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Assessment of carbon sequestration potential in urban street trees: A case study

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Abstract
The importance of street trees within urban environments cannot be overstated due to their multifaceted contributions. These trees serve as a crucial resource for the city by mitigating the urban heat island effect, lowering ambient temperatures, minimizing rainwater runoff, reducing aerial particulate matter, enhancing the visual appeal of the urban landscape, and notably, by storing and sequestering a significant amount of carbon from the surrounding CO_2. Our study focused on the carbon storage and sequestration potential specifically exhibited by the roadside trees. The highest C_{seq} was recorded for *Eucalyptus spp*. (13803.72 kg tree^{-1}) and lowest C was sequestered by *Lagerstroemia speciosa* (104.25 kg tree^{-1}). On the area basis total C_{seq} by street trees on VIP road was 508.76 t ha^{-1}. This study sought to provide quantifiable data showcasing the remarkable role these trees play in absorbing and retaining carbon within their biomass, contributing to the mitigation of atmospheric CO_2 levels.

Keywords: Carbon sequestration potential, urban street trees, CO_2

Introduction

Cities are the hubs of economic growth and development. Urban areas contribute close to half of India's gross domestic product today, but the rapid urbanization is a major driver of global change, driving land use change, habitat loss, biodiversity decline, climate change, and pollution both within and outside the city (Satterthwaite *et al*., 2010) [5]. Trees in urban areas are valuable resource. A tree is a valuable commodity - they ameliorate temperature, reduce air and noise pollution, minimize soil erosion and also give the visual aesthetics and provide shade to city dwellers. Trees enhance the landscape and give significant environmental benefits thus tree planting become one of the important events on urban lands.

According to Singh *et al*., 2018 [7], "Trees comprise the natural capital assets for cities as they provide immense benefits and ecosystem services for the wellbeing of city dwellers". Limited data have been extrapolated to provide national estimates of carbon storage and sequestration. Only a few studies of urban forest carbon assessment are carried out so far; further, a limited tree inventory data and biomass assessment of Indian cities lead to immense gap in this research area (Ugle *et al*., 2010) [11]. Urban trees provide a tremendous amount of cultural ecosystem services. In fact, carbon storage and sequestration are identified among the four key ecosystem services contributing to Sustainable Development Goals (Wood *et al*., 2018) [12]. Street trees do reduce the demand for air-conditioners.

Quantifying the biomass stocks in Raipur's green spaces provides valuable insights into the city's overall carbon storage potential. By measuring the biomass of different tree species, we can estimate their individual and collective contributions to carbon sequestration, which is essential for mitigating greenhouse gas emissions and combating climate change. Understanding the biomass accumulation in Raipur's green spaces allows us to assess the effectiveness of urban greening efforts, identify carbon sinks, and make informed decisions to maximize carbon sequestration potential. In the present study, estimates of biomass and sequestered carbon is conducted in the street side plantation of VIP road, Raipur, city of Chhattisgarh, India.

Study site description

The study area, lies between longitude 081.41596" E and latitude 21.13061" N. In the study area, 100 m stretch of the street was randomly selected and the total 500 m length of streets taken under study with tree plantation on both sides.

The street is a significant part of the green infrastructure which connects Vivekananda Airport and residential areas of the city. The trees providing shade to pedestrians and for greenery and avenue purpose (*Delonix regia*, *Dalbergia sissoo*, *Pongamia pinnata*, *Samanea saman* etc).

Materials and Methods

Tree Height and Girth at Breast Height (GBH)/DBH: A non-destructive method of biomass estimation was used to measure the tree height and GBH of individual trees of the roadside plantation. Height of each tree was measured by holding a meter stick perpendicular to the ground as described by Brower and Zar (1998) [1]. In each plot, all woody plants with > 30 cm GBH (girth at breast height i.e., 1.3 m from the ground) was identified at species level, counted the individuals and GBH was measured using a dendrometer (Chaturvedi *et al*., 2010) [2].

Estimation of Biomass

The stem biomass (dry weight) of each tree was measured by using DBH, height and wood density. The expression given by King *et al*., (2006) [3] and Chaturvedi *et al*., (2010) [2] given below was followed:

Stem biomass (ABG) (B, Kg tree^{-1}) = $0.5(\pi/4)\ \rho$ D2 H

Where, 0.5 is the assumed form factor, defined as the ratio of stem volume to the volume of a cylinder with the height (in meters) and DBH (in cm) of the tree and ρ is the wood density value for the species obtained from website http://db.worldagroforestry.org/wd.

The below-ground biomass (BGB) was estimated by multiplying the AGB value by 0.20 (Nguyen, 2012) [4].

BGB (kg tree^{-1}) = AGB x 0.20

Total Biomass = AGB+ BGB

Carbon stored in the biomass was estimated by multiplying the biomass value with 0.47 (Singh and Singh, 1991) [8].

CBS= 0.47 x TAB 45

Where CBS is the amount of carbon measured in terms of tonnes per hectare (tonnes/ha). TAB is the amount of biomass (tonnes/ha), and 0.47 the default conversion factor. And

CO2 sequestered = 3.67 x carbon

Results and Discussion

A total of 15 species belonging to 8 families were measured across the sampled plot. Among the 15 species quantified in the study sites, 11 species (73%) were native and 04 species (27 %) were non-native species (Table 1). Across the species in the study sites, Fabaceae family stands out as the most abundant, comprising a substantial 8 species, representing around 53 % of the total. The Fabaceae family, demonstrates its diversity through a wide array of species, including, *Acacia leucophloea*, *Acacia nilotica*, *Bauhinia sp*, *Dalbergia sissoo*, *Delonix regia*, *Peltophorum pterocarpum*, *Pongamia pinnata*, *Samanea saman* (Table 1).

The most dominant species on the VIP roadside plantation is *Delonix regia*, with a total of 80 trees. *Delonix regia* is planted chiefly for beautification of the environment due to its decorative flowers and canopy formation. It is planted as street plantation to provide shade and as a source of recreation and conservation purpose. The second and the third most common tree species are *Dalbergia sissoo* (26 trees) and *Samanea saman* (21 trees).

The tallest species, on the basis of average values, was *Eucalyptus spp*. followed by the *Terminalia arjuna*, *Acacia nilotica* and *Samanea saman*. Sumida *et al*., 2013 [10] reported maximum height of trees varied from 20-30 m in the natural forest, while Chaturvedi *et al*. (2011) [13] reported the mean height across all species, sites and individuals was 6.58 m. for 40 species growing in a nearby natural forest. This compares with 6.97 m average height across all species of the present study of urban trees in street plantation. In the present study in urban street trees, DBH of *Acacia nilotica* was maximum followed by *Samanea saman*, *Eucalyptus spp.*, *Acacia leucophloea*, which ranged from 9.87-41.40 cm. Chaturvedi *et al*., 2011 [13] reported the DBH ranged from 9 to <12.7 cm in the natural forest.

In the present study, highest biomass was recorded for *Eucalyptus spp*. (8002.62 kg tree^{-1}) and lowest biomass was recorded for *Lagerstroemia speciosa* ((60.44 kg tree^{-1}). Total stand biomass was 294.95 t ha^{-1}, which was within the range reported by Singh *et al.*, (2023) [6] between 144.06 and 2327.81 t ha^{-1}.

The highest quantity of C storage was recorded for *Eucalyptus spp*. (3761.23 kg tree^{-1}) and lowest carbon was stored by *Lagerstroemia speciosa* (28.41 kg tree^{-1}). Total C stored in the trees of this site was 138.63 t ha^{-1}. The highest C_{seq} was recorded for *Eucalyptus spp*. (13803.72 kg tree^{-1}) and lowest C was sequestered by *Lagerstroemia speciosa* (104.25 kg tree^{-1}). On the area basis total C_{seq} by trees on this site was 508.76 t ha^{-1}. Singh *et al.*, (2023) [6] reported the range of carbon storage and C_{seq}, between 72.03 - 1163.90 t ha^{-1} and 264.35- 4271.54 t ha^{-1}, respectively. Singh *et al.*, (1985) [9] reported carbon stock in Central Himalayan forest as 35.0 to 35.2 t C ha^{-1} in poor forests, 75.2 to 131.5 t C ha^{-1} in medium forests and 131.5 to 225.6 t C ha^{-1} in good forests.

Table 1: Tree dimension, biomass and C_{seq} by street trees in VIP road Raipur

Species	Family	No. of individuals	Avg DBH (cm)	Avg Ht (m)	AGB (kg tree^{-1})	BGB (kg tree^{-1})	TB (kg tree^{-1})	Carbon storage (kg tree^{-1})	CO_2 sequestered (kg tree^{-1})
*Peltophorum pterocarpum**	Fabaceae	5	23.56	6.00	1315.65	263.13	1578.78	742.03	2723.24
*Delonix regia**	Fabaceae	80	14.42	4.26	284.22	56.84	341.06	160.3	588.29
*Bauhinia sp.**	Fabaceae	2	12.58	3.00	124.23	24.85	149.07	70.06	257.13
Pongamia pinnata	Fabaceae	12	22.50	7.50	1035.99	207.2	1243.19	584.3	2144.38
Acacia leucophloea	Fabaceae	2	30.97	7.75	2302.83	460.57	2763.39	1298.79	4766.57
Ailanthus excelsa	Simaroubaceae	2	12.34	4.75	119.02	23.8	142.83	67.13	246.37
Dalbergia sissoo	Fabaceae	26	22.29	6.44	1184.95	236.99	1421.94	668.31	2452.7
*Samanea saman**	Fabaceae	21	41.04	9.76	2929.04	585.81	3514.84	1651.97	6062.75
Gmelina arborea	Verbenaceae	2	23.09	5.00	457.06	91.41	548.47	257.78	946.06
Ficus religiosa	Moraceae	4	15.84	5.88	298.59	59.72	358.3	168.4	618.03
Terminalia arjuna	Combretaceae	7	25.21	10.71	1882.95	376.59	2259.54	1061.98	3897.48
*Eucalyptus spp.**	Myrtaceae	3	37.69	14.00	6668.85	1333.77	8002.62	3761.23	13803.72
Azadirachta indica	Meliaceae	1	21.18	7.00	844.88	168.98	1013.86	476.51	1748.81

Acacia nilotica	Fabaceae	1	41.40	10.00	5080.49	1016.1	6096.59	2865.4	10516.01
Lagerstroemia speciosa	Lythraceae	1	9.87	2.50	50.37	10.07	60.44	28.41	104.25
	Total	169		Total (kg)	24579.12	4915.83	29494.92	13862.61	50875.79
				t/ha	245.79	49.16	294.95	138.63	508.76

*Non-native species

Conclusion

A total of 169 trees belonging to 15 species have been measured on VIP street plantation, with 508.76 t ha^{-1} carbon sequestration potential. The results of the study represent the importance of urban trees, as ornamental and aesthetic plantations, and also for mitigating the impacts of climate change at a local level. Roadside plantation has an important role in expanding their green infrastructure so as to act as local carbon sinks. The results of the study can be used for future greening plans in urban areas, and act as a baseline for future assessments of the roadside carbon sink.

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