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Research Paper

Carbon sequestration potential of Achan (*Hardwickia binata*) under different girth class interval in Vellore Reserve forest of Tamil Nadu

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Abstract
The study was conducted during 2020 at Vellore forest circle 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}. Achan (*Hardwickia binata*) were selected at 5 different Reserve forest of G.C Kuppm R.F., Neelakandarayan pettai R.F., Senoor R.F, Veerachathirapalli R.F. and Pitchanoor R.F. in Vellore for the estimation of carbon sequestration potential. Totally 10 sample plots with the plot size of 0.1 ha (31.62 m X 31.62 m) were laid out in 5 different Reserve forest of Achan plantation for assessing the biometric attributes, volume, biomass and biomass carbon through Non-destructive sampling method. Among the selected at 5 different Reserve forest, Senoor R.F exhibited the maximum biomass (381.64 kg. /tree and 236.60 tonnes/hectare) and biomass carbon content (381.64 kg. /tree and 236.62 tonnes/hectare) followed by Neelakandarayan pettai R.F. and minimum was recorded in Veerachathirapalli R.F. Among the five different girth classes, 106-125 cm (G5) class trees were produce maximum amount of carbon sequestration per tree and followed by girth class G4. Due to its medium density content, Achan tree is considered as suitable for high carbon storage from atmosphere through photosynthesis mechanism. This tree has minor utility value and commercial importance, it can also have the maximum potential in carbon sequestration.
Keywords: Biometric, Carbon sequestration, Biomass, Non-destructive sampling, Girth

Introduction

Indiscriminate deforestation in tropical world has become a major cause of increased carbon dioxide concentration in our atmosphere, It was reported that the global average of the gross emission rate of tropical deforestation was 2.9 petagrams of carbon (Pg C y^{-1}) and that tropical regrowth forests were partially compensated for by a carbon sink of 1.6 Pg C y^{-1} within an area of 557 Mha. The main cause of this change is rapid increase greenhouse gases (GHG) especially CO2, CH4 and N2O and their atmospheric concentration which has increased by 40%, 150% and 20% respectively. Reducing atmospheric concentration of CO2 is the need of the hour for slowing down global warming and climate change. Studies of Indian forests as part of the national forest carbon balance (Ravindranath *et al.* 1997; Haripriya 2000; Chhabra and Dadhwal 2004; Manhas *et al.* 2006; Gupta 2009; Kaul *et al.* 2009) have examined strata and state/regional forest area changes. Their results range from the finding that the forests are a major source to the finding that they are a sink for atmospheric carbon.

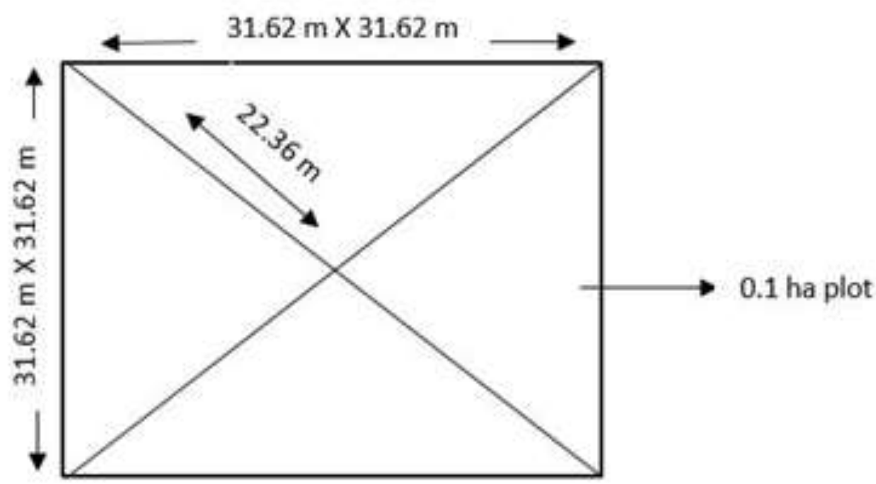
Removal of greenhouse gases (Especially CO_2) from the atmosphere through sinks (i.e. Trees and Soil) is one way of addressing climate change. In the wake of global efforts to address climate change, considerable interest has been generated about carbon sequestration potential of trees. Tree plantations 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. This system helps in mitigating climate change by sequestering large amount of CO2 in the form of tree biomass and soil organic carbon (SOC) while also providing benefits like soil erosion control, modification of micro climate and production of resources like fodder, fuel, fruit, fibre and wood. 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. Achan *(Hardwickia binata)* is widely adapted to species for arid and semi-arid conditions of all over India. It grows naturally in sub-humid tropical lowland to mid-elevation climates, generally in areas with annual temperature of 20 to 25 °C (minimum), annual temperature of 29 to 35 °C (maximum), annual rainfall of 500 to 1200 mm and a dry season of 6 to 8 months. This tree can thrive in dry areas and even can withstand for prolonged drought. *Hardwickia binata* is moderate to large sized tree, leafless for a short time or nearly evergreen, with drooping slender branches with greyish green coriaceous bi-foliate leaves. Achan wood is hard, heavy, and durable resistant to rot and white ants. It is largely used for naves of cart wheels, oil mills, ploughs, posts, beams, mine props, bridges and wells. It is also used for carving, turning and ornamental work. The bark yields a red-brown fibre used for well ropes and other agricultural purposes. The leaves are used as cattle fodder and manure. The tree is often pollarded not only for the fodder and manure supplied by the leaves, but also for the fibre obtained from the young branches. A medium density wood species with the specific gravity about 0.61 g/cm^3 lead to sequestrate more carbon from the atmosphere through photosynthesis and wider adaptability. 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.

Hence, this study aimed to characterize the growth, partitioning of biomass, carbon content through non-destructive method in Achan. 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 forest circle 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 d S 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.

Achan (*Hardwickia binata*) were selected at 5 different Reserve forest of G.C Kuppm, Neelakandarayan pettai, Senoor, Veerachathirapalli and Pitchanoor in Vellore. Totally 10 sample plots with the plot size of 0.1 ha (31.62 m X 31.62 m) were laid out in 5 different Reserve forest of Achan plantation for assessing the volume and carbon sequestration potential. Achan plantation of 5 different Reserve forest were laid with the spacing of 4m x 4m with a tree density of 620 Nos. per hectare. The estimation of carbon sequestration in Achan 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. Five different girth classes *viz*., G1 (25-45 cm), G2 (46-65 cm), G3 (66-85 cm), G4 (86-105 cm) and G5 (106-125 cm).



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.

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

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). Total Biomass

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 Achan was calculated as 0.61 g/cm^3.

AGB (kg/tree) = Volume of tree (m^3) x Wood density (kg/m^3)

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

Below Ground Biomass (kg. /tree) = AGB (kg/tree) x 0.26

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

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

ii). Carbon Content

The biomass carbon content of Achan was calculated by utilizing the arithmetic value of biomass. The formula for calculating biomass carbon in Achan 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).

Table 1. Biometric attributes and biomass carbon content of Achan (*Hardwickia binata*) in Vellore Reserve forest

Sl. No.	Reserve Forest	Height (m)	Girth (cm)	Volume (m^3)	Average Biomass (kg. $tree^{-1}$)	Average Biomass Carbon (kg. $tree^{-1}$)
1	G.C Kuppm R.F.	9.77	75.49	0.44	340.86	160.20
2	Neelakandarayan pettai R.F.	10.15	77.25	0.48	370.61	174.19
3	Senoor R.F.	10.54	76.94	0.50	381.64	179.37
4	Veerachathirapalli R.F	7.90	50.20	0.16	121.79	57.24
5	Pitchanoor R.F	10.67	70.57	0.42	325.34	152.91
SE(d)		**0.29**	**1.06**	**0.03**	**2.01**	**1.27**
CD (0.05%)		**0.58**	**2.12**	**0.06**	**4.02**	**2.54**

A scientific estimation of carbon sequestration potential in Achan at different R.F. were analyzed at Vellore, Tamil Nadu was taking up biometric attributes namely height and diameter at breast height (DBH) measurements followed by estimation of volume. Among the 5 R.F. the maximum height of 10.67 m was recorded in Pitchanoor R.F. followed by Senoor R.F. with 10.54 m. and the minimum was observed in Veerachathirapalli R.F of 7.90 m. Grith of 77.25 cm was observed maximum in Neelakandarayan pettai R.F. followed by Senoor R.F. with 76.94 cm. and the minimum of 50.20 m was recorded in Veerachathirapalli R.F. Volume of 0.50 m^3 was recorded in Senoor R.F. and followed by Neelakandarayan pettai R.F. with 0.48 m^3 and 0.16 m^3 of minimum volume were observed in Veerachathirapalli R.F. 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 Achan plantation (Per tree and hectare)

In the study, carbon sequestration was estimated in 5 Different R.F. with the total biomass (Including above ground and below ground biomass) and biomass carbon in Vellore of Tamil Nadu. The biomass and biomass carbon was calculated per tree as well as tonnes per hectare. Among the 5 Different R.F., the maximum biomass was recorded in Senoor R.F. with the value of 381.64 kg. /tree and 236.60 tonnes/hectare. The second maximum biomass (370.61 kg. /tree and 229.78 tonnes/hectare) was exhibited in Neelakandarayan pettai R.F. and the minimum amount of biomass was recorded in Veerachathirapalli R.F with the value of 121.79 kg. /tree and 75.51 tonnes/hectare. It is also interesting to note that, the Achan is a medium 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.

Table 2. Biomass and biomass carbon content (tonnes ha^{-1}) of Achan (*Hardwickia binata*) in Vellore Reserve forest

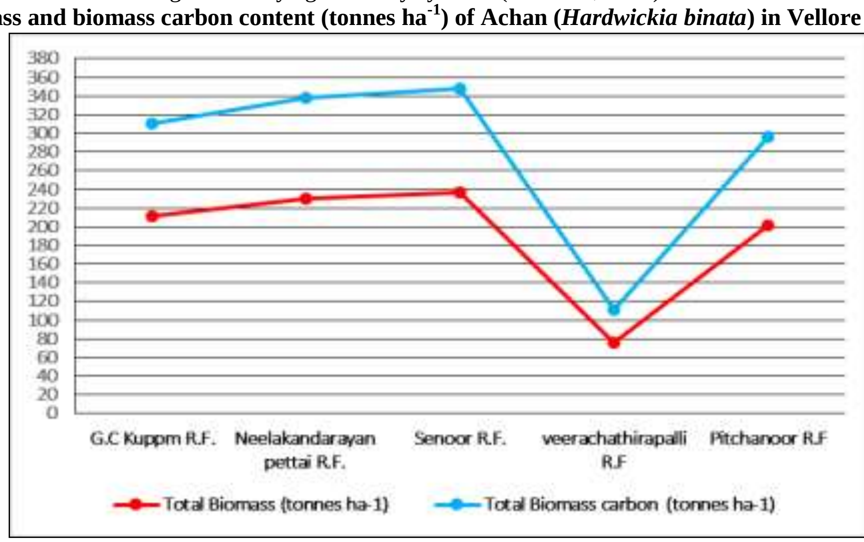
Sl.No.	Reserve Forest	Total Volume (m^3)	Total Biomass (tonnes ha^{-1})	Total Biomass Carbon (tonnes ha^{-1})
1	G.C Kuppm R.F.	274.96	211.33	99.33
2	Neelakandarayan pettai R.F.	298.96	229.78	107.99
3	Senoor R.F.	307.85	236.62	111.21
4	Veerachathirapalli R.F	98.24	75.51	35.49
5	Pitchanoor R.F	262.44	201.71	94.80
	SE(d)	**2.36**	**3.17**	**1.65**
	CD (0.05%)	**4.72**	**6.34**	**3.3**

Biomass carbon in Achan 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 Senoor R.F. with the value of 381.64 kg. /tree and 236.62 tonnes/hectare followed by Neelakandarayan pettai R.F. with the biomass carbon content of 370.61 kg/tree and 229.78 tonnes/hectare and lowest biomass carbon (121.79 kg/tree and 75.51 tonnes/hectare) was exhibited in Veerachathirapalli R.F. 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).

Fig. 1. Biomass and biomass carbon content (tonnes ha^{-1}) of Achan (*Hardwickia binata*) in Vellore Reserve forest



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).

Table 3. Girth class wise comparison of growth and carbon sequestration of Achan (*Hardwickia binata*) in Vellore Reserve forest

Sl.No.	Girth class (cm)	Height (m)	Volume (m^3)	Total biomass (kg. $tree^{-1}$)	Carbon content (kg. $tree^{-1}$)	Co2 (kg. $tree^{-1}$)
1.	25- 45 cm	4.95	0.06	47.36	22.26	81.69
2.	46-65 cm	9.74	0.27	205.06	96.38	353.71
3.	66-85 cm	10.67	0.48	371.29	174.50	640.43
4.	86-105 cm	12.47	0.86	657.95	309.24	1134.89
5.	106 - 125 cm	11.20	1.20	923.38	433.99	1592.73

Table 4. Estimation of biomass and carbon sequestration of Achan (*Hardwickia binata*) at different plantation sites in Vellore Reserve forest

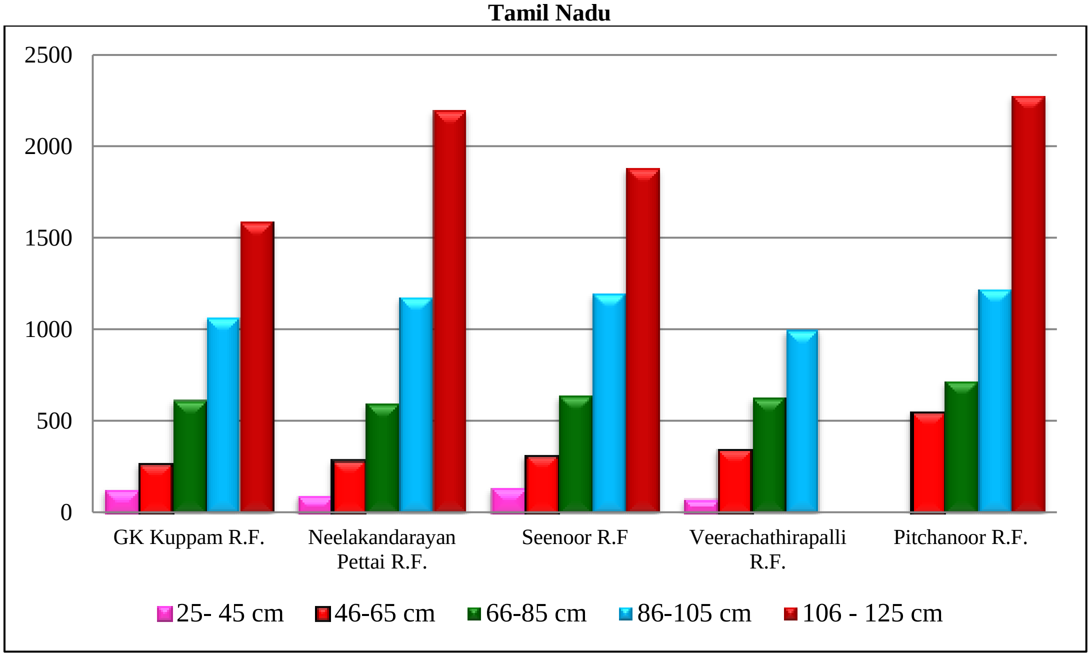
Plantation Sites	Girth class (cm)	Height (m)	Volume (m^3)	Total biomass (kg. $tree^{-1}$)	Carbon content (kg. $tree^{-1}$)	Co_2 (kg. $tree^{-1}$)
GK Kuppam R.F.	25- 45 cm	6.64	0.09	69.79	32.80	120.38
	46-65 cm	8.08	0.20	157.26	73.91	271.25
	66-85 cm	10.18*	0.46	356.86	167.73	615.55
	86-105 cm	11.61*	0.81*	620.62*	291.69*	1070.51*
	106 - 125 cm	12.36*	1.20*	923.05*	433.83*	1592.16*
Neelakandarayan Pettai R.F.	25- 45 cm	5.64	0.07	51.18	24.06	88.29
	46-65 cm	8.13	0.22	166.04	78.04	286.41
	66-85 cm	10.24*	0.45	345.98	162.61	596.79
	86-105 cm	12.58*	0.89*	684.29*	321.62*	1180.34*
	106 - 125 cm	14.17*	1.66*	1276.26*	599.84*	2201.42*
Senoor R.F.	25- 45 cm	6.40	0.10	75.82	35.64	130.79
	46-65 cm	8.69	0.24	182.30	85.68	314.45
	66-85 cm	10.67*	0.48	371.40	174.56	640.63
	86-105 cm	12.76*	0.90*	695.17*	326.73*	1199.09*
	106 - 125 cm	14.17*	1.42*	1093.95*	514.15*	1886.95*
Veerachathirapalli R.F.	25- 45 cm	6.09	0.05	40.00	18.80	68.99
	46-65 cm	9.78	0.26	200.93	94.44	346.58
	66-85 cm	11.24*	0.47	364.59	171.36	628.88
	86-105 cm	12.38*	0.75*	579.79*	272.50*	1000.08*
	106 - 125 cm	0.00	0.00	0.00	0.00	0.00
Pitchanoor R.F.	25- 45 cm	0.00	0.00	0.00	0.00	0.00
	46-65 cm	14.00*	0.41	318.79	149.83	549.87
	66-85 cm	11.02*	0.54	417.59	196.27	720.30
	86-105 cm	13.05*	0.92*	709.87*	333.64*	1224.46*
	106 - 125 cm	15.30*	1.72*	1323.63*	622.11*	2283.13*
Mean		9.81	0.57	441.01	207.27	760.69
SED		0.17	0.02	13.06	8.09	59.54
CD (5%)		0.34	0.04	26.12	16.18	119.08

Significant variation among 5 girth classes studied for tree height, volume, total biomass, carbon content and CO2 sequestration in *Hardwickia binata* (Table 3). The tree height was ranged from 4.95 m (G1) to 12.47 m (G4). Girth class G5 recorded maximum volume (1.20 m3) followed by G4 (0.86 m3) and G3 (0.48 m3). Total biomass shows significant variation among the different girth classes and it ranged from 47.36 kg to 923.38 kg in lower to higher girth classes. Total carbon sequestration potential per tree was ranged between 22.26 kg (G1) and 433.99 kg (G5). Similar to CO 2 sequestration were ranged from 81.69 kg (G1) to 1592.73 kg (G5) followed by G4 (1134.89 kg) and G3 (640.43 kg).

Among the different plantation sites Pitchanoor RF recorded maximum carbon content and CO2 sequestration in all girth classes (maximum in G5 girth class 622.11 kg and 2283.13 kg) followed by Neelakandarayan Pettai RF (599.84 kg and 2201.42 kg) and Senoor RF (514.15 kg and 1886.95 kg). Some of the girth classes were not found different plantation sites are G5 at Veerachathirapalli RF and G1 at Pitchanoor RF (Table 4).

To study the carbon potential of trees at different age classes in biomass accumulation and carbon sequestration among the tropical forest, especially, fast growing species. The carbon pool for Indian forest are estimated to be 7,044 million tones (SFR 2015). Recent report suggested that the increase in the carbon stock is in line with the INDC targets. The INDC target for forestry sector envisages creation of additional carbon sink of 2.5 to 3.0 billion tonnes of CO2 (Luna *et al*., 2016). In India carbon storage potential of eucalyptus plantations were estimated at different age group, carbon content was found to be 38.18 to 42.66 and 115.88 to 129.04 t/ha, respectively one and four year plantation.

Fig. 2 Carbon di-oxide sequestration in different girth classes at Vellore Reserve forest, Tamil Nadu



Conclusion

Achan (Hardwickia binata) is widely adapted to species for arid and semi-arid conditions of all over India with the low value utility. Due to this species grows abundantly which leads sequester of more carbon from the atmosphere. This species is with medium 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, Achan is a commercial unexploited species and also have a potential tree species in environmental protection through carbon storage from atmosphere.

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