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Carbon Sequestration Potential of Teak (*Tectona grandis*) Plantations in Kerala

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Abstract

Teak (Tectona grandis) is the most important forest plantation species and it occupies the major area under forest plantations in Kerala. In addition to its value as an ideal timber, it also plays an important role in storing carbon. The silviculture of teak necessitates felling at regular intervals of 5, 10, 20, 30, 40 and 50 years of age. The present study was carried out to estimate the carbon storage in different compartments of teak in each of these felling periods to arrive at an estimate of its carbon sequestration potential. Carbon content of teak biomass was estimated using CHNS analyser. There was slight variation in carbon content between age groups and considerable difference between various parts of the tree. The wood contained around 46%, bark around 32%, branches around 40% and the roots around 45% of carbon. Regression equations were developed to predict the total tree carbon storage from tree measurements. It was found that around 181 ton carbon per hectare is stored by a teak plantation in Kerala during its life time of 50 years by yielding biomass at different stages of thinning operations and at final felling stage.

Key words: Teak, carbon sequestration, Kerala.

Introduction

Teak (*Tectona grandis* Linn. F) is a valuable timber yielding species in the tropics especially India, Indonesia, Malaysia, Myanmar, northern Thailand, and northwestern Laos. The first teak plantation in the world was raised in Nilambur, Kerala, India in the year 1840. The Kerala Forest Department now has about 56510 ha under teak, out of which approximately 64 per cent is in the first rotation and the remaining 36 percent in the second and third rotation stages and about 1000 ha is being felled and replanted every year[1,2].

Global warming due to increased concentration of green house gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and sulphur hexa fluoride (SF6) in the earth's atmosphere is one of the most important concerns of mankind today[3]. United Nations Framework Convention on Climate Change (UNFCCC) created during the Rio Earth Summit in 1992 to stabilize GHG concentration in the atmosphere came into force in March 1994. The 3rd conference of parties (CoP 3) which met in Japan in 1997 decided on certain protocols which came to be known as Kyoto protocol. The Kyoto protocol legally binds 39 developed countries to reduce their GHG emissions by an average of 5.2% relative to 1990 levels by the period 2008-2012, referred as the first commitment period. The Kyoto protocol permits the developed countries to reach their targets through several mechanisms. They are emission trading, joint implementation and clean development mechanism (CDM). CDM allows developed nations to achieve reduction obligation through projects in developing countries that reduce emissions or sequester CO_2 from the atmosphere[4,5]. The CoP 7 of UNFCCC that met in Bonn (Germany) in July 2001 decided to include Afforestation and Reforestation (A/R) as an effective way to reduce atmospheric carbon by building up terrestrial carbon stocks and to produce Certified Emission Reductions (CERs).

It has been suggested that improved land management could result in sequestration of substantial amount of soil carbon and can be an option to reduce atmospheric CO_2 concentration [6,7,8]**.** Forest management such as rotation length is seen as an activity that countries may apply under the Kyoto Protocol to help them meet the commitments for reduction of green house gas emissions[9]. However, the benefits can get reversed through disturbances and harmful practices during harvest which would release the carbon back to the atmosphere. Individual trees and stands of trees sequester carbon within their main stem wood, bark, branches, foliage and roots. Carbon sequestered by the main stem wood results in longer sequestration while other components sequester and release carbon on shorter intervals due to natural pruning and decomposition[10].

Carbon sequestration potential of tree species becomes relevant in this respect. It varies with species, climate, soil and management. Forest plantations have significant impact as a global carbon sink[11,12]. Young plantations can sequester relatively larger quantities of carbon while a mature plantation can act as a reservoir. Long rotation species such as teak (*Tectona grandis*) has long carbon locking period compared to short duration species and has the added advantage that most of the teak wood is used indoors extending the locking period further.

Material and Methods

Teak plantations in different thinning regimes and at final felling were surveyed in Nilambur forest division, Kerala and seven sites corresponding to the prescribed felling schedule and on comparable site quality selected for the study. Measurements of fifty standing trees as regards height and GBH were taken while the ten felled trees were measured as logs. Fifty trees closest to transects taken at right angles to each other were considered for the purpose of height and GBH measurements. Samples of wood from ten felled trees in each of the sites were collected by slicing thin discs from the cut portions of logs. Samples of wood were also collected from different branches of each felled tree. Root systems of the selected ten trees in each site were excavated manually by starting at the stump and following the roots to possible limits. The stump along with the exposed roots were pulled out with the help of tractor. Estimation of fine roots was done by taking pits around each tree from which all soil was removed to isolate fine roots to possible extent. They were weighed in the field itself and samples collected from different parts of the root system to estimate dry mass.

The schedule of felling operations presently followed by the Kerala Forest Department in teak plantations is the first mechanical thinning at the age of 5 years by removing every alternate row to facilitate space for growth which is followed by selective silvicultural thinnings at 10, 15, 20, 30, and 40 years when 1739, 318, 126, 103, 40 and 19 trees respectively are removed from a hectare. The plantations are clear felled at 50 years when hardly 155 trees remain.

Carbon storage was worked out at two levels *viz*., tree level and plantation level. Above ground and below ground biomass of teak was estimated by destructive sampling. Biomass of trees that are removed from the site through felling at each stage including the final felling stage was only considered for estimating carbon sequestration.

Various regression equations were fitted for each age class using DBH as an independent variable and total tree carbon storage (wood + branches + root + bark) as dependent variables using data from 10 trees/age class. Data were transformed to log to the base 10 as is commonly done to linearize data of this type. The statistical analyses were conducted using SPSS soft ware package.

Results and Discussion

Biomass of teak trees of different ages: Data on biomass of teak at different felling cycles is given compartment wise as wood, bark, branches and root (table 1). Above ground biomass represent mean of 50 trees and below ground biomass represent 10 trees. It can be seen that at the 5th year mechanical thinning wood biomass amounted to 50.56 kg/tree on an average, bark constituted 8.92kg/tree while the contribution of root was 8.33kg/tree. Wood constituted 75%, bark 13% and root 12% of the total biomass. At the age of 10 year the wood biomass was estimated to be around 91.5kg, the bark around 14.89kg, branches 26.91kg and root around 21.28kg per tree. Wood constituted 59%, bark 10%, branches 17% and root 14% of the total biomass.

At the second silvicultural thinning of fifteenth year, wood constituted 121.5kg, bark 16.76kg, branches 27kg and root 38.67kg per tree. The contribution of wood was found to be 50%, bark 8%, branches 25% and root 17% of the total biomass. At the age of 20 years the respective figures were 142.28kg of wood, 19.4kg of bark, 27.53kg of branches and 48.51kg of roots per tree. Wood constituted 60%, bark 8%, branches 12% and root 20% of the total biomass.

At the 30th year of fourth silvicultural thinning, wood was found to yield 254.34kg, while the bark constituted around 28.26kg per tree. The contribution of branches was 38.38kg and that of root 87.60kg per tree towards the tree biomass. Wood constituted 62%, bark 7%, branches 9% and root 21% of the total biomass. The wood biomass at the 5th silvicultural thinning at the age of 40 years was found to be around 480.48kg, bark biomass around 44.63kg while the branches were found to weigh about 95.93kg per tree and the root portion contributed 131.28kg of biomass. Wood constituted 64%, bark 6%, branches 13% and root 17 percent of the total biomass. Biomass partitioning at the age of 50 years was found to be in the order of 635.85kg wood, 59.07kg bark, 183.55kg branches and 173.73kg of roots per tree. Wood constituted 66%, bark 6% and branches and root 17% each of the total biomass.

Table-1
Biomass distribution in various compartments at different thinning stages

	Mean biomass (kg/tree) ± SD						
Compartments	5 year	10 year	15 year	20 year	30 year	40 year	50 year
Wood	50.56 ±3.00	91.50 ±8.55	112.15 ±18.47	142.28 ±54.00	254.34 ±94.50	480.48 ±67.55	635.85 ±155.45
Bark	8.92 ± 0.06	14.89 ±2.03	16.76 ±4.56	19.40 ±4.37	28.26 ±9.24	44.63 ±10.30	59.07 ±12.50
Branches	-	26.91 ±11.53	27.00 ±18.62	27.53 ±22.14	38.38 ±25.34	95.93 ±23.65	183.55 ±64.53
Root	8.33 ±0.50	21.28 ±3.24	38.67 ±4.32	48.51 ±15.00	87.60 ±20.40	131.28 ±25.00	173.73 ±46.53
Total	67.81	154.59	223.14	237.72	408.57	752.32	1052.20

SD - Standard Deviation

Table-2
Mean carbon content in different compartments at various stages of growth

Compartments	**Mean carbon content (kg/tree) ± SD**						
	5 year	**10 year**	**15 year**	**20 year**	**30 year**	**40 year**	**50 year**
Wood	23.26 ±1.50	42.09 ±4.21	51.59 ±7.70	65.45 ±24.25	116.99 ±24.40	221.02 ±21.24	292.49 ±102.50
Bark	2.86 ±0.30	4.77 ±0.45	5.36 ±1.20	6.21 ±2.06	9.04 ±3.22	14.28 ±2.36	18.90 ±6.04
Branches	-	11.30 ±3.23	11.42 ±5.24	11.56 ±7.24	16.12 ±11.76	40.29 ±12.30	77.09 ±20.20
Root	3.33 ±0.15	8.94 ± 1.65	16.63 ±2.22	20.86 ±6.00	38.55 ±9.35	57.76 ±8.54	76.44 ±18.36

SD - standard deviation

Table-3
Regression equations for predicting per tree total carbon content

Plantation	**Regression**	**Adjusted R^2**	**t-value for slope coefficient**
5 Year	Log (Y) = 1.301 + 0.197 log (DBH)	0.875	7.992**
10 Year	Log (Y) = 0.429 +1.201 log (DBH)	0.909	9.542**
15 Year	Log (Y) = 0.381 +1.293 log (DBH)	0.840	6.957**
20 Year	Log (Y) = 0.261 +1.344 log (DBH)	0.944	12.395**
30 Year	Log (Y) = -0.412 +1.818 log (DBH)	0.981	21.509**
40 Year	Log (Y) = -0.282 +1.743 log (DBH)	0.953	13.507**
50 Year	Log (Y) = 0.268 +1.461 log (DBH)	0.883	8.292**

** significant at p = 0.01

Carbon content of teak trees of different ages: Carbon content of teak partitioned in the wood, bark, branches and root is given in Table 2. It can be seen that at the age of 5 years, the wood portion of the tree contained 23.26 kg carbon, the bark 2.86 kg and the root 3.33 kg carbon per tree. At the first silvicultural thinning of 10^{th} year, carbon content in wood was found to be 42.09 kg, that in bark around 4.77kg, branches around 11.3kg and the roots contained around 8.94kg carbon per tree. At 15 year of age, wood portion of the tree on an average was found to contain 51.59kg carbon while the bark contained 5.36kg, the branches 11.42kg and the roots 16.63kg carbon.

Carbon content of wood was found to be 65.45kg, that of bark 6.21kg, branches 11.56kg and the root 20.86kg on an average per tree at the time of third silvicultural thinning at 20 years of age. At thirty year age when the fourth silvicultural thinning is carried out the average carbon content per tree was found to be 116.99kg in wood portion, 9.04kg in bark, 16.12kg in branches and 38.55kg in the roots. At the fifth silvicultural thinning at the 40^{th} year carbon content in wood was about 221.02kg, that in bark around 14.28kg, while the branches contained about 40.29kg and the root 57.76kg per tree. Carbon content of wood portion was found to be around 292.49kg, bark around 18.99kg, branches around 77.09kg while the roots contained 76.44kg carbon per tree at the age of 50 years.

Carbon content in compartments of different aged teak trees is shown in Fig 1. It can be seen that most of the carbon was stored in the wood portion which was followed by root, branches and bark, the trend becoming more pronounced in the latter years.

Development of prediction equations of carbon storage: Various regression equations were fitted for each component of carbon storage to develop non destructive predictors and are given in table 3. The ‘t’ values of regression coefficients of the equations were also highly significant in all cases.

Linear regression equations of log DBH versus per tree total carbon content show that these relationships are strong yielding coefficients of determination (R^2) of 0.840 to 0.981 in various thinning regimes which means that the variation in total carbon content could be well explained by DBH of trees in all the plantations.

Estimation of carbon storage potential of teak plantations in Kerala: Carbon storage potential of teak plantations in Kerala was calculated based on the number of trees removed at each felling cycle and is given in table 4. The carbon storage potential was found to be 51.20 t/ha at the first mechanical thinning of 5 year growth, followed by 21.34, 12.21, 10.72, 7.23 and 6.33 t/ha during the first, second, third, fourth and fifth silvicultural thinning at 10, 15, 20, 30 and 40 years of age respectively and 72.1t/ha at the time of final felling.

Table-4
Plantation level carbon sequestration (Tons per hectare)

Felling regime	No. of trees removed	Carbon (t/ha)
5	1739	51.2
10	318	21.34
15	126	12.21
20	103	10.72
30	40	7.23
40	19	6.33
50	155	72.1
Total	2500	181.13

Conclusion

It can be concluded within the limitations of the present study that 181.13 ton carbon per hectare could be stored by a teak plantation in Kerala during its life time of 50 years by yielding biomass at different stages of thinning operations and at final felling stage.

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