

Carbon Stock Sequestered by tree plantations in University campus at Coimbatore, India

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ABSTRACT

Tree plantations in university campus play a major role in carbon sink. We estimated the potential of carbon stock sequestered by two different tree plantation types, Eucalyptus plantation (EP) and mixed species plantation (MP) in Bharathiar University campus at Coimbatore, India. Total carbon stock (TCS) of all live trees (≥ 9.5 cm diameter at breast height) was determined by non destructive method. Tree density and total biomass were 320 & 468 stems ha^{-1} and 48.05 & 39.64 tonne ha^{-1} at sites EP and MP, respectively. Total carbon stock sequestered by the two plantations was 27.72 and 22.25 t/ha respectively. There was a positive correlation ($p > 0.05$) between TCS with tree density as well as total biomass at both sites. This reveals that TCS increases with increase in tree density and biomass. Our results show that the carbon sequestration potential of the fast growing Eucalyptus plantation is 11% higher than the mixed species plantation in Bharathiar University. Hence, we recommend government to include Eucalyptus trees in planting programmes for effective trapping of atmospheric carbon to mitigate global warming and thereby climate change.

Keywords: Tree plantations, biomass, carbon sequestration, Coimbatore.

1. Introduction

Developmental activities and increased transportation activities are increasing the concentration of air pollutants as greenhouse gases, especially CO_2 (Chavan and Rasal, 2010). These are leading to increased atmospheric temperature through the trapping of certain wavelengths of heat radiation in the atmosphere. The increasing carbon emission is of major concerns, and addressed in Kyoto Protocol (Ravindranath et al., 1997). Natural forests, forest plantations, agroforestry practices and some other agricultural activities act as a sink for carbon dioxide (CO_2) through photosynthesis and store carbon as biomass (Benites et al., 1999; David and Crane, 2002; Thangata and Hildebran, 2012). They reduce the amount of CO_2 in the atmosphere, and provide benefit to the global climate (Kort and Turnock, 1999).

Forests are a critical component of the global carbon cycle, storing over 80% of global terrestrial aboveground carbon (Dixon et al., 1994). Forests play a significant role in the global carbon cycle through dynamic exchange of CO_2 with the atmosphere. The management of such terrestrial forest carbon stocks can deliver a significant component to International climate change abatement strategies (Read et al. 2009). Forest ecosystems play a leading role in global terrestrial carbon cycle owing to their huge carbon pool and high productivity (Schlesinger et al., 1997). Several studies so far suggested that forest action can cost effectively provide roughly 30% of the total global effort needed in all sectors to meet climate mitigation strategies (Webb, 1992). With an increasing concern for global climate changes resulting from more and more anthropogenic greenhouse gas, protecting carbon stocks in the existing forests and getting the new carbon stocks through afforestation and

reforestation have become the important measures to enhance the carbon sequestration capacity in the terrestrial ecosystems and mitigate the increasing carbon dioxide concentration in the atmosphere (Lal, 2005). Global forest plantation was 187 million ha in 2005, about 1.4% of the total world available land area. Of this planted area 36% was located in the tropics and 64% in the non-tropical regions. The tropical forest plantation area more than doubled from 1995 to 2005, and on average, the growth rate of tropical forest plantations was 8.6% per year (FAO, 2006; Arias et al., 2011). Plantation forests are important sources of timber that alleviate the pressure on native forests for commercial forest products and are viewed as an effective means of short-term carbon sequestration (Turner et al., 1999; Silver et al., 2000; Curlevski et al., 2010). Growing trees in urban areas can be a potential contributor in reducing the concentration of CO₂ in the atmosphere by its accumulation, therefore in the form of biomass (Chavan and Rasal, 2010).

Biomass is an essential aspect of studies of carbon cycle (Cairns et al., 2003; Ketterings et al., 2001). There are two methods to calculate forest biomass, one is direct method and the other is indirect method (Salazar et al., 2010). Direct methods, also known as destructive methods, involves of felling trees to determine biomass (Parresol, 1999; Salazar et al., 2010). Indirect means of estimation of stand biomass are based on allometric equations using measurable parameters. The use of circumference or girth at breast height alone (expressing the basal area) for above-ground biomass estimation is common to many studies that showed that diameter at breast height (DBH) is one of the universally used predictors, because it shows a high correlation with all tree biomass components and easy to obtain accurately (Razakamanarivo et al., 2012; Antonio et al., 2007; Heinsoo et al., 2002; Zianis, 2008).

Most of the research works revealed that AGB is strongly correlated with tree diameter (Brown, 1997; Brown and Lugo, 1984; Clark et al., 2001). Also, it is accepted that simple model with only diameter as input is a good estimator of above-ground biomass (Brown, 1997; Nelson et al., 1999; Clark et al., 2001; Djomoa et al., 2010). Hence, in the present study we used allometric equation using tree diameter to estimate above-ground biomass following Brown et al. (1989).

Tree plantations in university campus play a major role in carbon sequestration. The present study aimed to estimate and compare the potential of total carbon stock sequestered by two plantation types - (1) Eucalyptus plantation and (2) Mixed species plantation in a university campus at Coimbatore, India.

2. Material and methods

The present study was carried out in two plantations (approximately 15 years old) - Eucalyptus plantation (EP) and mixed species plantation (MP) located at Bharathiar University campus, Coimbatore district of Tamil Nadu, India (Figure 1). The sites are near the foot hill of Marudamalai, Western Ghats. Sites, MP (11° 02' 26.1" N latitude & 76° 53' 05.6" E longitude) and EP (11° 02' 25.2" N latitude & 76° 53' 10.2" E longitude) cover 2.5ha and 2ha area, respectively.

Terrains of the plantations are plain with an altitude of 1584 ft asl for site EP and 1591 ft asl for site MP. Both sites are predominantly with non-calcareous sandy loam red soil, with low organic carbon. Available Nitrogen (N), Phosphorous (P) & Potassium (K) are greater in site

MP - 182 (kg ha⁻¹), 17.0 (kg ha⁻¹) & 247 (kg ha⁻¹) than site MP - 162 (kg ha⁻¹), 9.0 (kg ha⁻¹) & 190 (kg ha⁻¹), respectively.

The climate data of study sites available for 10 years (2002-2011), reveals that the mean minimum and maximum temperature are 26.25°C and 38.78°C, respectively. The pattern of mean monthly temperature and mean monthly rainfall for the study area is given in Figures 2 and 3, respectively. The average annual rainfall in Coimbatore district for the last 10 years – 2002 to 2011 is 645.49mm, and it is minimum during the year 2002 (333.5mm) and maximum during 2011 (973.7mm).

In this study, the total carbon stock sequestration of tree species was determined by non destructive methods which include, field survey, laboratory analysis and allometric equations. A plot of 0.5ha (50m x 100m) was established in both the study sites MP & EP, during December 2011, and it was subdivided into fifty 10m x 10m quadrats to facilitate data collection. All live trees with ≥ 9.5 cm diameter at breast height (DBH) were inventoried. The inventory data was used for determination of tree species density, basal area, and above and below ground biomass. Simultaneously, woody samples of all the species were collected for determination of carbon content percentage in the laboratory using loss-on-ignition (LOI) method in a muffle furnace. LOI method involves combusting samples at high temperature and measuring the weight loss, which is an inexpensive, convenient and accurate method to estimate organic carbon. In the laboratory, after taking the fresh weight, the wood samples were dried in the oven for 1 hour at 105°C to get dried weights. Oven dried grind samples were taken (1.00g) in pre-weighted crucibles. The crucibles were placed in the furnace at 550°C for 1 hour. Crucibles were cooled slowly inside the furnace. After cooling, the crucibles with ash were weighted for calculation of percentage of organic carbon.

Allometric equations following Brown et al. (1989) and MacDicken (1997) were used to estimate aboveground and below ground biomass, respectively, and Allen et al. (1986) was adopted for estimation of organic carbon percentage. Allometric equations are given below,

Estimation of above ground biomass (AGB):

$$Y = 34.4703 - 8.0671D + 0.6589 D^2$$

Where Y is above ground biomass, D is diameter at breast height in cm

Estimation of below ground biomass (BGB):

$$BGB = AGB \times (15/100)$$

Total biomass (TB):

$$TB = AGB + BGB$$

Calculation of ash (%) for estimation of organic carbon:

$$A_{sh} (\%) = (W_3 - W_1)/(W_2 - W_1) \times 100$$

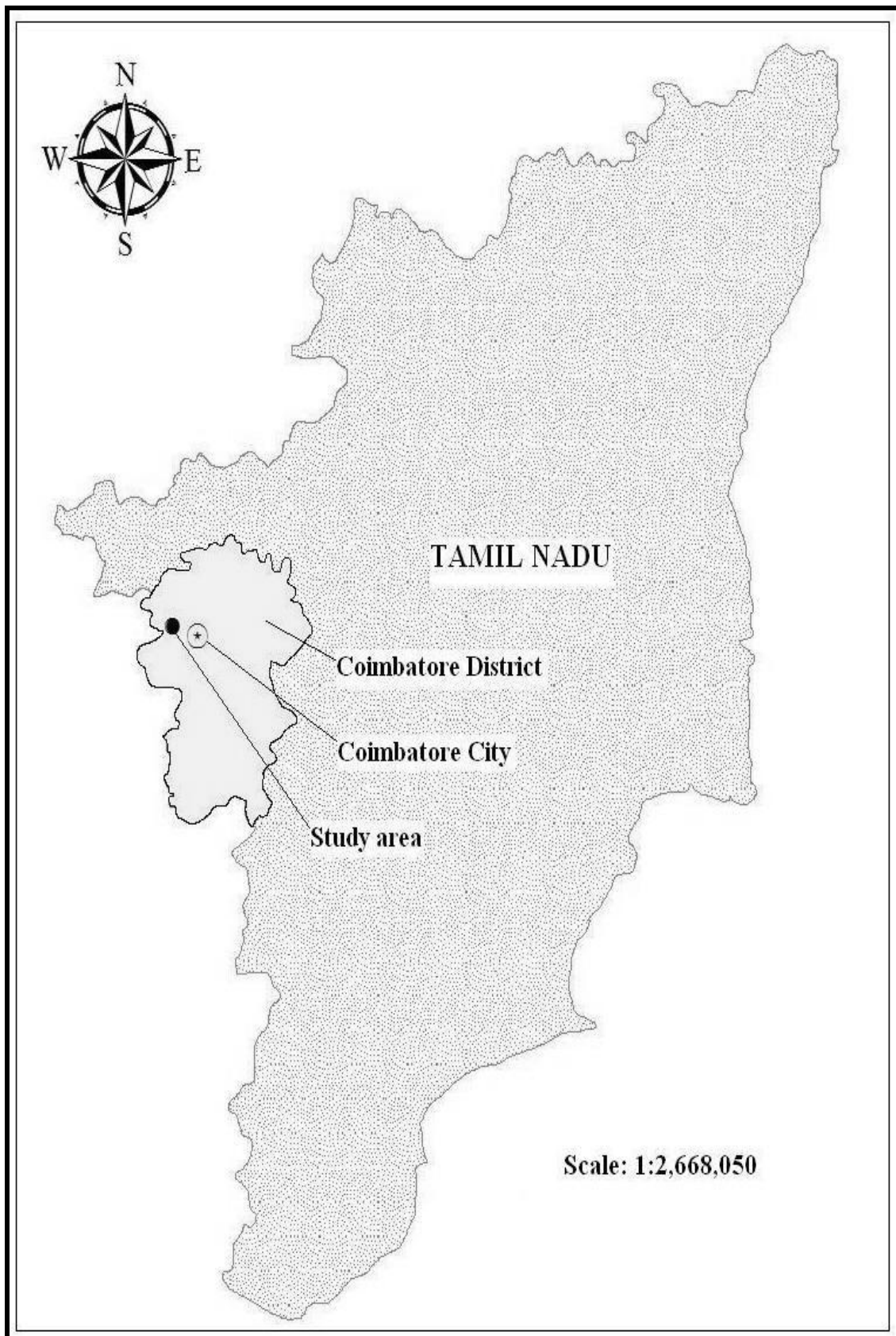
Where W₁ is the weight of crucibles,

W₂ the weight of oven dried grind samples + Crucibles,

W₃ is the weight of ash + Crucibles

Estimation of organic carbon (OC):

$$OC (\%) = (100 - A_{sh} \%) \times 0.58$$



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Figure 1: Map showing the location of the study area in Tamil Nadu State of India

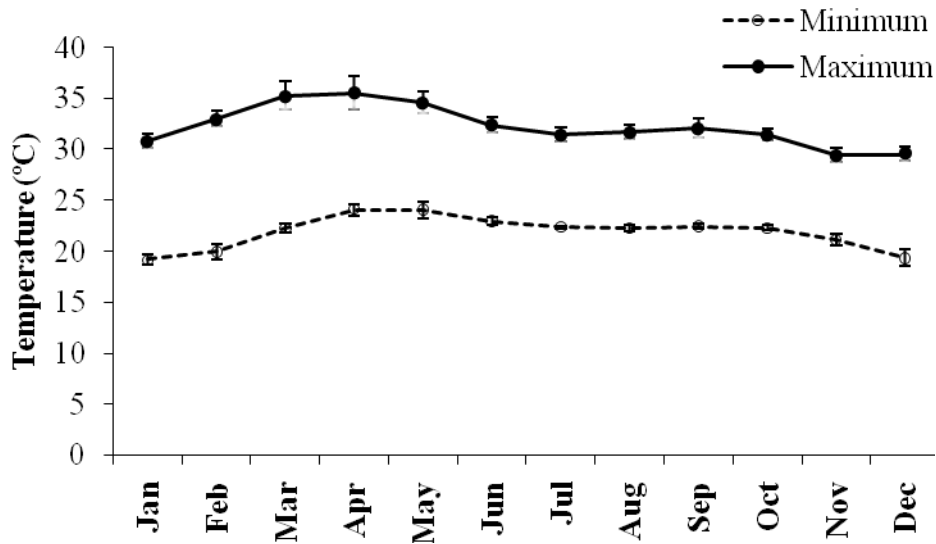


Figure 2: Mean monthly minimum and maximum temperature (with \pm SD) for the study area

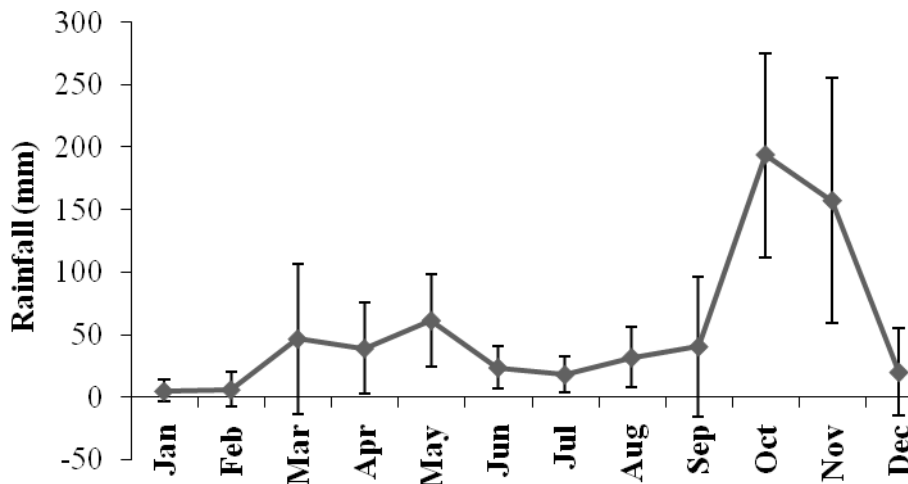


Figure 3: Mean monthly rainfall (with \pm SD) for the study area

3. Result and conclusion

Tree density was high at site MP 468 stems ha^{-1} representing four species, and it was 320 stems ha^{-1} at site EP with single species *Eucalyptus tereticornis* Sm. (Myrtaceae) (Table 1). At site MP, *Acacia farnesiana* (Mimosaceae) shared a maximum of 36.3% of the total stand density, while, *Cassia montana* (Caesalpinaceae), *Acacia nilotica* (Mimosaceae) and *Prosopis juliflora* (Mimosaceae) shared 32.9 %, 22.9 % and 8.1% respectively.

The above and below ground biomass respectively for the sites EP and MP were 41.78 & 6.27 tonne ha^{-1} and 34.47 & 5.17 tonne ha^{-1} . The total biomass at site EP was greater (48.05 tonne ha^{-1}) than site MP (39.64 tonne ha^{-1}) (Table 2). T-test clarified that there was no significant difference in AGB value between the two sites ($t = 0.131$, $P < 0.05$). In the present study, AGB was positively correlated ($p > 0.05$) with stand density at both the study sites EP and MP, revealing that AGB increases with increase in stand density.

Table 1: Tree density of the two study sites EP and MP

S.no	Common name	Scientific name	Family	Tree density (stems/ha)
Site MP				
1	Sweet Acacia	<i>Acacia farnesiana</i> (L.) Willd.	Mimosaceae	170
2	False Senna	<i>Cassia montana</i> Heyne ex. Roth.	Caesalpinaceae	154
3	Algarroba	<i>Prosopis juliflora</i> (Sw.) DC.	Mimosaceae	38
4	Babool	<i>Acacia nilotica</i> (L.) Willd. ex Delile	Mimosaceae	106
Total				468
Site EP				
5	Forest Red Gum	<i>Eucalyptus tereticornis</i> Sm.	Myrtaceae	320

Table 2: Above ground and below ground biomass of the two study sites EP and MP

S.no	Scientific name	Above ground biomass (tonne/ha)	Below ground biomass (tonne/ha)	Total biomass (tonne/ha)
Site MP				
1	<i>Acacia farnesiana</i> (L.) Willd.	7.54	1.13	8.67
2	<i>Cassia montana</i> Heyne ex. Roth.	5.71	0.86	6.57
3	<i>Prosopis juliflora</i> (Sw.) DC.	3.56	0.53	4.09
4	<i>Acacia nilotica</i> (L.) Willd. ex Delile	17.66	2.65	20.31
Total		34.47	5.17	39.64
Site EP				
5	<i>Eucalyptus tereticornis</i> Sm.	41.78	6.27	48.05

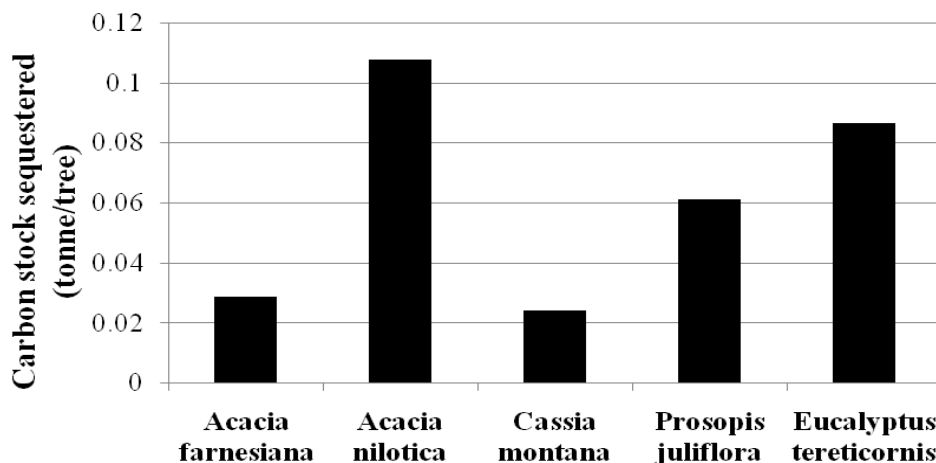
Although the tree density of Eucalyptus plantation is 19% less than mixed plantation, its AGB value was 10% greater than the mixed plantation. This shows that site EP is growing faster than the site MP. AGB value of the present study was lower than the estimated above ground biomass of moist tropical forests in South and Southeast Asia with weighted average of 225 t/ha as reported by Brown et al. (1991).

The above- & below ground organic carbon stock for the sites EP and MP were 24.10 & 3.62 tonne ha⁻¹ and 19.35 & 2.90 tonne ha⁻¹, respectively (Table 3). Total organic carbon stock sequestered by the two plantations was 27.72 and 22.25 t/ha respectively (Table 3).

Table 3: Above ground and below ground organic carbon stock of the two sites EP and MP

S.no	Scientific name	Above ground organic carbon (tonne/ha)	Below ground organic carbon (tonne/ha)	Total organic carbon (tonne/ha)
Site MP				
1	<i>Acacia farnesiana</i> (L.) Willd.	4.22	0.63	4.85
2	<i>Cassia montana</i> Heyne ex. Roth.	3.20	0.48	3.68
3	<i>Prosopis juliflora</i> (Sw.) DC.	2.02	0.30	2.32
4	<i>Acacia nilotica</i> (L.) Willd. ex Delile	9.91	1.49	11.40
Total		19.35	2.90	22.25
Site EP				
5	<i>Eucalyptus tereticornis</i> Sm.	24.10	3.62	27.72

In this study, the contribution of above ground biomass to total carbon stock was maximum, and minimum by below ground biomass. The total organic carbon stock of site EP is 11% higher than site MP, enlightening its high potential in carbon sequestration. There was a positive correlation ($p > 0.05$) between total organic carbon stock with tree density and total biomass at both the study sites. This reveals that the potential of carbon stock sequestration of plantations increase with increase in density as well as with biomass. The carbon stock in the present study was low when compared with the tropical rain forest (137.73 tonne/ha), tropical dry evergreen forest (70.29 tonne/ha) and the tropical mixed deciduous forest 48.14 tonne/ha, of Thailand (Terakunpisut et al., 2007). In the present study, the average carbon capture by single tree was maximum for site EP (0.09 tonne C/tree) and it was 0.05 tonne C/tree for site MP. And, it was maximum for *Acacia nilotica*, followed by *Eucalyptus tereticornis*, *Prosopis juliflora*, *Acacia farnesiana* and *Cassia montana* (Figure 4). In this study, *Acacia nilotica* sequestered 0.11 tonne C/tree, which was low when compared to the species carbon stock of 0.69 tonne C/tree at Dr. Babasaheb Ambedkar Marathwada University, Aurangabad (Chavan and Rasal, 2010). This difference in value for the species may be attributed to different geographic location with different patterns in temperature, rain fall, soil nutrients and pH, which strongly impacts on the tree growth.

**Figure 4:** Carbon stock sequestered (average for single tree) by the five tree species enumerated from the two study sites EP & MP

Our study shows that the carbon sequestration potential of the fast growing Eucalyptus plantation is 11% higher than the mixed species plantation. *Acacia nilotica* (0.11 tonne/tree) and *Eucalyptus tereticornis* (0.09 tonne/tree) captured maximum carbon per tree. Though Eucalyptus is a non-native species to India and considered to be a threat to the wild population, they grow faster, produce more biomass and contribute significantly in terms of carbon sequestration to mitigate global warming and thereby climate change. Also, it is evident that Eucalyptus is one of the most widely planted plantation tree around world due to its fast growing nature, and occupies 3.9 million ha in India (Booth, 2012) and almost 20 million ha worldwide (Iglesias and Wistermann, 2008; Hubbard et al., 2010). Hence, we recommend government to include Eucalyptus trees in planting programmes in Coimbatore for effective trapping of atmospheric carbon.

To rescue the world from global warming and climatic change, the sustainable management of forest with the objectives of carbon sequestration is mandatory. The present study will unbolt a new arena in the aspect of forest management in India and also in different parts of the world. Coimbatore city is one of the ever-burgeoning cities of India. Destruction of more than 100 years old trees for broadening of roads, construction of new buildings are evident. This adds to the glowing global warming in the city. Institutions like Bharathiar University harbouring natural forests and tree plantations are the “GREEN LUNGS” of the city.

5. References

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