Assessment of biomass and carbon sequestration potentials of standing *Pongamia pinnata* in Andhra University, Visakhapatnam, India

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ABSTRACT

The significance of forested areas in carbon sequestration is conventional, and well renowned. But, hardly any attempts have been made to study the potential of trees in carbon sequestration from urban areas. Andhra University was selected for the study in Visakhapatnam city with the objectives of quantifying the total carbon sequestration by *Pongamia pinata*. Stratified random sampling was used for assessing biomass in two site and about 230 *P. pinnata* trees were taken. Biomass was calculated using Non-destructive allometric models. The biomass carbon content was taken as 55% of the tree biomass. Soil samples were taken from soil profile up to 40 cm depth for deep soils and up to bedrock for shallow soils at an interval of 10 and 20 cm for top and sub-soil respectively. Walkley-Black Wet Oxidation method was applied for measuring soil organic carbon. Belowground biomass was estimated by the Root:Shoot ratio relationship. Total biomass and soil carbon was higher in Site-2 than in Site-1. Total carbon sequestration in Site-2 was found 1.59 times higher compared to Site-1 but the mean SOC stored was found higher in Site-1 than in Site-2, i.e.,14.48 tC/ha and 10.33 tC/ha, respectively.

Key words: Allometric Model, Carbon sequestration, *Pongamia pinnata*.

INTRODUCTION

Currently, global warming is more certain and alarming than ever. Most of the observed increase in global average temperatures is due to the observed steady increase of CO_2 in our atmosphere, i.e. from 280 parts per million (ppm) in 1850 up to 394 ppm in 2012 (NOAA, 2012). At the 16th Conference of the Parties held in 2010, parties to the UNFCCC agreed that future global warming should be limited below 2°C relative to the pre-industrial temperature level (UNFCCC, 2011). Forest cover more than one third of the world's land area and constitute the major terrestrial carbon pool (Roberntz and Sune, 1999). The amount of carbon sequestered and stored in forest varies greatly based on a large number of factors, including the type of forest, its Net primary production, the age of the forest, and its overall composition (Millard, 2007). Carbon storage in forest ecosystems involves numerous components including biomass carbon and soil carbon. As more photosynthesis occurs, more CO_2 is converted into biomass, reducing carbon in the atmosphere and sequestering it in plant tissue above and below ground (Gorte, 2009; IPCC, 2003) resulting in growth of different parts (Chavan and Rasal, 2010). Biomass production in different forms plays important role in carbon sequestration in trees (Chavan and Rasal, 2012). Above Ground Biomass, Below Ground Biomass, Dead Wood, Litter, and Soil Organic Matter are the major carbon pools in any ecosystem (FAO, 2005; IPCC, 2003; IPCC, 2006). Assessment of carbon stocks and stock changes in tree biomass are relevant to deal with the united nation Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol report (Green *et al.*, 2007; Almgir and Al-Amin, 2007).

P. pinnnata is a deciduous tree species and one of the widely available tree found in the study area. Studying about this particular species is valuable in various aspects particularly estimating the carbon sequestration potential and extraction of biodiesel from the seed of this tree to be an input for the climate change mitigation activities taking place in India and in the world at large, since climate change is the worldwide issue.

MATERIALS AND METHODS

Study Site Description

The study area, under investigation, lies between East longitude 83^0 15' – 83^0 22' and North latitude 17^0 14' – 17^0 46'. About 70% of the annual rainfall is received during South-West monsoon season, average varying from 500-1000mm. In other seasons, rainfall, if any, is mainly due to thunderstorms and cyclones. The average temperatures are high and uniform and the mean annual temperature is approximately 25^0 C and the highest mean temperature is reached in the month of May. The relative humidity varies from 60-90% with some diurnal fluctuations in the various seasons mentioned above. The soil prevailing inland is of the red type and most of it is of the least fertile variety. Quartzites, quartz veins and red loamy soil are also found in various places. . The vegetation of Andhra University is dry deciduous and deciduous scrub types.

Tree Sampling

Stratified random sampling was used for collecting data for the tree biomass under study. Nested quadrates of size 10 m x 10 m for trees were laid. The sampling stratums were located in the field by selecting coordinate pairs randomly after determining the number of sampling quadrates in each stratum. The number of samples for each stratum was selected proportional to its extent. The geographical positions were fixed in the European Coordinate Reference Systems (CRS identifier ERTS89, Ellipsoidal CRS) (Boucher and Altamini, 1992). The coordinate pairs of each stratum were located in the field with a global positioning system (GPS).

Biophysical Measurements

Mathematical model was developed for the measurements of biomass by considering Diameter at Breast Height (DBH) and the girth at DBH at approximately 1.3 meter. The tree having diameter above 7.5 cm were treated as trees. Techniques, such as clinometers, wooden pole, and considering the height of the near building to the tree were implemented according to the situation where the trees were grown. The height of the tree was calculated by considering the angle between the tree top and eye view at breast height angle (α).

Soil Sampling

The soil sample was taken from the centre of each quadrate by driving a core sampler up to 40 cm depth. Soil cores were sectioned into 0-10, 10-20 and 20-40 cm increments for 40 cm samples, then the soil was categorised as top soil (up to 20 cm) and Sub soil (up to 40 cm). The sampling points were taken 1 m distant from tree stems and animal holes, disturbances like wind-thrown trees and trails were avoided (IPCC, 2003).

Biomass Estimation of the Tree

The biomass was estimated from allometric relations between the tree diameter at DBH and tree biomass (Ter-Mikaelian *et al.,* 1997; Tritton and Hornbeck, 1982; Zewdie *et al.,* 2009). For the estimation of aboveground biomass, the model developed by Brown *et al* (1989) has been used. The equation used for estimation of biomass was:

$$\mathbf{Y = Exp.\ \{-2.4090 + 0.9522\ In\ (D^2 \times H \times S)\}}$$

Where; Exp. {....} means the "raised to the power of {....}". **Y** is the above ground biomass (kg), **H** is the height of the trees (meter), **D** is the diameter at breast height in cm, and **S** is the wood density (gm/cm^3).The specific gravity of *P. pinnata* tree was taken as 0.609 (Rajput *et al.,* 1985).

Belowground biomass was estimated 20% of the aboveground biomass (Cairns *et al.,* 1997; Mokany *et al.,* 2006) and 15% of aboveground biomass was considered for litter biomass estimation (Achard *et al.,* 2002).

Estimation of Soil Organic Carbon

The amount of SOC that was stored in a soil was calculated using the equation given by Broos and Baldock 2008, i.e.

SOC (t/ha) = Depth (cm) x Bulk Density (g/cm^3) x Organic Carbon Content (%)

Walkley-Black wet oxidation method was employed to assess the organic carbon content (%) of the soil (Walkley and Black, 1934).

Bulk Density Measuremen:

The bulk density of the soil under investigation was determined based on the method suggested by IPCC 2003.

$$BD_{sample} = \frac{ODW - RF}{CV}$$

Where; BD_{sample} means bulk density of the < 2mm fraction, in grams per cubic centimetre (g/cm^3), **ODW** is oven dry mass total sample in gram, **CV** is core volume in cm^3, and **RF** is mass of coarse fragments (> 2 mm) in gram.

Estimation of C-Stock of the Tree

The coefficient of 0.55 was adapted for the conversion of biomass to carbon, offered by Winrock 1997.

RESULTS AND DISCUSSION

Standing *P. pinnata* Distribution

About 230 *P. pinnata* was identified to assess the biomass and C-Stock. The average number of *P. pinnata* counted per quadrate was 3.29 in Site-1 and 3.19 in Site-2. The respective mean biomass stored per quadrate was found to be 0.42t and 1.32t in Site-1 and in Site-2, respectively. This shows that there was negative relationship between biomass and number of trees present per quadrate. It is due to the presence of less matured, but high number, *P. pinnata* trees found in Site-1. *P.pinnata* attaining a height of about 18 m and a trunk diameter of more than 50 cm in its maturity stage (GOI, 1983). The highest DBH trees were observed in Site-2, i.e., 64.65cm, 62.10cm, and 57.00cm.The DBH of the sampled trees was ranged from 7.64 cm to 64.65 cm.

Biomass Estimation

The average number of *P. pinnata* counted per quadrate was 3.29 in Site-1 and 3.19 in Site-2. The respective mean biomass stored per quadrate was found to be 0.42t and 1.32t in Site-1 and in Site-2, respectively. The total biomass in above-ground, below-ground and litters of both sites was found to be 46.92 t, 9.38 t and 7.04 t, respectively. The biomass observed in Site-1 was much lesser than Site-2 with 23% and 77%, respectively. The mean biomass fraction of 0.28 t per tree was resulted in the study area. A significant difference in biomass between Site-1 and Site-2 has been observed and also a structural difference between trees sampled from both places was seen. Based on the allometric equation used, most of the biomass was accumulated in the aboveground compartment of the plant, i.e. 80% biomass. These were coinciding with many studies giving percentages of aboveground biomass, e.g. 81.9% (Nascimento and Laurance, 2002) and 81% (Henry *et al.,* 2009).

C-Stock Estimation

The amount of sequestered organic carbon in the aboveground, belowground, and litter biomass was 5.93 tC, 1.17 tC, and 0.89 tC in Site 1 and 19.93 tC, 3.99 tC, and 2.99 tC. Regarding to the mean carbon sequestration rate of the aboveground biomass, Site-2 sequestered more organic carbon (53.85 tC/ha) than Site-1 (17.45 tC/ha). Considering both Sites, the belowground biomass mean C-Stock per tree was 0.023 tC. The estimated average C-Stock of *P. pinnata* was 23.52 tC ha^{-1} in Site-1 and 72.70 tC ha^{-1} in Site-2 and an average equivalent of 86.34 tCO_2 ha^{-1} and 266.84 tCO_2 ha^{-1} has been stored (Table 1).

Total Biomass, C-Stock and CO_2 Sequestered by the Tree

A total of 63.34t biomass, 34.90t of C and 128.08t of CO_2 was estimated by this assessment from the sampled *P. pinnata* trees. Since the highest DBH trees were accumulated in Site-2 (64.65cm, 62.10cm, 57.00cm), the biomass got more in Site-2 than Site-1. There were large differences in C-Stock between stratums. The range of carbon stored in biomass of the surveyed trees was from 1.41 to 34.30 tC ha^{-1}. This was due to the large variation in biomass between stratums (Fig. 1).

Table 1: Mean C-Stock and CO_2 sequestered across stratum

Stratum	Mean C-Stock (t ha^{-1})						Mean CO_2 (t ha^{-1})					
	AGB		BGB		Litter		AGB		BGB		Litter	
	S-1	S-2	S-1	S-2	S-1	S-2	S-1	S-2	S-1	S-2	S-1	S-2
1	21.21	80.17	4.13	16.03	3.18	12.02	77.83	294.22	15.16	58.84	11.67	44.13
2	17.72	67.85	3.54	13.57	2.66	10.18	65.05	249	13.01	49.80	9.76	37.35
3	10.45	39.21	2.09	7.84	1.57	5.88	38.36	143.91	7.67	28.78	5.75	21.6
4	32.17	18.48	6.43	3.71	4.82	2.77	118.06	67.83	23.61	13.63	17.71	10.17
5	11.99	28.15	2.40	5.63	1.78	4.22	43.99	103.31	8.8	20.66	6.6	15.5
6	14.41	47.77	2.88	9.55	2.16	7.16	52.88	175.30	10.58	35.06	7.93	26.3
7	-	37.40	-	7.48	-	5.61	-	137.26	-	27.45	-	20.59
8	-	95.73	-	19.15	-	14.36	-	351.33	-	70.27	-	52.70
9	-	58.04	-	11.61	-	8.71	-	213.03	-	42.60	-	31.95
10	-	66.42	-	13.28	-	9.96	-	243.75	-	48.75	-	36.56
11	-	254.05	-	50.81	-	38.11	-	932.36	-	186.47	-	139.85
12	-	126.3	-	25.26	-	18.94	-	463.51	-	92.70	-	69.53

AGB: Aboveground biomass; BGB: Belowground biomass; S-1: Site 1; S-2: Site 2

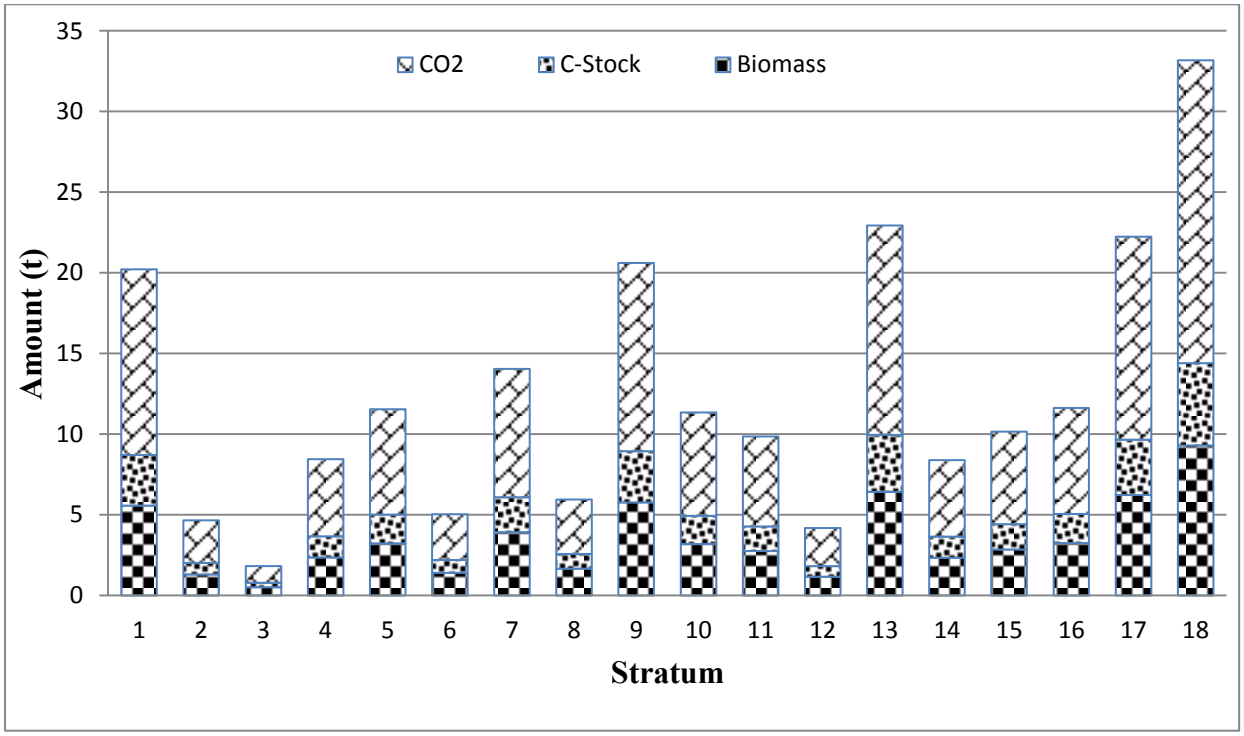

Fig. 1: Tree Biomass, C-Stock and CO_2 sequestered across the stratum

Bulk Density Determination

The average bulk density at each site was 0.66 g/cm^3 in Site-1 and 1.12 g/cm^3 in Site-2. On one hand, this implies that, the organic matter presented in Site-1 was more compared to Site-2, on the other hand, the rate of decomposition of letters and dead woods in Site-2 was. This led to lower amount of carbon stored by the soil in Site-2.

Soil Organic Carbon Sequestration

A total of 210.77 tC SOC was found to be sequestered in the study area. The highest mean C-Stock of the soil was observed in Site-1 than Site-2, i.e., 14.48 tC ha^{-1} and 10.33 tC ha^{-1}, respectively. It was the result of stable situation observed to decompose the litters in Site-1. The study area, where this assessment has been made, was relatively disturbed and less protected land. Therefore the amount of SOC decreases as litter input is relatively low, due to regular removal of litters and dead woods, so that it leaves only the roots as input to the belowground C-pool.

Total Carbon and CO_2 Sequestered

The cumulative amount of carbon and CO_2 sequestered throughout the study area was about 245.67 tC and 901.61 tCO_2, respectively. This result represents the carbon stock and CO_2 presented in aboveground, belowground, litter and soil organic matter. The SOC was accounted for 86 % of the total carbon sequestered in the study area and the remaining 14 % of the carbon was by the tree biomass. The organic carbon sequestered per species at Nandghur village in Pune district were *Mangifera indica* (95.2 tons), *Dalbergia lanceolaria* (73.082 tons), *Ficus racemosa* (57.96 tons), *P. pinnata* (60.48 tons), *Lagerstoemia microcarpa* (43.0 tons), *Syzygium cumini* (41.36 tons), *Acacia spp* (24.0 tons), *Dendrocalamus strictus* (19.5 tons), *Memecylon umbellatum* (18.6 tons), and *Bombax ceiba* (11.7 tons) (Hangarge *et al.*, 2012). The assessment made in the university campus of Aurangabad shown that the above ground carbon, below ground carbon and mean organic carbon of *Azadirachta indica* was 1.91, 0.26, 2.08 t/tree respectively (Chavan and Rasal, 2010). Our assessment revealed that 34.39 tons of carbon was sequestered in both sites of the study area by *P. pinnata.* The significant amount of carbon sequestered at both sites of the study area (with total area of 422 acres) indicates the potential and significant CO_2 sequestration by *P. pinnata* and the soil. Thus, this study confirms that *P. pinnata* is a potential tree found in the study area in plenty amount that provides a substantial role in cleaning the atmosphere from CO_2 dirt.

ACKNOWLEDGMENT

The first author likes to express special gratitude to the faculty members of Department of Environmental Sciences, Andhra University. Further, this author also thanks the Ethiopian Ministry of Education, Ethiopian Embassy, and Adama Science and Technology University for their moral and financial support.

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How to Cite this Article:

Annissa Muhammed Ahmedin, Surendra Bam, Keredin Temam Siraj, AJ Solomon Raju, 2013. Assessment of biomass and carbon sequestration potentials of standing *Pongamia pinnata* in Andhra University, Visakhapatnam, India. *Biosci. Disc.,* **4**(2):143-148.