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# Carbon Stock in Biomass of Important Plantations in the Southern Zone of Tamil Nadu, India

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**ABSTRACT**

Plantations are efficient sequesters of carbon and can mitigate the predicted rise in atmospheric $CO_2$ concentration and future climate change. Trees can capture atmospheric $CO_2$ through photosynthesis and store it in biomass with a turnover time of several decades. The present investigation was undertaken to study the carbon stock in biomass of important plantation species of clonal and seedling origin in the Southern agro-climatic zone of Tamil Nadu. The existing stands of three different ages of a tree plantation were selected from within the available plantations on farmlands, and data on girth and height were recorded for all the trees. The results revealed that the total carbon stocks (537.8 Mg $ha^{-1}$) was maximum under Eucalyptus clonal plantation of >6 years. Aboveground biomass was greater than belowground biomass, accounting for 79% of total biomass in *Casuarina* clonal plantation of > 5 years. Biomass carbon stock in Melia increased from 49.8 Mg C $ha^{-1}$ in 1 to 4 years plantation to 95.5 Mg C $ha^{-1}$ in >7 years old plantation. The findings explain the ability of clonal plantations of *Casuarina* and Eucalyptus in accumulating maximum biomass carbon stock.

***Key words:*** *Biomass, Plantations, Carbon stock*

## Introduction

Climate change has been at the center of various international agreements since the 1980s. India has committed to reducing total projected carbon emissions by up to 1 billion tons by 2030 apart from other ambitious climate change targets agreed upon in the recently held COP26 summit in Glasgow. Among different mitigation and adaption options available, trees can play a pivotal role in global carbon flux and help store huge quantities of carbon for a long period of time (Panwar *et al.,* 2022). Globally, plantations are being established at an increasing rate, and now account for 5% of the global forest cover. Also, plantations are efficient sequesters of carbon and can mitigate the predicted rise in atmospheric $CO_2$ concentration and future climate change (Zhang *et al.,* 2012). Biomass is an important carbon pool in forest ecosystems especially tree biomass, including the trunk, branches, foliage, and roots. Most of the total carbon in plantations is stored in aboveground biomass (trunk, branches, foliage) (Aholoukpe *et al.,* 2013). It has been suggested that atmospheric carbon sequestration through increasing the volume of plantation forest lands on the planet is an effective measure for mitigating atmo-

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spheric carbon dioxide (Taylor *et al.,* 2007; Banik *et al.,* 2018). Trees can capture atmospheric $CO_2$ through photosynthesis and store it in biomass with a turnover time of several decades. Thus, tree plantations play important roles in global C cycling and the uses of tree products can mediate various anthropogenic C releases (Dmitry *et al.,* 2007). Among the various carbon pools, vegetation carbon can be managed with relative ease to reduce atmospheric carbon concentrations. Multiple studies have shown that vegetation's carbon sinks potential could be significantly enhanced by adhering to sustainable forest management principles (Griscom *et al.,* 2017). Interest in biomass studies has increased globally due to its importance as a source of food, energy, and fibre (Wang *et al.,* 2020).

Tree species such as Eucalyptus, Casuarina, Teak, and Melia were selected for the present study, as they are planted on a large scale in India, particularly in Tamil Nadu for pulpwood production, timber, plywood veneer and other end uses and also they are well- accepted plantation species by tree growers. Information on the carbon sequestration potential of these plantations of clonal and seedling origin is not available, particularly in Tamil Nadu. By considering the above facts, the present project was undertaken to study the carbon stock in biomass of important plantation species of clonal and seedling origin in the Southern zone of Tamil Nadu.

## Materials and Methods

### Study area

The present study was carried out in the Southern agro-climatic zone of Tamil Nadu. The Southern zone is situated between 8° and 10° 55′ North latitude and 77° and 79° 50′ East longitude. The southern zone consists of Tirunelveli, Virudhunagar, Ramanathapuram, Thoothukudi, Sivagangai, Madurai (Tirumangalam, Madurai South, Madurai North and Melur taluks) and Dindigul (Natham and Dindigul taluks). The zone receives a mean annual rainfall is 876.4 mm. The maximum temperature ranges between 30.0° C and 37.5° C, while the range of minimum temperature is 20.0° C to 27.0° C. Predominant soil types occurring in this zone are black soil, red soil, deep red loam soil, red sandy soil, lateritic soil, river alluvium and saline coastal alluvium. The plantations selected for the study were Eucalyptus, Casuarina, Melia and Teak.

### Measurement of Biometric parameters

The existing stands of three different ages of a tree plantation were selected from the available plantations on farmlands, and data on girth and height were recorded for all the trees in randomly selected quadrates of 20 x 20 m size. Height of the trees was measured from the ground level to the terminal tip using the Laser Distance Meter and results were expressed in meter. The Girth at Breast Height was measured with a measuring tape at 1.37m aboveground level. Volume of the trees was calculated using the quarter girth formula as follows,

$V=(g/4)^2 x\ h$

Where, V is the volume ($m^3$), g the GBH (m) and h is the height of the tree (m).

### Aboveground biomass (AGB)

Biomass of trees was calculated by following non-destructive method. Calculated stem volume was converted to biomass by multiplying it with Biomass Expansion Factor (BEF) and wood density as per good practices guidelines provided by Intergovernmental Panel on Climate Change (IPCC, 2003) to obtain aboveground biomass (AGB).

AGB (t $ha^{-1}$)= Volume x Wood density x BEF

### Belowground biomass (BGB)

The Belowground biomass (BGB) was calculated by multiplying the AGB with IPCC default value of 0.26 (IPCC, 2003).

BGB (t $ha^{-1}$) = AGB x 0.26

### Total Biomass (TB)

This was estimated by adding the aboveground biomass and belowground biomass values.

TB (t $ha^{-1}$) = AGB + BGB

### Estimation of biomass carbon

The carbon sequestered was calculated by multiplying the total biomass by 0.47, which is again an IPCC default value

All statistical tests were performed with SPSS ® 19.0 version statistical software. One-way analysis of variance (ANOVA) was used to assess the biomass carbon. Duncan's test was performed to separate means if differences were significant (P=0.05).

## Results and Discussion

### Biomass and carbon storage in Eucalyptus plantation

The results of girth and height recorded in Eucalyptus plantations of seedling and clonal origin is presented in Table 1. GBH, height and volume varied significantly among the different plantations of seedling origin and clones. Mean GBH, height and volume were found to be 0.219 m, 10.23 m and 0.031 $m^3$ $tree^{-1}$, respectively in 1 to 2 years aged plantation, which reached up to 0.558m, 23.52m and 0.458 $m^3$ $tree^{-1}$ in >6 years old clonal plantation. Our results indicate that clonal plantations of Eucalyptus recorded highest mean GBH, height and volume. Similar results were reported by Srivastav *et al.* (2020) where significant variation among clones of *E. camaldulensis* for DBH at the age of 3 years was observed, The study results revealed that the maximum Aboveground biomass (870.7 Mg $ha^{-1}$), Belowground biomass (226.4 Mg $ha^{-1}$), and biomass carbon stock (515.6Mg C $ha^{-1}$), were recorded in the clonal plantation of >6 years, while minimum values of Aboveground biomass (58.5 Mg $ha^{-1}$), Belowground biomass (15.2 Mg $ha^{-1}$), and biomass carbon stock (34.6Mg C $ha^{-1}$) were recorded in seedling origin plantation of 1 to 2 years (Fig. 1). Among the different plantations of seedling and clonal origin studied, clonal plantations registered higher biomass carbon stock when compared to plantations of seedling origin. The variation in carbon stocks may be attributed to age class distribution (Arora *et al.,* 2014). Chaturvedi *et al.* (2016) stated that an average of 81.89 percent of the above-ground biomass is contributed by (stem, branch, leaves, and litter) and 18.11 percent from below-ground biomass (roots). Tree biomass constituted a major part of the biomass carbon pool and increased rapidly with plantation age in both the above and belowground biomass (Du *et al.,* 2015).

**Biomass and carbon storage in Casuarina plantation**

Growth parameters *viz,* Girth at Breast Height, height and volume increased markedly with stand age (Table 2). The data indicated that, Mean GBH, height and volume varied from 0.130 m, 9.07 m and 0.015 $m^3$ $tree^{-1}$ to 0.638 m, 22.07 m and 0.524 $m^3$ $tree^{-1}$ among the different Casuarina plantations

**Table 1.** Carbon stock in biomass (Mg C $ha^{-1}$) of Eucalyptus plantation in the Southern zone

| Plantation | Height (m) | GBH (m) | Volume ($m^3$ $tree^{-1}$) | AGB (Mg $ha^{-1}$) | BGB (Mg $ha^{-1}$) | Total Biomass (Mg $ha^{-1}$) | Biomass Carbon stock(Mg C $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| Eucalyptus -1 to 2 years | 10.23±0.09$^{a}$ | 0.219±0.0001$^{a}$ | 0.031±0.0001$^{a}$ | 58.5±1.52$^{a}$ | 15.2±0.39$^{a}$ | 73.7±1.91$^{a}$ | 34.6±0.89$^{a}$ |
| Eucalyptus -4 to 5 years | 15.00±0.17$^{c}$ | 0.381±0.006$^{c}$ | 0.136±0.003$^{b}$ | 258.4±7.49$^{b}$ | 67.2±1.94$^{b}$ | 325.6±9.44$^{b}$ | 153.0±4.43$^{b}$ |
| Eucalyptus - > 6 years | 20.93±0.18$^{e}$ | 0.5401±.006$^{e}$ | 0.412±0.01$^{d}$ | 783.1±19.2$^{d}$ | 203.6±4.98$^{d}$ | 986.7±24.2$^{d}$ | 463.7±11.4$^{d}$ |
| Eucalyptus clone –1 to 2 years | 12.54±0.11$^{b}$ | 0.255±0.003$^{b}$ | 0.051±0.0001$^{a}$ | 97.0±2.52$^{a}$ | 25.2±0.65$^{a}$ | 122.2±3.17$^{a}$ | 57.5±1.49$^{a}$ |
| Eucalyptus clone-4 to 5 years | 17.80±0.20$^{d}$ | 0.429±0.003$^{d}$ | 0.204±0.006$^{c}$ | 388.5±11.3$^{c}$ | 101.0±2.92$^{c}$ | 489.5±14.2$^{c}$ | 230.1±6.67$^{c}$ |
| Eucalyptus clone- >6 years | 23.52±0.21$^{f}$ | 0.558±0.006$^{f}$ | 0.458±0.01$^{e}$ | 870.7±22.9$^{e}$ | 226.4±5.97$^{e}$ | 1097.1±28.9$^{e}$ | 515.6±13.6$^{e}$ |

Values are mean ±SE; Means in a column followed by different lower case letters are significantly different at $P<0.05$

**Table 2.** Carbon stock in biomass (Mg C $ha^{-1}$) of Casuarina plantation in the Southern zone

| Plantation | Height (m) | GBH (m) | Volume ($m^3$ $tree^{-1}$) | AGB (Mg $ha^{-1}$) | BGB (Mg $ha^{-1}$) | Total Biomass (Mg $ha^{-1}$) | Biomass Carbon stock(Mg C $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| Casuarina -1 to 2 years | 14.45±0.13$^{b}$ | 0.130±0.0001$^{a}$ | 0.015±0.003$^{a}$ | 19.5±0.51$^{a}$ | 5.1±0.13$^{a}$ | 24.5±0.65$^{a}$ | 11.5±0.31$^{a}$ |
| Casuarina -3 to 5 years | 18.94±0.17$^{c}$ | 0.439±0.005$^{c}$ | 0.228±0.003$^{b}$ | 292.0±2.93$^{b}$ | 75.9±0.76$^{b}$ | 368.0±3.69$^{b}$ | 172.9±1.73$^{b}$ |
| Casuarina -> 5 years | 20.68±2.84$^{c}$ | 0.638±0.01$^{f}$ | 0.524±0.07$^{c}$ | 672.3±85.1$^{d}$ | 174.8±22.1$^{c}$ | 847.1±107.2$^{c}$ | 398.2±50.4$^{c}$ |
| Casuarina clone -1 to 2 years | 9.07±0.08$^{a}$ | 0.229±0.0001$^{b}$ | 0.030±0.0001$^{a}$ | 57.4±1.51$^{a}$ | 14.9±0.39$^{a}$ | 72.3±1.91$^{a}$ | 34.0±0.89$^{a}$ |
| Casuarina clone-3 to 5 years | 14.95±0.13$^{b}$ | 0.458±0.001$^{d}$ | 0.196±0.003$^{b}$ | 378.1±3.79$^{c}$ | 98.3±0.98$^{b}$ | 476.4±4.78$^{b}$ | 223.9±2.25$^{b}$ |
| Casuarina clone-> 5 years | 22.07±0.97$^{c}$ | 0.578±0.01$^{e}$ | 0.462±0.03$^{c}$ | 888.6±51.7$^{e}$ | 231.0±13.5$^{d}$ | 1119.6±65.2$^{d}$ | 526.2±30.6$^{d}$ |

Values are mean ±SE; Means in a column followed by different lower case letters are significantly different at $P<0.05$

of seedling and clonal origin. AGB, BGB, total biomass and biomass carbon stock varied significantly among the different plantations of seedling origin and clones (Fig.1). Aboveground Biomass values were 19.5, 292.0 and 672.3 Mg ha$^{-1}$ in 1 to 2 years, 3 to 5 years and > 5 years plantations of seedling origin. Biomass allocation pattern and carbon stock density of the tree layer showed overall higher biomass and carbon storage in clonal plantations of Casuarina compared to seedling origin. Aboveground biomass was greater than Belowground biomass, accounting for 79% of total biomass in Casuarina clonal plantation of > 5 years. The values are comparatively higher than the estimates of 25.94 MT C ha$^{-1}$ reported by Ravi *et al*. (2012).

**Biomass and carbon storage in Melia plantation**

The data on biomass and carbon storage in Melia plantation is given in Table 3. GBH, height and volume varied significantly among the different plantations of Melia. In one to four years old Melia plantation, the mean GBH, height and volume were 0.368 m, 10.47 m and 0.088 m$^3$ tree$^{-1}$, which reached up to 0.429 m. 14.75 m and 0.169 m$^3$ tree$^{-1}$ in >7 years old plantation. The present study revealed maximum GBH, height and volume in plantations of >7 years old. The aboveground biomass and belowground biomass values in >7 years old plantation were 161.2 Mg ha$^{-1}$ and 41.9 Mg ha$^{-1}$ with the aboveground biomass accounting for 79.3% of total biomass. Biomass carbon stock increased from 49.8 Mg C ha$^{-1}$ in 1 to 4 years plantation to 95.5 Mg C ha$^{-1}$ in >7 years old plantation (Fig.1). Carbon accumulated in the Melia plant biomass increased markedly with plantation age. The aboveground biomass and belowground biomass values in >7 years old plantation were

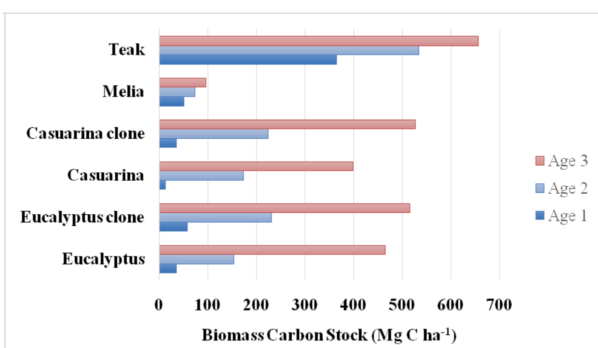


**Fig. 1.** Biomass Carbon Stock of different plantations of Southern zone

maximum with the aboveground biomass accounting for 79.3% of total biomass. The present estimates of total biomass and biomass carbon stock in Melia plantation, however, fall within the range of those reported by Singh *et al.* (2022).

**Biomass and carbon storage in Teak plantation**

Growth parameters *viz,* Girth at Breast Height, height and volume and carbon stock in biomass are summarized in Table 4. Girth at Breast Height, height and volume significantly differed with stand age. Mean GBH, height and volume were found to be 0.887 m, 16.45 m and 0.809 m$^3$ tree$^{-1}$, respectively in 5 to 10 years aged plantation, which reached up to 1.093m, 19.51m and 1.453 m$^3$ tree$^{-1}$ in >15 years old teak plantation. In the present study, maximum biomass carbon stock of 656.1 Mg C ha$^{-1}$was registered in teak plantations of >15 years (Fig. 1), which was twice the amount stored in plantation of 5 to 10 years (365.0 Mg C ha$^{-1}$). In the present study, maximum biomass carbon stock was accumulated in teak plantations of >15 years, while plantation of 5 to 10 years old recorded minimum biomass carbon stock. The present estimates of total biomass and biomass carbon stock in Teak plantation, however, fall within the range (223.7 t/ha and 111.86 t/ha) of those reported by Behera and Mohapatra, (2015).

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**Table 3.** Carbon stock in biomass (Mg C ha$^{-1}$) of Melia plantation in the Southern zone

| Plantation | Height (m) | GBH (m) | Volume ($m^3$ tree$^{-1}$) | AGB (Mg ha$^{-1}$) | BGB (Mg ha$^{-1}$) | Total Biomass (Mg ha$^{-1}$) | Biomass Carbon stock (Mg C ha$^{-1}$) |
|---|---|---|---|---|---|---|---|
| Melia -1 to 4 years | 10.47±0.09 $^a$ | 0.368±0.004 $^a$ | 0.088±0.001 $^a$ | 84.1±3.73 $^a$ | 21.9±0.97 $^a$ | 105.9±4.73 $^a$ | 49.8±2.22 $^a$ |
| Melia -5 to 7 years | 12.96±0.11 $^b$ | 0.400±0.01 $^b$ | 0.130±0.001 $^b$ | 123.4±6.24 $^b$ | 32.1±1.62 $^b$ | 155.5±7.87 $^b$ | 73.1±3.69 $^b$ |

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**Conflict of interest**

The authors do not have any conflict of interest to declare.

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