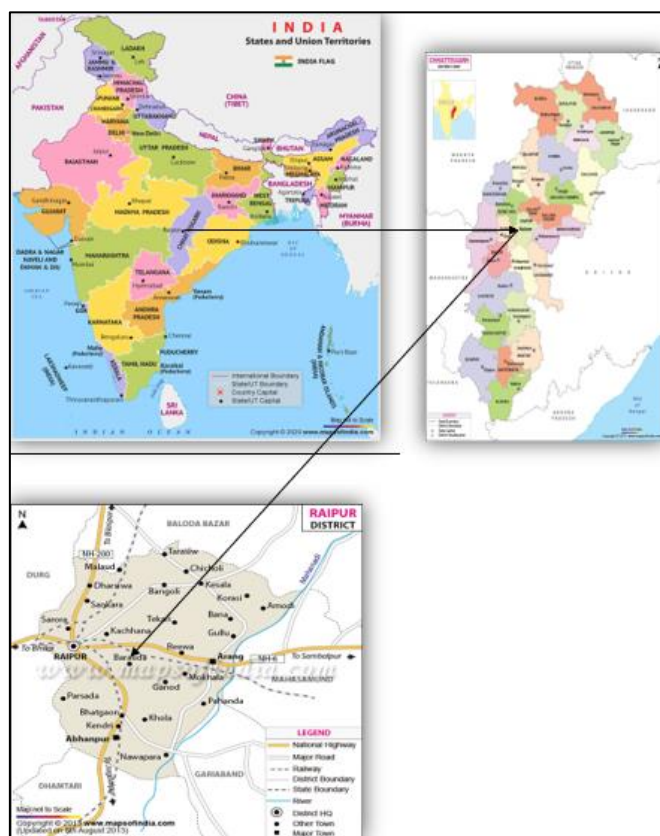


Fig 1: Location map of the study area

3. Results

3.1 Species structure of *A. catechu* plantation site

The tree layer of *A. catechu* plantation site was dominated by *A. catechu* followed by *T. grandis* and *L. leucocephala*. Maximum density was measured for *A. catechu* (535 stems ha⁻¹) followed by *T. grandis* (20 stems ha⁻¹) and *L. leucocephala* (20 stems ha⁻¹). Maximum basal area was observed for *A. catechu* (17.66 m² ha⁻¹) followed by *T. grandis* (0.72 m² ha⁻¹) and *L. leucocephala* (0.22 m² ha⁻¹). Highest IVI was calculated for *A. catechu* (246.74) followed by *T. grandis* (30.89) and *L. leucocephala* (22.31). The total density and basal area for tree layer was 575 stems ha⁻¹ and 18.6 m² ha⁻¹, respectively. In the sapling layer of *A. catechu* plantation site *A. catechu* was the dominant species followed by *L. leucocephala* and *T. grandis*. Maximum density was recorded for *A. catechu* (25 stems ha⁻¹) followed by *L. leucocephala* (15

stems ha⁻¹) and *T. grandis* (10 stems ha⁻¹). Maximum abundance was observed for *A. catechu* (2) followed by *L. leucocephala* (1.5) and *T. grandis* (1.33). Highest IVI was calculated for *A. catechu* (133.06) followed by *L. leucocephala* (94.38) *T. grandis* (72.53). The total density and abundance for sapling layer was 50 stems ha⁻¹ and (4.83), respectively. In the seedling layer of plantation site *A. catechu* was dominant species followed by *L. leucocephala*. Maximum density was measured for *A. catechu* (140 stems ha⁻¹) followed by *L. leucocephala* (60 stems ha⁻¹). Maximum abundance was observed for *A. catechu* (6.22) followed by *L. leucocephala* (6). Highest IVI was reported for *A. catechu* (109.13) followed by *L. leucocephala* (109.85). The total density and abundance for seedling layer was 200 stems ha⁻¹ and 12.22, respectively.

Table 3.1: Species structure of tree layer of *A. catechu* plantation sites

<i>A. catechu</i> Plantation					
Sr. no.	Species	F%	D (stems ha ⁻¹)	BA (m ² ha ⁻¹)	IVI
1	<i>T. grandis</i>	40	20	0.72	30.89
2	<i>L. leucocephala</i>	30	20	0.22	22.31
3	<i>A. catechu</i>	100	535	17.66	246.74
Total		170	575	18.6	299.94

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

Table 3.2: Species structure of sapling layer of *A. catechu* plantation site

<i>A. catechu</i> Plantation					
Sr. no.	Species	F%	D (stems ha ⁻¹)	Abund.	IVI
1	<i>T. grandis</i>	30	10	1.33	72.53
2	<i>L. leucocephala</i>	40	15	1.5	94.38
3	<i>A. catechu</i>	50	25	2	133.06
Total		120	50	4.83	299.97

Table 3.3: Species structure of seedling layer of *A. catechu* plantation site

<i>A. catechu</i> Plantation					
Sr. no.	Species	F%	D (stems ha ⁻¹)	Abund.	IVI
1	<i>T. grandis</i>	0	0	0	0
2	<i>L. leucocephala</i>	40	60	6	109.85
3	<i>A. catechu</i>	90	140	6.22	190.13
Total		130	200	12.22	299.98

3.2 Species diversity of *A. catechu* plantation site

The Shannon index values calculated in *A. catechu* plantation site for the tree, sapling and seedling layer was 0.43, 1.46 and 0.93, respectively. The Simpson's index values calculated for tree, sapling and seedling layer was 0.13, 0.62 and 0.42, respectively. The evenness measured in *A. catechu* plantation

site for tree, sapling and seedling was 0.39, 1.33 and 1.34, respectively. Species richness measured for tree, sapling and seedling layer was 0.31, 0.51 and 0.18, respectively. Beta diversity calculated in *A. catechu* plantation site for tree, sapling and seedling layer was 1.76, 2.5 and 2.3, respectively

Table 3.4: Diversity Parameter of *A. catechu* plantation site:

<i>A. catechu</i> Plantation				
S.no.	Parameter	Tree layer	sapling layer	seedling layer
1	Shannon index (H')	0.4338	1.46	0.93
2	Simpson index (cd)	0.132	0.62	0.42
3	Equitability (e)	0.39	1.33	1.34
4	Richness (d)	0.31	0.51	0.18
5	Beta diversity (βd)	1.76	2.5	2.3

3.3 Biomass (t ha⁻¹) in *A. catechu* plantation site

The total biomass in *A. catechu* plantation site was 177.42 t ha⁻¹ of which 155.88 t ha⁻¹ was above ground and 21.54 t ha⁻¹ in below ground parts. *Acacia catechu* had the highest biomass 171.93 t ha⁻¹ followed by *T. grandis* 3.77 t ha⁻¹ and *L.*

leucocephala 1.72 t ha⁻¹. The allocation of biomass in the various components was 67.65 t ha⁻¹ in bole, 84.68 t ha⁻¹ in branch, 3.55 t ha⁻¹ in leaf and 21.54 t ha⁻¹ in root. The share of bole, branch, leaf, and root was 38.12%, 47.72%, 2% and 12.14%, respectively of the total biomass.

Table 3.5: Biomass (t ha⁻¹) of different components in *A. catechu* plantation site

<i>A. catechu</i> plantation						
Sr. no.	Species	Bole	Branch	Leaf	Root	Total (t ha ⁻¹)
1	<i>T. grandis</i>	1.92	0.84	0.41	0.6	3.77
2	<i>L. leucocephala</i>	0.53	0.44	0.06	0.69	1.72
3	<i>A. catechu</i>	65.2	83.4	3.08	20.25	171.93
Total						177.42

3.4 Litter mass (t ha⁻¹) in *A. catechu* plantation site:

The total litter mass was 8.49 t ha⁻¹ in *A. catechu* plantation site. Of the total litter mass 3.06 t ha⁻¹ was leaf litter, 2.29 t ha⁻¹ was wood litter and 3.14 t ha⁻¹ was partially decomposed

litter. The leaf litter, wood litter and partially decomposed litter constituted 36.04%, 26.97%, 36.98% of the total litter mass.

Table 3.6: Litter mass (t ha⁻¹) in the *A. catechu* plantation study area

Litter mass	<i>A. catechu</i> Plantation
Leaf litter	3.06
Wood litter	2.29
Partially decomposed Litter	3.14
Total (t ha ⁻¹)	8.49

3.3 Carbon Stock (t ha⁻¹) in *A. catechu* plantation site

The total carbon stock for *A. catechu* plantation site was 77.38 t ha⁻¹. *Acacia catechu* had the highest carbon stock of 75.1 t ha⁻¹ followed by *T. grandis* 1.61 t ha⁻¹ and *L. leucocephala* 0.67 t ha⁻¹. The allocation of carbon stock in various

components was 29.42 t ha⁻¹ in bole, 38.66 t ha⁻¹ in branch, 1.64 t ha⁻¹ in leaf and 7.66 t ha⁻¹ in root. The share of bole, branch, leaf and root was 38.02%, 49.96%, 2.11%, 9.89%, respectively of the total carbon stock.

Table 3.7: Carbon stock (t ha⁻¹) in *A. catechu* plantation sites

<i>A. catechu</i> Plantation						
Sr. no.	Species	Bole	Branch	Leaf	Root	Total (t ha ⁻¹)
1	<i>T. grandis</i>	0.83	0.38	0.19	0.21	1.61
2	<i>L. leucocephala</i>	0.23	0.2	0.02	0.22	0.67
3	<i>A. catechu</i>	28.36	38.08	1.43	7.23	75.1
Total		29.42	38.66	1.64	7.66	77.38

3.5 Physico-chemical properties for upper and lower soil layer in *A. catechu* plantation site

Soil pH, EC, total available nitrogen, available phosphorous, total available potassium and organic carbon in *A. catechu* plantation was 6.02, 114.7 ds/m, 288.51 kg/ha, 6.68 kg/ha, 123.42 kg/ha and 0.76%, respectively. Soil pH, EC, total available nitrogen, available phosphorous, total available potassium and organic carbon in *A. catechu* plantation was 6.5, 115.8 ds/m, 163.07 kg/ha, 6.38 kg/ha, 122.3 kg/ha and 0.70%, respectively.

Table 3.8: Physico-chemical properties of soil in *A. catechu* plantation sites

Particular	Soil depths	
	0-10	10-20
Ph	6.02	6.5
EC	114.7	115.8
% Organic carbon	0.76%	0.70%
Available N (kg/ha)	288.51	163.07
Available P (kg/ha)	6.68	6.38
Available K (kg/ha)	123.42	122.3

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