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CARBON SEQUESTRATION POTENTIAL OF RED SANDER (*PTEROCARPUS SANTALINUS*) PLANTATIONS UNDER DIFFERENT AGES IN VELLORE AND THIRUVALLUR DISTRICTS OF TAMIL NADU

SEWA SINGH
I.F.S.,
ADDITIONAL PRINCIPAL CHIEF CONSERVATOR OF FORESTS, VELLORE CIRCLE,
TAMIL NADU, INDIA.
Corresponding author's e-mail: singh_seva@yahoo.com

ABSTRACT:

The study was conducted during 2020 at Vellore and Thiruvallur districts of Tamil Nadu that lies between 12°15' and 13° 15' of the northern latitude and 78° 20' and 79° 15' of the eastern longitude. The soil was red loamy soil and sandy Loamy with the pH of 6.3 to 8.2 and electrical conductivity with 0.08 to 0.80 dSm^{-1}. Red sanders (*Pterocarpus santalinus*) plantation at different age groups, *viz*., 10, 20, 30, 40, 50 and 60 were selected for estimation of carbon sequestration potential. Totally 16 sample plots with the plot size of 0.1 ha (31.62 m X 31.62 m) were laid out in 6 different age group of Red sanders plantation for assessing the biometric attributes, volume, biomass and biomass carbon through Non-destructive sampling method. Among the 6 age group, 60-year-old exhibited the maximum biomass (1186.30 kg/tree and 628.74 tonnes/hectare) and biomass carbon content (557.56 kg. /tree and 295.51 tonnes/hectare) followed by 50-year-old plantation and minimum was recorded in 10-year-old Red Sanders plantation. Due to its high density content, Red sanders tree is considered as suitable for high carbon storage from atmosphere through photosynthesis mechanism. Even though, it's a tree with high value utility and commercial importance, it can also have the

maximum potential in carbon sequestration.

KEY WORDS: *Red sanders, Carbon sequestration, Biomass, Non-destructive sampling, Age-class.*

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 414.11 ppm (NOAA, 2020), which is highest over 8,00,000 years. The increase of CO_2 in the atmosphere implies the changing scenario of climate and its effect on human, animal and crop diversity of world. Among the UN countries, China is the world's largest CO_2 emitter with accounting more than one-quarter of emissions, which eventually followed by the United States of America (15 %), European Union - 28 (10 %), India (7 %) and Russia (5%). The adverse effect due to climate change is changing in weather patterns (Leads to floods, droughts, storms and heat waves), increases the sea level, ecological, physical and health impacts in humans and animal system.

Removal of greenhouse gases (Especially CO_2) 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). Forest carbon sequestration is the process of increasing the carbon content of forest through processes that remove carbon dioxide from the atmosphere (i.e. Photosynthesis). Carbon sequestration techniques helped in transforming atmospheric carbon dioxide into biomass and thus decreasing the amount of greenhouse gases in Earth's atmosphere. According to Global Forest Assessment Report (FAO, 2010), the total forest carbon stock of the world is 652 Giga tonnes (161.80 t/ha), out of this, the forest tree biomass contains 289 Giga tonnes (71.60 t/ha). In India, carbon stock is estimated as 7,124.60 million tonnes, with an increase of 42.60 million tonnes of carbon stock of the country as compared to the last assessment of ISFR, 2017 (ISFR report, 2019). In Tamil Nadu, the total carbon stock of forests including the TOF is 216.78 million tonnes (CO equivalent of 794.86 million tonnes), which contributes nearly 3.00 per cent of total forest carbon of the country. 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.

Pterocarpus santalinus (Red Sanders) is so narrowly endemic species confined to Southern parts of Eastern Ghats of India especially in Andhra Pradesh. It is also found partly distributed in Vellore and Chengalpattu districts of Tamil Nadu and also in Karnataka (GOI, 2014). The wood

and wood products of Red Sanders continue to be in high demand and are traded internationally in large volumes that find use in the musical instruments, furniture, handicrafts, cosmetics, medicine and food industry. Over exploitation without commensurate replenishment of natural stands and illegal logging has posed a severe threat to the very existence of this precious timber species and classified as globally threatened in the IUCN Red List. A high density wood species with the specific gravity about 0.77 - 1.05 g/cm3 lead to sequestrate more carbon from the atmosphere through photosynthesis. Hence, this species gains more attention and plays a vital role in conserving the natural ecosystem by accumulating more carbon in the form of wood.

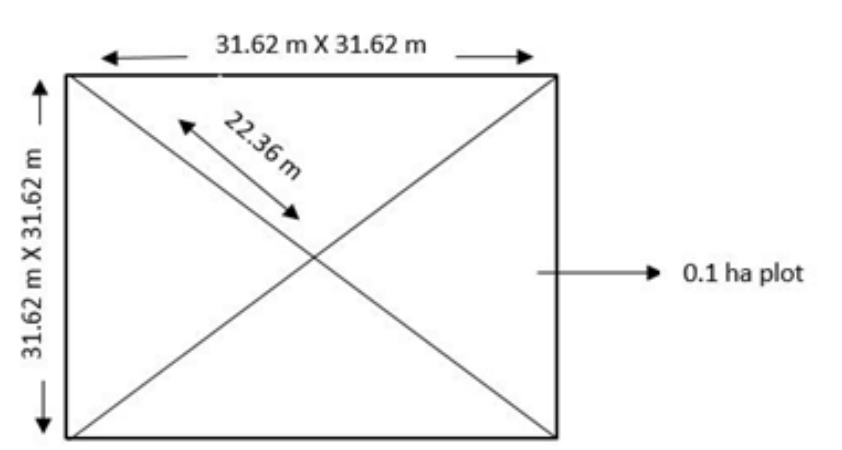
It is rare to found studies related to the biomass and carbon sequestration estimation in Red sanders (*Pterocarpus santalinus*). Hence, this study aimed to characterize the growth, partitioning of biomass, carbon content through non-destructive method in Red sanders. This could provide new information 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; Redondo, 2007).

MATERIALS AND METHODS:

The study was conducted during 2020 at Vellore and Thiruvallur districts of Tamil Nadu that lies between 12°15’ and 13° 15’ of the northern latitude and 78° 20’ and 79° 15’ of the eastern longitude. The soil was red loamy soil and sandy Loamy with the pH of 6.3 to 8.2 and electrical conductivity with 0.08 to 0.80 dS m^{-1}. The soil nutrient status was low to medium in available nitrogen (150-365 kg ha^{-1}), high in available phosphorus and high in available potassium (320-350 kg ha^{-1}). The mean annual rainfall was 800 - 920 mm and the mean annual temperature was 30-35°C during winter and 42-45°C during summer. Palar River is the major river draining the district, flowing towards east for a distance of about 295 km, which runs parallel to the hill ranges of the Eastern Ghats for a major part of its course.

Red Sanders (*Pterocarpus santalinus*) plantation at different age groups, *viz.*, 10, 20, 30, 40, 50 and 60 were selected at Vellore and Thiruvallur districts. The GPS Co-ordinates (Latitude and Longitude) of the different age groups with the study site is tabulated in Table 1.

Totally 16 sample plots with the plot size of 0.1 ha (31.62 m X 31.62 m) were laid out in 6 age groups of Red sanders plantation for assessing the volume and carbon sequestration potential. Red sanders plantations of 6 age groups were laid with the spacing of 4m x 4m with a tree density of 620 Nos. per hectare. The estimation of carbon sequestration in Red sanders is carried out by Non-destructive sampling method. The biometric attributes, *viz.*, height (m) and girth (cm) at breast height (1.37m) of standing tree in sample plot was measured using Blume-leiss altimeter and measuring tape.



The procedure adopted to assess the carbon sequestration of trees is volume estimation of trees and biomass and biomass carbon through non-destructive method.

A) Volume estimation

The volume of trees was estimated using the formula given by Chaturvedi and Khanna, (1982) and expressed in m^3.

$$V = \pi r^2 h \text{ X Form Factor}$$

Where, V= Volume, r = Radius, h = Total height

B) Biomass and biomass carbon content

The biomass of the trees estimated using non-destructive sampling method. The biomass of the trees, *viz.*, above ground biomass, below ground biomass and total biomass was calculated by the methodology given by Pandya et al. (2013).

i) Above Ground Biomass (AGB)

The above ground biomass of the tree species was estimated using non- destructive sampling method. In order to estimate the above ground biomass of the trees, the volume of the standing trees was measured and wood density of Red Sanders was calculated between 0.77 to 1.05 g/cm^3.

$$\text{AGB (kg/tree)} = \text{Volume of tree } (m^3) \text{ x Wood density } (kg/m^3)$$

ii) Below ground biomass (BGB)

The below ground biomass were calculated by multiplying above ground biomass by 0.26 factors as the root: shoot ratio.

$$\text{Below Ground Biomass (kg. /tree)} = \text{AGB (kg/tree)} \times 0.26$$

iii) Total biomass

Total biomass of trees was calculated by addition of both above ground and below ground biomass.

Total Biomass (kg. /tree) = AGB + BGB

iv) Biomass carbon estimation

The biomass carbon content of Red sanders was calculated by utilizing the arithmetic value of biomass. The formula for calculating biomass carbon in Red sanders plantation was given by Manickam et al. (2014).

Carbon Storage = Biomass / 0.47 per cent

The experimental data were subjected to statistical analysis for the possible relationship between the different parameters and analysis of variance employing randomized block design as described by Panse and Sukhatme (1985). The data were analyzed using AGRES software developed by Tamil Nadu Agricultural University (TNAU) Coimbatore. The data on every parameter were analyzed separately in single factor analysis, using AGRES software. Then the values of critical difference (CD) at 0.05 and standard error deviation (SEd) were given in the respective tables.

RESULTS AND DISCUSSION:

Carbon sequestration is a natural method for the removal of carbon from the atmosphere by storing it in the biosphere (Chavan and Rasal 2010). A carbon sink absorbs CO_2 from the atmosphere and stores it as carbon. Trees serve as a sink for CO2 by fixing carbon during photosynthesis and storing excess carbon as biomass. As more photosynthesis occurs, more CO_2 is converted into biomass by reducing carbon in the atmosphere and sequestering it in plant tissues as above and below ground (IPCC 2003, Gorte 2009) by resulting in the growth of different parts (Chavan and Rasal 2010).

A scientific estimation of carbon sequestration potential in Redsanders at different age groups, viz., 10, 20, 30, 40, 50 and 60 were analysed at Vellore and Thiruvallur district of Tamil Nadu was taking up biometric attributes namely height and diameter at breast height (DBH) measurements followed by estimation of volume. Among the 6 age groups, the maximum height of 13.84 m, DBH of 0.32 m and volume of 0.896 m^3 was recorded in 60-year-old plantation followed by 50-year-old plantation with the height of 13.37 m, DBH of 0.32 m and volume of 0.801 m^3. The minimum height (6.56 m), diameter at breast height (0.11 m) and volume (0.062 m^3) were recorded in 20-year-old Red sanders plantation at Nemalur (Thiruvallur district) of Tamil Nadu. The findings of Ramabrahmam and Sujatha (2016) reported that Redsanders is a light-demanding moderate sized tree growing up to 8 m tall with a trunk of 50–150 cm diameter and it is also fast-growing in nature during young, which normally reaches height of 5 m tall in three years even on degraded soils. The result of Ilyas (2013) reported that *Acacia mangium* with mean height of 5.0 m in 3 years and 6.0 m in 5 years were registered at Indonesia. The good growth rate of *Dalbergia*

sissoo under red sandy clay soil indicated its suitability to higher temperature environment with height of 5m in three years at Sivagangai district of Tamil Nadu (Hari Prasath et al., 2016).

Biomass in Red Sanders plantation (Per tree and hectare)

In the study, carbon sequestration was estimated in 6 age groups of Red sanders plantation with the total biomass (Including above ground and below ground biomass) and biomass carbon in Vellore and Thiruvallur district of Tamil Nadu. The biomass and biomass carbon was calculated per tree as well as tonnes per hectare. Among the 6 age groups, the maximum biomass was recorded in 60-year-old with the value of 1186.30 kg. /tree and 628.74 tonnes/hectare. The second maximum biomass (1060.57 kg. /tree and 572.71 tonnes/hectare) was exhibited in 50-year-old plantation and the minimum amount of biomass was recorded in 10-year-old plantation with the value of 48.87 kg. /tree and 30.30 tonnes/hectare. It is also interesting to note that, the Red sanders (*Pterocarpus santalinus*) is a high density wood with the maximum amount of carbon storage as the dead materials, which eventually help in sequestering maximum carbon di-oxide from the atmosphere.

On supporting the present study, Hari Prasath et al. (2016) reported that the biomass carbon (Above ground and below ground biomass) was increase with the increase in age of the plantation, this was due to the growth increment of the plantation at Southern part of Tamil Nadu, India. He also reported that in red sandy clay soil the tree species namely *Dalbergia sissoo* and Bamboo has shown increase in biomass of tree, when compared with the *Gmelina arborea* and Teak in three years at Sivagangai district of Tamil Nadu. The highest biomass of 13.52 m ha^{-1} at the age of 5 years was reported in *Dalbergia sissoo* (Goel and Singh, 2008), *Tectona grandis* (Dhruw *et al*., 2009) in Uttar Pradesh in India.

Biomass carbon in Red sanders plantation (per tree and hectare)

Resource allocation of the biomass and biomass carbon 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) that help in storing of maximum carbon materials as dead component in the wood. The leaf shape, leaf size is contributing an important phenomenon in trees productivity and carbon accumulation (Hari Prasath et al., 2016).

Biomass carbon was recorded highest in 60-year-old Red sanders plantation with the value of 557.56 kg. /tree and 295.51 tonnes/hectare followed by 50-year-old plantation with the biomass carbon content of 498.47 kg/tree and 269.17 tonnes/hectare and lowest biomass carbon (22.97 kg/tree and 14.24 tonnes/hectare) was exhibited in 10-year-old plantation. 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 support 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, 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 Dhruw et al. (2009).

CONCLUSION:

Red sanders (*Pterocarpus santalinus*) is a highly endangered and endemic species of Andhra Pradesh and Tamil Nadu with the high value utility in National and International markets. Due to its commercial value, these species was listed under Red List category. This species is with high density with the capacity of storing maximum amount of carbon in wood, which help in sequestering maximum carbon di-oxide from the atmosphere. On concluding the study, Red sanders is not only a species of commercial importance but also a potential tree species in environmental protection through carbon storage from atmosphere.

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Table 1. GPS Co-ordinates of Red sanders plantation at different age groups in Vellore and Thiruvallur districts of Tamil Nadu

Age Group	Study Site	Plot Number	GPS Co-ordinates		Altitude (MSL)
			Latitude	**Longitude**	
10	Senoor (Vellore)	1	N 12.97079	E 079.10236	226
		2	N 12.97098	E 079.10324	217
20	Nemalur (Thiruvallur)	1	N 13.41790	E 080.00155	30
		2	N 13.41756	E 080.00181	29
30	Pachamalai (Vellore)	1	N 12.68040	E 079.38992	118
		2	N 12.56559	E 079.12329	185
40	Thagarakuppam (Vellore)	1	N 13.03955	E 079.31401	214
		2	N 13.03815	E 079.31512	229
	Kanniyambadi (Vellore)	1	N 12.7782	E 079.13526	240
		2	N 12.77074	E 079.12577	243
50	Mampakkam (Vellore)	1	N 12.68082	E 079.38650	129
		2	N 12.68043	E 079.38994	120
60	Pulivalam (Vellore)	1	N 12.77090	E 079.12547	223
		2	N 13.06943	E 079.44279	143
	G.C. Kuppum (Vellore)	1	N 13.02872	E 079.43718	152
		2	N 13.02364	E 079.43742	83

Table 2. Biometric attributes and biomass carbon content of Red Sanders (*Pterocarpus santalinus*) under different age groups in Vellore and Thiruvallur districts

Sl. No.	Age Group	Height (m)	Diameter (m)	Volume (m^3)	Average Biomass (kg. $tree^{-1}$)	Average Biomass Carbon (kg. $tree^{-1}$)
1	10	7.78^{d}	0.10^{e}	0.050^{e}	48.87^{e}	22.97^{e}
2	20	6.56^{e}	0.11^{d}	0.062^{e}	60.34^{e}	28.36^{e}
3	30	12.73^{c}	0.11^{d}	0.501^{d}	486.96^{d}	228.87^{d}
4	40	13.09^{bc}	0.26^{c}	0.595^{c}	788.17^{c}	370.44^{c}
5	50	13.31^{b}	0.28^{b}	0.801^{b}	1060.57^{b}	498.47^{b}
6	60	13.84^{a}	0.32^{a}	0.896^{a}	1186.30^{a}	557.56^{a}
SE(d)		0.206	0.003	0.004	11.243	5.523
CD (0.05%)		0.440	0.006	0.007	23.964	11.773

Table 3. Biomass and biomass carbon content (tonnes ha^{-1}) of Red Sanders (*Pterocarpus santalinus*) under different age group in Vellore and Thiruvallur districts

Sl. No.	Age Group	Total Volume (m^3)	Total Biomass (tonnes ha^{-1})	Total Biomass Carbon (tonnes ha^{-1})
1	10	31.20^{de}	30.30^{e}	14.24^{e}
2	20	38.56^{d}	37.41^{e}	17.58^{e}
3	30	311.19^{c}	301.91^{d}	141.90^{d}
4	40	327.66^{c}	433.49^{c}	203.74^{c}
5	50	432.89^{b}	572.71^{b}	269.17^{b}
6	60	475.24^{a}	628.74^{a}	295.51^{a}
SE(d)		2.699	5.562	3.234
CD (0.05%)		5.754	11.855	6.889

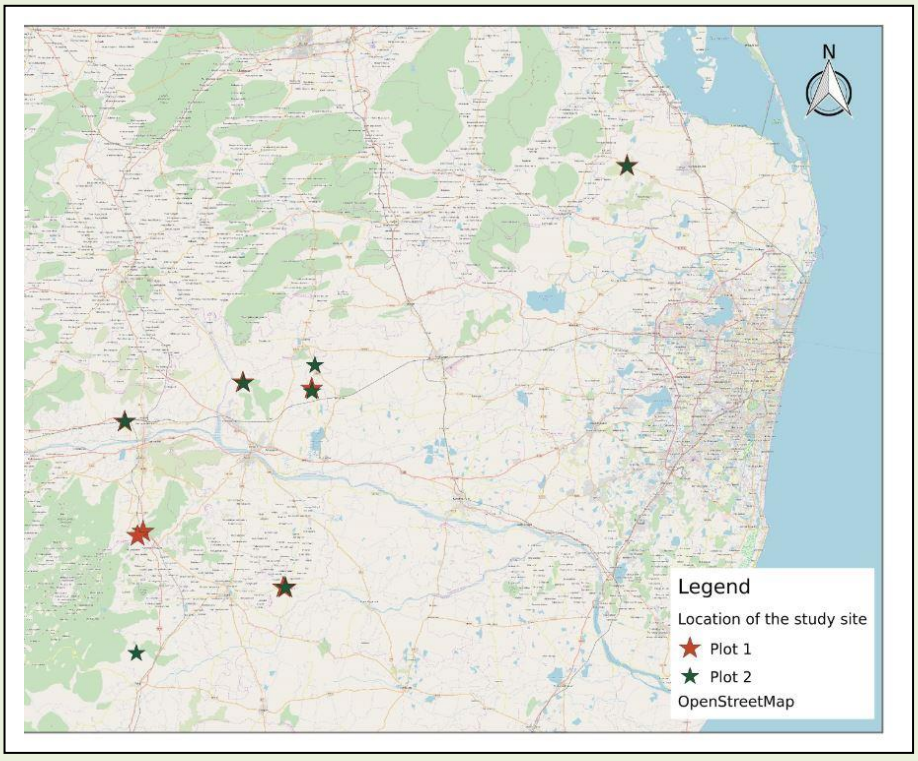

Fig. 1: Location of the sample plot

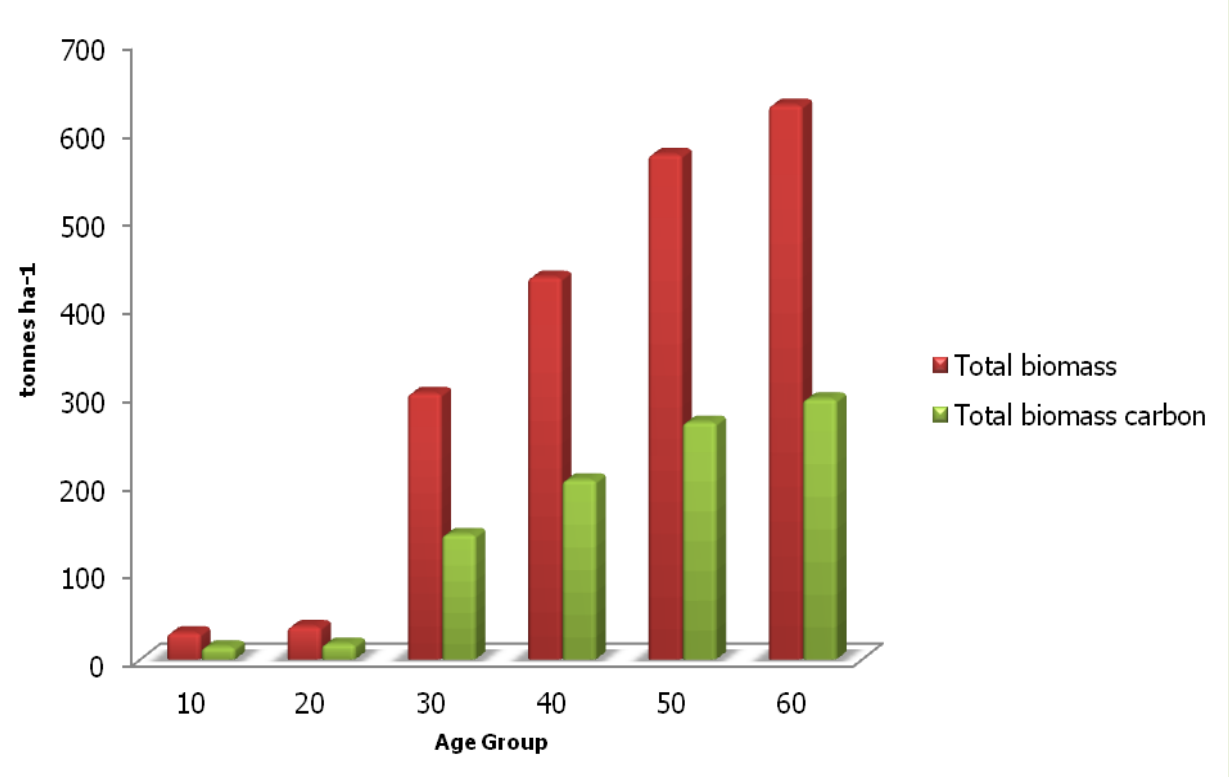

Fig. 2: Biomass and biomass carbon content (tonnes ha^{-1}) of Red Sanders (*Pterocarpus santalinus*) under different age group in Vellore and Thiruvallur districts