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Growth and carbon stock assessment in three year old fast growing trees grown under wasteland condition at Sivagangai district of Southern Tamil Nadu

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ABSTRACT : A field experiment was conducted to assess the growth and carbon sequestration potential of five fast growing trees namely *Tectona grandis*, *Gmelina arborea*, *Dalbergia sissoo*, *Bambusa vulgaris* var. *vulgaris* and *Swietenia macrophylla*. The saplings of these five species were planted and assessed for biometric, biomass production and carbon accumulation potential. Among the five tree species, *Dalbergia sissoo* and *Bambusa vulgaris* var. *vulgaris* were found to be superior interms of maximum height, basal diameter, biomass and biomass carbon. *Gmelina arborea* exhibited low height, basal diameter, biomass and biomass carbon. The per cent contribution of biomass carbon was higher in the stems of all the species followed by root, branches and leaves. The field study inferred that, *Dalbergia sissoo* and *Bambusa vulgaris* var. *vulgaris* performed well with higher biomass and biomass carbon productivity under dry land condition and hence these two species can be promoted for afforestation / reforestation of the wastelands in Tamil Nadu under protected irrigation conditions.

KEY WORDS : Fast growing trees, Wasteland, Growth performance, Carbon stock assessment

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INTRODUCTION

The intergovernmental panel on climate change (IPCC) ascertained that the pre industrial level of carbon in the atmosphere raised from 285 ppm to the current level of 398.29 ppm (NOAA, 2015). The increase of CO_2 in the atmosphere implies the changing scenario of climate and its effect on annual and perennials crop diversity. Removal of greenhouse gases from the atmosphere through sinks (*i.e.* trees and soil) is one way of addressing climate change. In the wake of global efforts to address climate change, considerable interest has been generated about carbon sequestration potential of trees. Tree plantations are being considered as a mitigation option to reduce atmospheric CO_2 and climate change (Kraenzel *et al*., 2003).

Global forest stores approximately about 800 billion tons of carbon in trees and forest soil. Agroforestry can

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be a better climate change mitigation option, in addition it will also accrue the secondary environmental benefits such as food security, secured land tenure, increased farm income, restoration and maintenance of above ground and below ground biodiversity. The tree components in agroforestry systems act as a significant sink of atmospheric carbon due to the problems related with land use and global warming by its structure and function (Albrecht and Kandji, 2003). Soil organic carbon being the largest terrestrial carbon pool plays a significant role in global terrestrial ecosystem and carbon balance.

The largest potential for carbon sequestration through trees is vested in subtropical and tropical regions (Watson *et al*., 2000) and there exist variation in per cent carbon in different tree species and among tree parts within a tree. The biomass and carbon content estimation for each species as well as each tree component is need to be documented (Lamlom and Savidge, 2003). Most studies, however, have focused on total aboveground biomass and carbon storage, whereas discrimination among the different parts of the tree, wood types and stocking densities by age is rarely done.

The present study aimed to characterize the growth, partitioning of biomass, carbon content in different parts of trees like stem, branches, leaves and roots. This could provide new information to improve the accuracy in the estimation of aboveground biomass and total carbon content for assessing the contribution of these species towards the increasing ecosystem service of carbon fixation and storage (Redondo and Montagnini,2006 and Redondo, 2007).

EXPERIMENTAL METHODS

Study area and planting material :

The study was conducted between 2009 - 2013 at Nattarasankottai Village, Sivaganga district in Tamil Nadu that lies between N $9^0$52'13.37'' and E $78^0$33'06.80''. The vegetation of the study area was shrubby grassland which was a typical wasteland lying fallow for decades together. The soil was red sandy clay type with the pH of 5.35-5.75 and electrical conductivity with 0.11 dS m^{-1}. The soil nutrient status was very low in available nitrogen (157-185 kg ha^{-1}), medium in available phosphorus (25-27 kg ha^{-1}) and high in available potassium (320-350 kg ha^{-1}). The mean annual rainfall was 400-600 mm and the mean annual temperature was 35^0C during winter and 42-45^0C during summer.

The native vegetation existed in the study area was removed and the tree species namely teak (*Tectona grandis* Linn. f), Gmelina (*Gmelina arborea* Roxb.), Sissoo (*Dalbergia sissoo* Roxb.), green bamboo (*Bambusa vulgaris* var. *vulgaris* Schrad exWendle.) and large leaf mahogany (*Swietenia macrophylla* King)were planted in Randomized Block Design with four replication (20 plants per replication). The spacing adopted was 2.5 m x 2.5 m for all the five species with a plant density of 1600 plants/ha. Biometric observations namely height and basal diameter were recorded once in every three months.

Estimation of biomass :

The above and below ground biomass estimation was carried out by destructive sampling method. Three trees were selected in each replication for all five tree species and felled at ground level using a mechanical chain saw. The above ground biomass and below ground biomass were separated into root, stem, branches and leaves. Fresh weights of all the above ground tree components were recorded immediately after felling by using spring scales in the field itself.

A small sample (500 g) of stem, branches and leaves were immediately transported to the laboratory in double sealed polythene bags. The collected samples were dried at 80^0C in hot air oven till constant weight was obtained. From the oven dried weight, carbon content in the tree biomass was analysed through laboratory technique (Lasco *et al*., 2005).

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

where,

ODW = Total oven dry weight
TFW = Total fresh weight
SFW = Sample fresh weight
SODW= Sample oven dry weight.

Estimation of carbon :

The components of trees *viz*., stem, branches, leaves and roots of the trees species were collected separately, air dried and oven dried. Oven dried biomass samples were grounded in Willey Mill and carbon concentration in different tree components were determined based on the ash content (Allen *et al.,* 1986) using the following formula.

$$\textbf{Ash\%} = \frac{(W_3 - W_1)}{(W_3 - W_1)} \times 100$$

where,

W_1 = Weight of crucibles

W_2 = Weight of oven dried powdered samples + crucibles

W_3 = Weight of ash + crucibles.

Carbon per cent in above ground biomass (AGB), below ground biomass (BGB), litter and dead organic matter was estimated by using the formula given by Dey (2005) and Dhruw *et al*. (2009).

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

The carbon stock in the above ground biomass, below ground biomass, litter and dead organic matter was computed by using the formula given below.

Carbon (MT) = Biomass (MT) x Carbon per cent

Percentage of organic carbon using the above procedure was estimated for all samples of fractionated biomass *viz*., leaf, stem, branch and root. Using the carbon per cent value, the above ground organic biomass carbon (t ha^{-1}), below ground organic biomass carbon (t ha^{-1}) and total organic biomass carbon (t ha^{-1}) were calculated for individual species on per hectare basis.

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

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

BGB carbon (t C ha^{-1}) = Components of below ground biomass (t ha^{-1}) x Carbon content (%)

Total biomass carbon stock (t C ha^{-1}) = AGB carbon + BGB carbon

Statistical analysis :

The data obtained were subjected for statistical analysis to evaluate the possible relationship between the different parameters and analysis of variance employing statistical methods described by Panse and Sukhatme (1985).

EXPERIMENTAL RESULTS AND ANALYSIS

The results obtained from the present investigation as well as relevant discussion have been summarized under the following heads :

Tree growth performance :

Among the tree species planted, the observation on 36 MAP revealed that *Dalbergia sissoo* exhibited maximum height (4.55 m), basal diameter (6.82 cm), number of branches per plant (15.30) and root length (219.24 cm) followed by *Bambusa vulgaris* var. *vulgaris* with height (4.14 m), basal diameter (4.09 cm) and number of culms per plant (14.12). The minimum height (1.64 m) and basal diameter (3.04 cm) were recorded in *Gmelina arborea* and least number of branches per plant (3.50) in *Swietenia macrophylla*. Though *Bambusa vulgaris* var. *vulgaris* registered a second best height and basal diameter, the root length (73.20 cm) was minimal due to its fibrous nature of root system (Table 1). Similar result in *Acacia mangium* with mean height of 5.0 m in 3 years and 6.0 m in 5 years were registered in Indonesia (Ilyas, 2013), and *Bambusa vulgaris* var. *vulgaris* was also shown good height of 2.25 m and basal diameter of 1.72 cm in Sivgangai, Tamil Nadu (Babu, 2012).

The good growth rate of *Dalbergia sissoo* under sodic soil indicated its suitability to hostile environments (Goel and Singh, 2008). The growth of *Dalbergia sissoo* was also attributed to its root spread and root growth with maximum root distribution (82.7 %) within one meter depth (Chauhan *et al.*, 2009).

Above and below ground biomass :

The fractionation of biomass in plant parts revealed

Table 1 : The growth potential of three year old tree seedlings under dryland condition

Name of tree species	Height (m)	Basal diameter (cm)	No. of branches (No's)	Root length (cm)
Tectona grandis	2.40	5.15	5.07	102.03
Gmelina arborea	1.64	3.04	4.55	82.05
Dalbergia sissoo	4.55	6.82	15.30	219.24
Bambusa vulgaris var. *vulgaris*	4.14	4.09	14.12	73.20
Swietenia macrophylla	1.87	3.69	3.50	106.66
S.E.±	0.38	0.62	0.63	0.91
C.D. (P=0.05)	0.84	1.35	1.38	1.99

that, the highest leaf biomass (2008.13 kg ha^{-1}) was registered in *Dalbergia sissoo* followed by *Bambusa vulgaris* var. *vulgaris* (1473.48 kg ha^{-1}), *Tectona grandis* (590.41 kg ha^{-1}) and *Swietenia macrophylla* (576.99 kg ha^{-1}). The lowest leaf biomass (233.72 kg ha^{-1}) was observed in *Gmelina arborea*. The highest (3227.14 kg ha^{-1}) and lowest (231.37 kg ha^{-1}) biomass branches were recorded in *Dalbergia sissoo* and *Tectona grandis*, respectively. The main stem biomass was maximum in *Dalbergia sissoo* (5897.46 kg ha^{-1}) followed by *Bambusa vulgaris* var. *vulgaris* (4253.97 kg ha^{-1}) and lowest stem biomass (634.05 kg ha^{-1}) was observed in *Gmelina arborea*. *Dalbergia sissoo* accumulated highest total biomass (14970.82 kg ha^{-1}) followed by *Bambusa vulgaris* var. *vulgaris* (9611.58 kg ha^{-1}) and the least total biomass were observed in *Gmelina arborea* of (1799.13 kg ha^{-1}). The lowest root biomass was accounted in *Swietenia macrophylla* (499.34 kg ha^{-1}) and the highest root biomass (3838.09 kg ha^{-1}) was recorded by *Dalbergia sissoo* (Table 2).

Adaptability trait of *Dalbergia sissoo* in semi arid climate and sodic condition was performed well in growth of coppice. Similarly, highest above ground biomass of 13.52 m ha^{-1} at the age of 5 years with a maximum segmented part of stem wood followed by branch wood and leaf was reported in *Dalbergia sissoo* (Goel and Singh, 2008), *Tectona grandis* (Dhruw *et al*., 2009) in Uttar Pradesh in India. The root biomass measurement and the relation between both biomass density and root: shoot ratios are dependent variables as the edaphic and climatic factors are independent variables (Cairns *et al.*, 1997).

Carbon measurement :

Among the fractionated tree components, leaf carbon content was highest in *Gmelina arborea* (42.00 %) and lowest leaf carbon content in *Swietenia macrophylla* (38.47 %). The branch (44.90 %) and stem (45.89 %) parts of *Dalbergia sissoo* recorded highest carbon content and lowest carbon content in branch (40.68 %) and stem (43.77 %) was recorded in *Gmelina arborea* and *Swietenia macrophylla*, respectively. In root component, *Swietenia macrophylla* exhibited the highest carbon content (43.24 %) and *Bambusa vulgaris* var. *vulgaris* registered lowest carbon content (40.85 %). On an average, the carbon content in tree parts was in the order of stem > root > branches > leaf. The *Dalbergia sissoo* recorded highest biomass carbon

Table 2 : Above ground biomass (AGB) and below ground biomass (BGB) and total biomass contribution of tree compartments in tree species at age of 3 years

Name of tree species	Above ground biomass			Below ground biomass	Total
	Leaf	Branch	Stem	Root	
Tectona grandis	590.41	231.37	1068.97	717.54	2608.29
Gmelina arborea	233.72	430.24	634.05	501.12	1799.13
Dalbergia sissoo	2008.13	3227.14	5897.46	3838.09	14970.82
Bambusa vulgaris var. *vulgaris*	1473.48	1429.06	4253.97	2455.07	9611.58
Swietenia macrophylla	576.99	534.49	1566.48	499.34	3177.30
S.E.±	1.62	1.25	2.61	2.33	3.38
C.D.(P=0.05)	3.54	2.72	5.69	5.08	7.38

Table 3: Carbon concentration (%) and biomass carbon content (kilogram/hectare) in tree components of different tree species (3 years old)

Name of tree species	Leaf		Branch		Stem		Root		Total
	%	t/ha	%	t/ha	%	t/ha	%	t/ha	
Tectona grandis	40.84	241.14	42.56	98.47	44.72	478.07	42.96	308.31	1125.99
Gmelina arborea	42.00	98.18	40.58	175.04	44.82	284.22	42.77	214.36	771.80
Dalbergia sissoo	40.42	811.68	44.90	1432.85	45.89	2706.70	42.79	1642.32	6593.55
Bambusa vulgaris var. *vulgaris*	38.61	568.96	44.45	635.22	43.98	1870.94	40.85	1003.75	4078.87
Swietenia macrophylla	38.47	221.98	41.35	221.04	43.77	685.64	43.24	215.95	1344.61
S.E.±	0.12	0.75	0.30	1.56	0.35	1.97	0.33	1.87	4.84
C.D.(P=0.05)	0.27	0.64	0.66	3.41	0.77	4.29	0.73	4.08	10.58

content in all fractionated tree components, leaf (811.68 kg ha^{-1}), branch (1432.85 kg ha^{-1}), stem (2706.70 kg ha^{-1}) and root (1642.32 kg ha^{-1}). Whereas, *Gmelina arborea* recorded the lowest biomass carbon content in leaf (98.18 kg ha^{-1}), stem (284.22 kg ha^{-1}) and root (214.36 kg ha^{-1}). *Tectona grandis* recorded least biomass carbon content (98.47 kg ha^{-1}) in its branches (Table 3). Dhruw *et al.* (2009) reported that *Dalbergia sissoo* found to contain more biomass carbon in stem than root, branch and leaf. Nath *et al.* (2009) also observed that *Bambusa vulgaris* var. *vulgaris* recorded high carbon per cent in culms than branch and leaf.

Biomass carbon by stem is higher in all the species followed by root, branches and leaf. In stem the maximum per cent of biomass carbon was in *Swietenia macrophylla* (50.99 %) and lowest was recorded in *Gmelina arborea* (36.83 %). Similar ranking order was observed in leaf and branch biomass carbon contribution per cent (Table 4). In the contrary to the above result biomass carbon per cent in root was more in *Gmelina arborea* of 27.77 per cent followed by *Tectona grandis* (27.38 %), *Dalbergia sissoo* (24.91 %), *Bambusa vulgaris var. vulgaris* (24.61 %) and lowest in *Swietenia macrophylla* (16.06 %).

Resource allocation into tree components is of fundamental importance in understanding the adaptive strategies of trees to different physiological condition. In trees, leaves are considered to be primary portion for the basic physiological activities (Photosynthesis, transpiration and stomatal conductance). Leaves helps in synthesizing the food molecules (Biomass) by physiological process in trees. The leaf shape, leaf size is contributing an important phenomenon in trees productivity and carbon accumulation. The highest biomass in tree component was contributed by stem as it attributed towards growth due to accumulation of photosynthesis effect and that leads to storage of sugar molecules into wood components by hardening tissue by ageing of trees. Likewise the tree branches supports the tree crown by extending its robust branches with foliage, which gives shape of tree by accumulating more biomass food storage into branches. Root systems of plants are the interface between plant and soil and thus gain central importance for the long-term, sustainable functioning of forestry/agroforestry systems (Chauhan *et al.,* 2009). Similarly, the above ground parameters, canopy structure, leaf phenology, stem straightness, etc. of trees also improve soil characteristics, increase productivity and modify micro-climate. The root spread in the below ground leads to a replicate of the crown and stem size in the tree. The roots are important in providing water and minerals and also providing physical support for the tree by storing the root biomass in highest proportion with highest contribution of carbon content than leaves and branches.

Conclusion :

The result of this study inferred that growth, biomass and biomass carbon was high in *Dalbergia sissoo* followed by *Bambusa vulgaris* var. *vulgaris* and *Swietenia macrophylla*. Hence, these three tree species can be promoted as suitable species for large scale afforestation programme in dryland with minimum intervention of protected irrigation. The other two species taken in this study, *Tectona grandis* and *Gmelina arborea* are not able to perform well in the prevailing dry climatic and poor edaphic conditions in terms of growth, biomass and carbon accumulation.

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Table 4 : Distribution of biomass carbon in tree compartments of tree year old trees

Name of tree species	Leaf	Branch	Stem	Root
Tectona grandis	21.41	8.75	42.46	27.38
Gmelina arborea	12.72	22.68	36.83	27.77
Dalbergia sissoo	12.31	21.73	41.05	24.91
Bambusa vulgaris var. *vulgaris*	13.95	15.57	45.87	24.61
Swietenia macrophylla	16.51	16.44	50.99	16.06

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