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Carbon sequestration potential of kapok (*Ceiba pentandra*) plantations in Theni district of Tamil Nadu, India

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ABSTRACT

Kapok (*Ceiba pentandra*) is the most important agroforestry tree species and it occupies major area under plantations in Theni district of Tamil Nadu. In addition its value for silk cotton, it also plays an important role in storing carbon. To assess the carbon sequestration potential, the study has been carried out to estimate the carbon storage in different tree parts of *Ceiba pentandra* at different age groups. Carbon sequestration potential was estimated through destructive felling method. Oven dried biomass samples were ground in a Wiley Mill and carbon content in different tree components was estimated by ash method. There was slight variation in carbon content between age groups and considerable difference between various parts of the tree. The wood contained around 44.7 per cent, leaves around 36.4 per cent, branches around 41.5 per cent and the roots around 42.5 per cent of carbon.It was found that 38.7 ton carbon per hectare is stored by a 12 years old kapok plantation. AGRES software was used to compute the results.

Key words : *Kapok, Carbon sequestration, Stem, Branch, Root, Leaves*

Introduction

Kapok (*Ceiba pentandra* (L.) Gaertn), belongs to the family Bombacaceae is valuable for its kapok fibre. Ceiba pentandra originated in the American tropics, where it spread to Africa, Indonesia, Java and Thailand. It has now become wild in Tropical Africa and was widely planted in Asia (Hora, 1981). Kapok is grown in all the districts of Tamil Nadu. It is grown in Theni, Coimbatore, Salem, Dharmapuri and Madurai. Among the different districts of Tamil Nadu, Theni comprises the maximum area of extent around 4650 hectares.

Trees play a very important role in the global carbon cycle. It stores about 60 per cent of above ground and 40 per cent of below-ground terrestrial organic carbon (IPCC 2001). Terrestrial ecosystem plays an important role in global carbon cycle as CO_2 source or sink. CO_2 exchange in terrestrial ecosystem is mainly controlled by photosynthesis and respiration. The role of terrestrial ecosystem as carbon sink can be enhanced by planting more trees for afforestation or reforestation. Plantation forest using fast growing species has been adopted in many countries as one option for a sustainable supply of tree products and also reducing the pressure on natural forest (Widyorini *et al.*, 2009). During productive season, CO_2 present in the atmosphere is taken up by vegetation and stored as tree biomass (Losi *et al.*, 2003; Phat *et al.*, 2004).

Trees can play two fundamental different roles as carbon sink and by capturing atmospheric CO_2 through photosynthesis, trees store large amount of organic carbon in above and below ground biomass. Trees in an ecosystem can continue to act as a carbon sink for several centuries. Tree biomass can also be harvested and converted into durable plant products. Long-term carbon sequestration can be

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achieved, when carbon from above ground biomass transfer to the roots and enters the pool of soil carbon (Jansson *et al.* 2010).

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 (Reddy *et al.* 2012; Metting *et al.* 1999). 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).

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 (Montagmini *et al.*, 1998).

Material and Methods

Six age groups of the trees were selected namely viz., 1, 2, 5, 8, 10 and 12 years old kapok plantations in the all the eight blocks of the district. Carbon sequestration potential was estimated through destructive felling method. Representative sample trees were selected for felling. Samples of wood from 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 trees in each site were excavated manually by starting at the stump and following the roots to possible limits. The stumps along with the exposed roots were pulled out with the help of tractor or manual power. 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.

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

A small sample (500 g) of stem, branches and leaves were immediately transported to the laboratory in double sealed polythene bags. The collected tree samples were dried at 80°C till constant weight was obtained. The oven dry weight (ODW) of the whole sample was calculated using the formula given below by (Lasco *et al.*, 2005).

$$\text{ODW (t)} = \frac{\text{TFW} - \{\text{TFW* (SFW-SODW)}\}}{\text{SFW}}$$

Where,
ODW = Total oven dry weight
TFW = Total fresh weight
SFW = Sample fresh weight
SODW = Sample oven dry weight

Oven dried biomass samples were ground in a Wiley Mill and carbon content in different tree components was estimated by ash method. Silica crucible was washed with 6 N hydrochloric acid and distilled water and dried in an oven at 65°C for one hour. One gram of powdered sample was transferred in pre-weighed silica crucible. The crucible was kept inside the muffle furnace. The furnace temperature was adjusted to 550°C by slowly increasing the temperature and ignition was continued for one hour. Then the silica crucible was cooled, and after complete cooling, the crucible with ash was weighed and the percentage of ash was calculated as per the procedure given by Allen *et al.*, (1986) with the following formula.

$$\text{Ash percentage} = \frac{(\text{W3--W1})}{(\text{W2--W1})} \times 100$$

Where,
W1 = Weight of crucible
W2 = Weight of oven dried powdered sample + crucible
W3 = Weight of ash + crucible

Carbon percentage in above ground biomass and below ground biomass was estimated by the method followed by Negi *et al.*, (2003); Dey (2005) and Dhruw *et al.*, (2009) using the following formula given below:

Carbon percentage = 100-{Ash percentage + Molecular weight of O_2 (53.3 percent) in $C_6H_{12}O_6$)

The carbon stock in the above ground biomass and below ground biomass was computed by using the formula given below.

Carbon (t ha^{-1}) = Biomass (t ha^{-1}) × Carbon content (%)

The total biomass carbon was calculated by using the following formula.

(i) AGB carbon (t C ha^{-1}) = Components of above ground biomass (t ha^{-1}) × Carbon content (%)

(ii) BGB carbon (t C ha^{-1}) = Components of below ground biomass (t ha^{-1}) ×

Statistical analysis was conducted using AGRES software package were data of treatments and replications were fitted.

Results

Biomass of kapok trees of different ages

Data on biomass of kapok at different age groups is given in component wise as leaf, branch, stem and root data shown in Table 1. Above ground and below ground biomass represent mean of three trees. It can be seen that 15 years old tree showed the average total biomass of 424.4 kg $tree^{-1}$ followed by 351.4, 292.6, 198.5, 73.9 and 40.5 kg $tree^{-1}$ of 12, 10, 8, 5, 2 and 1 year old kapok trees respectively of which 15 year old tree components constituted like leaf 62.6 kg $tree^{-1}$, branch 115.4 kg $tree^{-1}$, stem 165.8 kg $tree^{-1}$ and root 80.6 kg $tree^{-1}$. Biomass increased with the increase in age of the trees. Stem component of the tree contributed higher biomass followed by branch, root and leaf components.

Carbon content percent of kapok trees of different ages and different tree components

Carbon content percent at different age groups and different tree components is presented in Table 2. The mean of all the age groups selected showed the carbon content percent of 44.7, 42.5, 41.5 and 36.4 per cent in stem, root, branch and root components respectively. Slightly variation was found with mean carbon content percent at different age group i.e., 38.4, 39.3, 41.1, 42.3, 43.1 and 43.6 per cent in 1, 2, 5, 8, 10 and 12 years old kapok trees.

Table 2. Carbon content (%) in different tree components of kapok

Age group	Leaf	Branch	Stem	Root	Mean
	Carbon content (per cent)				
1	34.2	38.6	41.2	39.5	38.4
2	35.4	39.4	42.1	40.1	39.3
5	36.2	41.5	44.2	42.3	41.1
8	37.0	42.2	46.4	43.5	42.3
10	37.5	43.3	46.9	44.6	43.1
12	37.8	44.1	47.3	45.2	43.6
Mean	36.4	41.5	44.69	42.53	41.3
SEd	0.67	1.30	1.18	1.24	1.74
CD (P= 0.05)	1.51	2.91	2.63	2.76	3.18

Biomass carbon content of kapok trees of different ages and tree components

Biomass carbon content expressed in kg $tree^{-1}$, showed increasing order with increase in age of the

Table 1. Above and below ground biomass per tree (kg $tree^{-1}$) and per hectare (t ha^{-1}) in kapok at different age group

Age of the tree	Leaf	Branch	Stem	Root	Total	Age of the tree	Leaf	Branch	Stem	Root	Total
	Biomass (kg $tree^{-1}$)						Biomass (t ha^{-1})				
1	5.80	10.3	15.6	8.80	40.5	1	1.18	2.10	3.18	1.19	7.65
2	10.3	19.0	30.8	13.8	73.9	2	2.10	3.88	6.28	2.82	15.1
5	22.4	48.7	96.6	30.8	198.5	5	4.57	9.93	19.7	6.28	40.5
8	40.5	75.52	122.4	54.2	292.6	8	8.26	15.4	25.0	11.1	59.8
10	49.6	94.6	136.3	70.9	351.4	10	10.1	19.3	27.8	14.5	71.7
12	62.6	115.4	165.8	80.6	424.4	12	12.8	23.5	33.8	16.4	86.4
Mean	31.8	60.6	94.6	43.2	230.2	Mean	6.48	12.4	19.3	8.72	46.8
SEd	1.07	1.40	0.91	0.68	1.73	SEd	0.79	0.91	0.75	0.79	1.56
CD (P= 0.05)	2.39	3.12	2.02	1.52	3.81	CD (P=0.05)	1.78	2.02	1.68	1.76	3.42

trees viz., 15.9, 29.7, 84.0, 127.3, 155.1 and 189.4 kg tree^{-1} at 1, 2, 5, 8, 10 and 12 year old trees respectively. 12 year old tree showed the carbon content of 23.7, 50.9, 78.4 and 36.4 kg in leaf, branch, stem and a root component of the tree is represented in Table 3.

Table 3. Biomass carbon content (kg tree^{-1}) at different age group and tree components of kapok

Age group Biomass carbon per tree (kg tree^{-1})	Leaf	Branch	Stem	Root	Total
1	1.98	3.98	6.43	3.48	15.9
2	3.65	7.49	13.00	5.53	29.7
5	8.11	20.2	42.7	13.0	84.0
8	15.0	31.9	56.8	23.6	127.3
10	18.6	41.00	63.9	31.6	155.1
12	23.7	50. 9	78.4	36.4	189.4
Mean	11.8	25.9	43.5	18.9	100.2
SEd	0.93	0.97	1.05	0.53	1.87
CD (p= 0.05)	2.08	2.18	2.35	1.17	3.74

Estimation of carbon storage potential of kapok plantations in Theni district of Tamil Nadu

Carbon storage potential of 12 year old plantation was found to be 38.7 t ha^{-1} followed by 10, 8, 5, 2 and 1 year old plantation of 31.6, 26.0, 17.2, 6.09 and 3.25 t ha^{-1} respectively which is shown in Table 4.

Table 4. Carbon storage potential kapok plantation at different age group

Age group Biomass carbon per hectare (t ha^{-1})	Leaf	Branch	Stem	Root	Total
1	0.41	0.81	1.32	0.71	3.25
2	0.74	1.54	2.65	1.16	6.09
5	1.67	4.11	8.71	2.66	17.2
8	3.07	6.50	11.6	4.83	26.0
10	3.79	8.36	13.0	6.47	31.6
12	4.84	10.4	16.0	7.41	38.7
Mean	2.42	5.29	8.88	3.87	20.5
SEd	0.63	1.02	0.55	0.61	1.36
CD (P= 0.05)	1.42	2.28	1.22	1.36	3.05

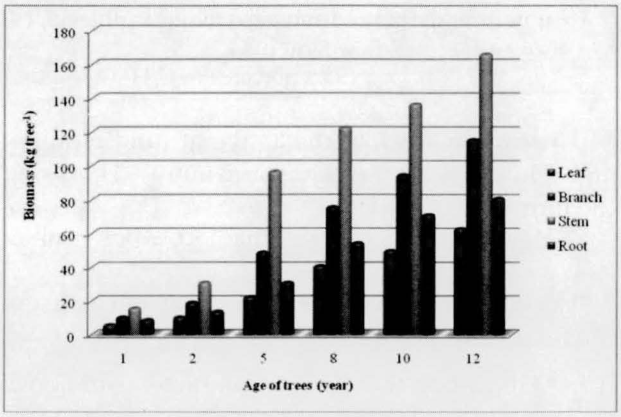

Fig. 1. Above and below ground biomass (kg tree^{-1}) of kapok at different age group

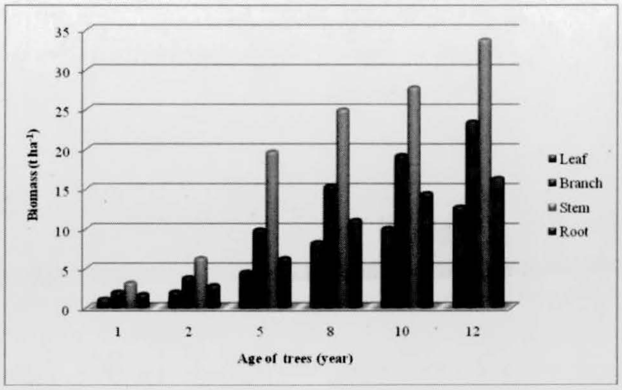

Fig. 2. Above and below ground biomass (t ha^{-1}) of kapok at different age group

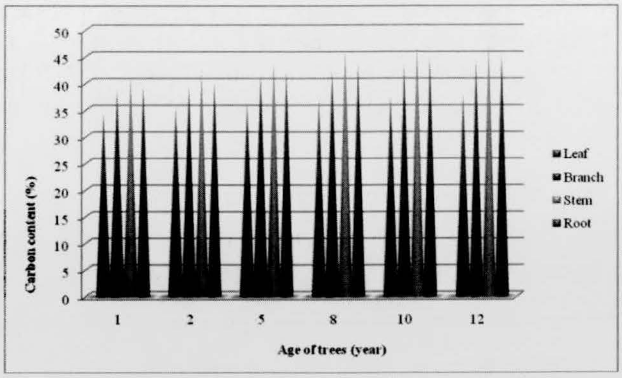

Fig. 3. Carbon content (%) in different tree components of kapok at different age group

Discussion

Ceiba pentandra usually planted at the spacing of 7 x 7 m where 204 trees accommodated in one hectare of plantation. It can be seen that 15 years old plantation showed the average total biomass of 86.4 t ha^{-1} followed by 71.7, 59.8, 40.5, 15.1 and 7.65 t ha^{-1} of 12, 10, 8, 5, 2 and 1 year old kapok plantation respectively which is shown in Table 1. (George 1997) stated that increased above ground biomass of Eucalyptus hybrid was recorded in 12 years old tree (258.2 kg tree^{-1}) as compared to 9 years old tree (41.3 kg tree^{-1}).

Among the carbon content recorded in the different components of the tree, stem bole recorded the highest and it may be due to more density in the wood portion and higher biomass have been allocated in the stem part in order to give more strength and support to the tree. Sreejesh *et al.* (2012) reported that wood, bark, branches and roots contained 46, 32, 40 and 45 per cent of carbon respectively. Ranabhat *et al.* (2007) observed the mean carbon content of 40.5 per cent in stem, 33 per cent in branches, 9.5 per cent in leaves and 16.4 per cent in bark of *Alnus nepalensis*.

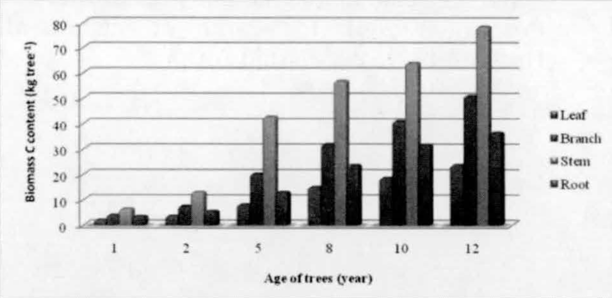

Fig. 4. Biomass carbon content (kg tree^{-1}) of different tree components of kapok at different age group

In one hectare of kapok plantation, 12 years old plantation registered the highest mean biomass carbon content of 38.7 t ha^{-1} followed by 10 years old plantation (31.6 t ha^{-1}). The lowest mean biomass carbon content was registered in one year old plantation (3.25 t ha^{-1}). Among different tree components, in 12 years old plantation, stem contributed the maximum biomass carbon content is represented in Table 3 and Fig. 5). Wauters *et al.* (2008) reported that the carbon stock of 14 years old rubber tree plantation in Brazil and Ghana was 41.7 t C ha^{-1} and 76.3 t C ha^{-1} respectively. Carbon content increased with biomass.

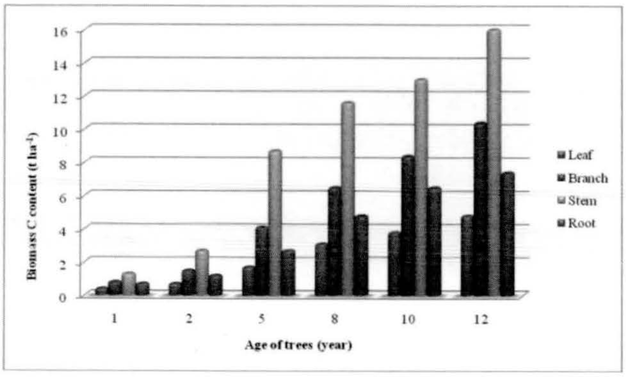

Fig. 5. Biomass carbon content (t ha^{-1}) of different tree components of kapok at different age group

It can be concluded within the limitations of the present study that 38.7 carbon per hectare could be stored by a kapok plantation in Theni district of Tamil Nadu of 12 years old kapok plantation.

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