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Studies on growth potential and carbon stock of teak in dry deciduous forest of Adilabad district

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Abstract
Teak (*Tectona grandis*) is one the most important forest species and it is one of the royal timber species. Apart from having an excellent timber value, it is one of the important tree species which can sequestrate atmospheric carbon and can contribute significantly to adhere with the Kyoto Protocol in stabilizing the atmospheric abundance of carbon dioxide and other greenhouse gases to mitigate the risks of global warming. The objective of the present study was to estimate the above ground biomass, below ground biomass, Total biomass and Carbon stock in different forest divisions of teak growth in Adilabad district to arrive at an estimate of its average carbon stock. There was considerable variation found in the teak trees in three divisions of Adilabad district. The Above ground biomass of Utnoor division was highest with 378.98 t/ha which was followed by Echoda division with 342.57 t/ha and the lowest was observed in Adilabad division with 286.71 t/ha. Whereas the below ground biomass of Utnoor division was highest with 98.54 t/ha which was followed by Echoda division with 89.07 t/ha and the lowest was observed in Adilabad division with 74.54 t/ha. In the same way the Total biomass also showed highest in Utnoor division with 477.52t/ha which was followed by Echoda division with 431.64 t/ha and the lowest was found in Adilabad division with 361.25 t/ha. On the basis of this obtained data such as Above ground, Below ground and Total biomass the values of carbon stock of teak also showed the same trend like highest carbon stock present in Utnoor division with 238.76 t/ha which was followed by Echoda division with 215.82 t/ha and the lowest was found to be in Adilabad division with 180.62 t/ha. The present study concluded that, Teak can also be used in the planting programs to mitigate climate climate change by reducing the greenhouse effect and global warming.

Keywords: Teak, Adilabad, Utnoor, Echoda, above ground biomass, below ground biomass, total biomass, carbon stock

Introduction
Climate change is often regarded as the greatest worldwide threat of the twenty-first century (Kumar *et al*., 2017) [13]. Global climate change has already expressed itself within the form of a 0.6 to 0.8 °C increase in global average temperature throughout the twentieth century, as well as an increased frequency of severe occurrences such as very high intensity precipitation, frequent drought, and heat waves, among other things. (Singh *et al*., 2017) [21]. Forests and stable grasslands are carbon sinks because they can store large amounts of carbon in their vegetation and root systems for long periods of time. Tropical deciduous forests grow in a variety of climatic conditions, primarily with alternate wet and dry periods. The structure, composition, and functioning of deciduous forests, on the other hand, change with the length of the wet season, amount of rainfall, latitude, longitude, and altitude (Shankar, 2001) [19], as well as the effects of human and livestock activities. Tropical forests have the greatest biological and genetic diversity on the planet (Singh, 2002) [23].
Teak (*Tectona grandis* Linn. f.) is a tropical or sub-tropical tree that belongs to the Lamiaceae family. C. Linnaeus, a Swedish botanist, named the genus *Tectona* and its species *grandis* for the first time in 1781. *Tectona grandis* Linn. f., Tectona hamiltoniana Wall, and *Tectona philippinensis* Benth and Hooker. f. are the only three species in the genus Tectona. Only *Tectona grandis* is widely distributed in India. Teak genetic variety is highest in the country, with a dispersion of 8.9 million hectares. Teak grows wild in portions of India, Myanmar, Lao PDR, and Thailand, and it has been naturalised on the Indonesian island of Java, where it was presumably imported 400-600 years ago (Kadambi 1972; White 1991) [12, 24].
Teak was originally introduced from outside Asia in Nigeria in 1902 (Horne, 1966) [26], with the early importation being of Indian origin and then of Burmese origin.

Because of its outstanding timber characteristics, teak was imported to countries in Tropical Africa to supplement native timber supplies. Teak grows naturally between 10º N and 25º N on the Indian subcontinent and in south-east Asia, particularly in India, Burma, Thailand, Laos, Cambodia, Vietnam, and Indonesia. It is not found in nature in Malaysia. It has a patchy distribution in India, ranging from the western Aravallies to Jhansi in the north. Teak forests can be found in Kerala, Andhra Pradesh, Karnataka, Maharashtra, Madhya Pradesh, Gujarat, Rajasthan, and Orissa in southern India. It is also found in Manipur's Kabaw valley (Brandis, 1906) [5]. Outside of the forest, India's total number of 9 stems and volume of teak is estimated to be 10, 58, 05, 000 and 223.964 million m3, respectively (ISFR, 2013) [8].

Teak (*Tectona grandis* Linn. f.) is now commonly planted as an invasive species in Southeast Asia, Africa, and South and Central America. If the age of the assessments was modified, the outcomes would be drastically different. It is vital to estimate biomass production and carbon sequestration utilising non-harvest strategies in the context of climate change by establishing various regression equations.

By raising the rotation age of trees and/or shrubs and manufacturing durable products from them after harvesting (Jose, 2009) [11], the most quantity and most permanent form of carbon can be sequestered, and it is perhaps one of the choices to support the livelihood of small and marginal farmers through the Kyoto Protocol's Clean Development Mechanism (CDM) (Montagnini and Nair, 2004) [15].

Materials and Methods

Location

The present study was carried out at Adilabad circle in which all the three divisions namely Adilabad, Utnoor and Echoda were covered to get the primary and secondary data for estimating carbon sequestration in teak growths of Adilabad district. Adilabad is 259 m above sea level and located at 19.67° N 78.53° E. It is rich in red soil and it also has different types of soils like Black cotton, Saline, Alluvial soils.

Data collection

The preliminary information on different Teak forests location and area in Adilabad district was collected from Forest department of Telangana. Sample plots were laid out randomly in the teak patch forest areas in the three divisions of Adilabad district with 0.1% sampling intensity and sample plot size of 20 m X 20 m was followed and tree measurements were taken in that plot.

Experimental details

Tree Height (m)

The tree height was measured from the ground level to the tip with the help of Ravi Altimeter.

Tree DBH (cm)

The Diameter at Breast Height (DBH) of trunk of the trees was measured in centimetres at breast height (1.37 cm from ground level) with the help of callipers and measuring tapes.

Basal Area (m^2)

The cross-sectional area of trees recorded while sampling was determined by the formula

Basal area = $\pi d^2 /4$

Where: d = Diameter

Form factor

The form factor was calculated using the formula given by Pressler (1865) [18] and Bitterlich (1984) [27].

$$F=\frac{2h1}{3h}$$

F - Form factor, h_1 - Height at which the diameter is half of Dbh, h - Total height of the tree

Volume of standing trees (m^3)

Volume of standing trees was calculated by Pressler's formula (1865) [18] and expressed in cubic meters.

V = F x H x G

Where,

V – Volume, F - Form factor, H - Total height, G - Basal area

Biomass estimation

Stem biomass (t)

Stem biomass of tree was obtained by multiplying volume with specific gravity (Smith 1954) [28].

Stem biomass (t/ha) = VOB × WD

Where, VOB = volume over bark, WD = volume weighted average wood density

Above ground biomass (t)

The aboveground biomass of a tree was calculated following IPCC (2006) [9] by multiplying its volume with a biomass expansion factor. The biomass expansion factor for hardwood species and conifers was calculated using the equations (Brown and lugo 1992) [6].

Above ground biomass (t/ha) = Stem biomass (t/ha) × BEF

Where: BEF = Biomass expansion factor

Below ground biomass (t)

The tree below ground biomass was estimated using IPCC default value (0.26) i.e., root-shoot ratio which was given by IPCC (2006) [7].

Below ground biomass = Above ground biomass X 0.26

Total biomass (t)

The total biomass was calculated by adding biomass of all the components (Above ground and below ground).

Total system biomass = Above ground biomass + Below ground biomass

Carbon stock estimation (t)

Aboveground and belowground carbon content in plants was determined by multiplying biomass of trees with a conversion factor of 0.45 (Magnussen and Reed 2004; Woomer and palm 1998) [14, 25]. Aboveground biomass and belowground biomass was added to derive at total biomass of trees.

Carbon stock = Total Biomass of trees X 0.45

Statistical analysis

For finding out the significant difference in the values of tree carbon in the three divisions of Adilabad district one-way ANOVA was performed.

Results and Discussions

Biomass production of Adilabad district

Field research was limited to sample plots of the three divisions of the Adilabad districts tropical dry deciduous woods. From each of these teak growth stands, samples of the trees from these three divisions with various girths were taken for thorough observation. For additional data analysis, the fundamental information on variables such as height and diameter at breast height (DBH) was gathered.

Table 1 shows the above ground biomass, below ground biomass and carbon storage in biomass of teak forest patches in the three divisions of Adilabad district. The above ground biomass, below ground biomass, total biomass and carbon stock in the teak biomass varied from each division. The Above ground biomass showed the range of values from 46.45 t/ha to 471.24 t/ha. Below ground biomass showed the range of values from 12.08 t/ha to 122.52 t/ha, Total biomass showed range of values from 58.52 t/ha to 593.76 t/ha and carbon stock showed range of values from 29.26 t/ha to 296.88 t/ha among various plots of teak growth in Adilabad division with averages being 286.71t/ha, 74.54t/ha, 361.25t/ha and 180.62t/ha, respectively.

The Above ground biomass showed the range of values from 227.48 t/ha to 686.25 t/ha, Below ground biomass showed the range of values from 59.15 t/ha to 178.42 t/ha, Total biomass showed range of values from 286.63 t/ha to 864.67 t/ha and carbon stock showed range of values from 143.32 t/ha to 432.34 t/ha among various plots of teak growth in Utnoor division with averages being 378.98 t/ha, 98.54 t/ha, 477.52 t/ha and 238.76 t/ha, respectively.

The Above ground biomass showed the range of values from 223.82 t/ha to 580.77 t/ha, Below ground biomass showed the range of values from 58.19 t/ha to 151.00 t/ha, Total biomass showed range of values from 282.02 t/ha to 731.77 t/ha and carbon stock showed range of values from 141.01 t/ha to 365.88 t/ha among various plots of teak growth in Echoda division with averages being 342.57 t/ha, 89.07 t/ha, 431.64 t/ha and 215.82 t/ha, respectively.

Table 1: Height, DBH, Basal area, Volume, above ground biomass, below ground biomass and carbon storage in biomass of teak forest patches in the Adilabad district

District	Division	Plot no	Height(m)	Diameter (cm)	Basal Area(m^2/ha)	Volume (m^3/ha)	AGB(t/ha)	BGB(t/ha)	TBM(t/ha)	CS(t/ha)
Adilabad	Adilabad	1	10.47	15.17	7.68	44.24	46.45	12.08	58.52	29.26
		2	15.07	27.75	33.25	275.58	289.36	75.23	364.59	182.30
		3	16.42	29.23	36.88	333.07	349.72	90.93	440.65	220.33
		4	17.25	33.88	47.30	448.80	471.24	122.52	593.76	296.88
		5	15.26	28.63	28.95	242.97	255.12	66.33	321.45	160.72
		6	14.92	28.72	34.00	279.01	292.96	76.17	369.13	184.57
		7	16.21	29.95	38.73	345.30	362.56	94.27	456.83	228.41
		8	13.85	30.02	38.92	296.45	311.28	80.93	392.21	196.10
		9	13.62	29.42	32.27	241.71	253.79	65.99	319.78	159.89
		10	13.15	29.19	33.44	241.84	253.94	66.02	319.96	159.98
		11	13.12	27.02	25.78	186.06	195.36	50.79	246.16	123.08
		12	13.54	28.52	38.30	285.23	299.49	77.87	377.36	188.68
		13	13.82	29.97	44.08	335.06	351.81	91.47	443.29	221.64
		14	13.15	28.62	36.97	267.42	280.79	73.01	353.80	176.90
	Utnoor	1	13.61	26.13	28.94	216.65	227.48	59.15	286.63	143.32
		2	13.75	26.79	30.42	230.08	241.58	62.81	304.39	152.20
		3	13.67	26.52	29.81	224.15	235.36	61.19	296.55	148.28
		4	16.87	30.10	37.35	346.52	363.85	94.60	458.45	229.22
		5	17.25	32.75	48.40	459.24	482.20	125.37	607.57	303.79
		6	16.97	31.16	40.03	373.59	392.27	101.99	494.26	247.13
		7	16.84	31.16	45.72	423.49	444.66	115.61	560.27	280.14
		8	16.72	30.22	37.65	346.21	363.52	94.52	458.04	229.02
		9	18.23	33.62	51.02	511.53	537.10	139.65	676.75	338.38
		10	19.64	35.84	60.50	653.57	686.25	178.42	864.67	432.34
		11	17.23	31.66	37.38	354.25	371.96	96.71	468.67	234.34
		12	14.63	26.97	27.12	218.23	229.14	59.58	288.72	144.36
		13	16.54	29.63	36.19	329.21	345.67	89.88	435.55	217.78
		14	16.47	29.72	31.21	282.72	296.85	77.18	374.04	187.02
		15	17.21	32.76	48.45	458.56	481.49	125.19	606.67	303.34
		16	16.23	28.73	38.87	347.01	364.36	94.73	459.09	229.54
	Echoda	1	12.14	26.04	31.93	213.17	223.82	58.19	282.02	141.01
		2	13.92	30.85	39.21	300.22	315.23	81.96	397.19	198.59
		3	14.11	31.40	38.70	300.35	315.36	81.99	397.36	198.68
		4	15.21	34.70	51.98	434.87	456.61	118.72	575.33	287.66
		5	12.81	26.66	27.89	196.49	206.32	53.64	259.96	129.98
		6	13.54	29.47	35.78	266.48	279.80	72.75	352.55	176.27
		7	14.12	31.97	42.12	327.09	343.45	89.30	432.74	216.37
		8	13.84	29.89	36.82	280.29	294.30	76.52	370.82	185.41
		9	13.24	29.31	38.79	282.43	296.55	77.10	373.66	186.83
		10	15.98	27.94	29.11	255.86	268.66	69.85	338.51	169.25
		11	18.67	35.32	53.87	553.11	580.77	151.00	731.77	365.88
		12	15.56	26.89	26.95	230.66	242.20	62.97	305.17	152.58

		13	18.57	34.54	51.51	526.07	552.37	143.62	695.99	348.00
		14	16.68	29.99	31.77	291.46	306.03	79.57	385.60	192.80
		15	16.42	28.28	37.66	340.13	357.13	92.85	449.99	224.99
		16	16.97	31.18	41.98	391.80	411.39	106.96	518.35	259.18
		17	18.21	34.93	52.68	527.61	553.99	144.04	698.03	349.02
		18	15.75	26.87	26.92	233.19	244.85	63.66	308.51	154.25
		19	16.51	28.59	27.27	247.58	259.96	67.59	327.55	163.78
	Mean		15.34	29.59	36.88	320.08	336.09	87.38	423.47	211.73
	CD@5%		1.329	2.416	6.844	79.852	83.844	21.799	105.64	52.821
	SEm±		0.445	0.805	2.281	26.627	27.948	7.267	35.214	17.607

From the results it was found that the Utnoor division showed highest values in above ground biomass, Below ground biomass, Total biomass and carbon stock of teak in Adilabad district. It can be ascribed to improved growth and increased translocation of photosynthates to diameter growth, enhanced basal area and volume, and further which led increased above ground biomass, below ground biomass, total biomass and carbon stock. These results received support from Banrjee and Prakasam (2013) [2], where they were recorded highest (224.48 t/ha) above ground biomass at the age of 47 in *Tectona grandis* and also these results were on the higher side with the results observed by Sharma *et al*. (2010) [20], where they were observed that the above ground biomass density 279.64 Mg/ha in *Shorea robusta* for Moist Bhaber region and 143.63 Mg/ha for Shivalik region.

These results were on the higher side with the results reported by Banrjee and Prakasam (2013) [2], where they were recorded highest (44.74 t/ha) below ground biomass at the age of 47 in teak. Similar results were also reported by Iqbal *et al*. (2014) [10], where they were recorded highest below ground biomass density of 33.66±1.80 Mg/ha in *Bischofia japonica*.

The results received support from Pawar *et al*., (2014) [17] who reported that at Katghora forest division under Bilaspur circle of Korba district, Chhattisgarh considering three plots to estimate biomass and carbon storage shows that the Total biomass was estimated at between 127.69 t ha^{-1} and 227.71 t ha^{-1}. Similar results were reported by Banrjee and Prakasam (2013) [2] in teak, where they recorded highest (269.97 t/ha) total biomass at the age of 47.

These results are in accordance with A.K. Singh *et al*. 2020 [22] where they reported carbon storage in biomass of teak plantation forest in Eastern ghats varied from 24.41 – 233.60 kg m^{-2}. Similar findings receive support from Iqabl *et al*. (2014) [10], where they observed the highest (81.27±4.82 Mg/ha) total carbon in *Bischofia javanica* and 162.54±9.65 Mg/ha total biomass in *Bischofia japonica*.

Conclusion

The present work shows that teak species not only have a good carbon sequestration potential through its above ground biomass, below ground biomass, Total biomass and carbon stock but also offers significant assistance to scrub the carbon from the atmosphere, thereby serving as potent reservoir of carbon in the Adilabad district of Telangana, India. This study can be useful in forest management practices and for developing strategies to mitigate carbon under Indian climatic conditions.

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