

## Carbon Sequestered by Roadside Trees of Bangalore City- An Analysis

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### ABSTRACT

The CO<sub>2</sub>, is one of the major contributors of greenhouse gases has exceeded 400ppm, with an atmospheric lifetime of 5-200 years depending on different rates of uptake by different sequestering or scavenging processes ( IPCC). Anthropogenic activities over the years has most certainly hastened the phenomenon of global warming and the consequences. Bengaluru is one of the fast growing metropolitan cities in the country and as a result, carbon emission is increasing which in turn is adding contributing the effects of global warming. CO<sub>2</sub> is removed and stored by trees. This study aims to estimate the potential of roadside trees to sequester carbon.

**Key words:** Carbon sequestered, roadside trees, GBH

### INTRODUCTION

In 1997, Kyoto Protocol was signed by several countries, agreeing to the United Nations Framework Convention on Climate Change (UNFCCC), to reduce greenhouse gas emissions to 5% or more below 1990 levels by 2012 (<http://unfccc.int>). The Kyoto Protocol represents a major international effort related to carbon sequestration. (montag). In 2015 COP21, also known as the 2015 Paris Climate Conference, for the first time in over 20 years of UN negotiations, aim to achieve a legally binding and universal agreement on climate, with the objective of keeping global warming below 2°C. ([www.cop21paris.org/](http://www.cop21paris.org/))

Due to anthropogenic activities, emission of greenhouse gases has increased rapidly resulting in significant warming of earth's temperature thereby causing global warming. Carbon dioxide (CO<sub>2</sub>) is one of the three important greenhouse gases (Ramachandra et al., 2015). CO<sub>2</sub> has exceeded 400ppm, with an atmospheric lifetime of 5-200 years depending on the different rates of uptake by different removal processes ( IPCC). Accumulation of carbon dioxide and other greenhouse gases in the upper atmosphere is the major reason for global climate change (Montagnini, & Nair, 2004).

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India contributes about 5.3% of the total global GHG emissions, Bangalore being one of the major cities is witnessing rapid urbanization. Greater Bangalore emits 2.18 tonnes CO<sub>2</sub>/ lakh Rs after Chennai which emits 2.55 tonnes CO<sub>2</sub> eq/Lakh Rs. Carbon dioxide equivalent emissions from Greater Bangalore is 19796.5 Gg where transportation sector (43.5%) and domestic sector (21.6%) are significant contributors.<sup>7</sup>

In Urban areas, trees especially roadside trees have a significant role in general health of public by reducing automobile pollution (Sandhya et al., 2011), absorbing particulate matter, atmospheric pollutants, carbon dioxide, ozone and other air pollutants thereby purifying air (McPherson et al., 1994). Trees are also known to reduce atmospheric temperature by the cooling effect through transpiration, they affect local climate and energy use in buildings by modifying the storage and exchanges of heat among urban surfaces (McPherson et al., 1994). Furthermore roadside trees add aesthetic beauty, provides protection from sun and rain, acts as habitat to many birds and other tree-dwellers (Nagendra et al., 2010) and sequester carbon through photosynthesis (Montagnini, & Nair, 2004). Carbon so sequestered is utilized as a building material to form trunks, roots, stems, branches and leaves (Sandhya et al., 2011). The role of forest/roadside trees in carbon sequestration is limited in time and amount (Jandl et al., 2006). Photo sequestration of carbon by trees/forest is known to be a financially effective option for the removal of atmospheric carbon and thereby reducing the consequences of global warming (Jaiswal et al., 2018).

Finding low-cost methods to sequester carbon is emerging as a major international policy goal in the context of increasing concerns about global climate change (Montagnini, & Nair, 2004). This study aims to estimate the potential of roadside trees to sequester carbon.

## MATERIAL AND METHODS

### Study Area

Data for estimating carbon sequestered by roadside trees was collected from 19 locations in and around Bengaluru, where Karnataka State Pollution Control Board monitors the air quality. Once renowned as India's "Garden City" (Nagendra et al., 2010), Bengaluru is the fifth largest metropolis in India with a population of about 8.4 million (Ramachandra et al., 2014)., located 920m above mean sea level, has salubrious climate throughout the year with an annual rainfall of about 850-950mm. Due to rapid and unplanned urbanization, the spatial extent of Bengaluru has increased from 69sq.km (1949) to 741sq.km (2010) while water bodies have decreased to 98 (2010) from 265 (1962).<sup>6</sup> Bangalore's road network is estimated to cover approximately 3500 km (Nagendra et al., 2010) as a result numerous trees were cut for road network extension and widening purposes (Ramachandra et al., 2014). Estimated crown cover of the city is about 100.02 sq.km (14.08%), about 14,78,412 trees. This amounts to one tree for every 7 persons (Ramachandra et al., 2014).

**Climate:** Bangalore has a tropical savanna climate with distinct wet and dry seasons. Due to its high elevation, Bengaluru usually enjoys a more moderate climate throughout the year, although occasional heat waves can make summer somewhat uncomfortable.

(<http://www.thehindu.com/2005/05/18/stories/2005051818670300.html>). Coolest month is January with an average low temperature of 15.1 °C (59.2°F) and the hottest month is April with an average high temperature of 35 °C (95°F). (India Meteorological Department-2007. Bengaluru receives rainfall from both the northeast and the southwest monsoons and the wet months are September, October and August in that order. The summer heat is moderated by fairly frequent thunderstorms, which occasionally cause power outages and local flooding (Sumangala et al., 2018).

## Methods

A total of 19 locations were selected where the Karnataka State Pollution Control Board monitors air quality (as shown in figure.1). Using Vertex Geo Laser, height in meters and using measuring tape, diameter at breast height (DBH) in meters of roadside trees were measured for standing woody biomass and carbon stock estimation. 1km stretch of roadside trees at each location was surveyed.

## Determination of Carbon Stock

To estimate carbon sequestered by trees, the method by Jaiswal et al., 2018 was followed.

On the basis of DBH, height and wood density, Above Ground Biomass (AGB) was estimated. Wood density of various trees under study was obtained from wood density database of World Agro forestry Centre, wherever the wood density of tree species was unavailable, the standard average of wood value  $0.6\text{gm/cm}^3$  was used. Below Ground Biomass (BGB) incorporates all biomass of live roots barring fine roots having  $< 2$  mm distance across. The BGB has been computed by duplicating AGB by 0.26 factors as the root :shoot proportion. Total Biomass was obtained by adding AGB and BGB.

A mass-based carbon concentration of 50% in dry wood is widely accepted as a constant factor for conversion of biomass to carbon stock. According to Ye boah (2011) increasing carbon storage in intact African tropical forests carbon concentration varies with tree species. Since carbon concentration and specific wood density of tree species were known, the specific values were used to convert total biomass to estimated carbon stock. Generally, for any plant species 50% of its biomass is considered as carbon. The weight of carbon dioxide sequestered ( $\text{CO}_2$ ) is composed of one molecule of Carbon and 2 molecules of Oxygen and the atomic weight of Carbon is 12 g/mol; The atomic weight of Oxygen is 16 g/mol). Hence,

weight of  $\text{CO}_2$  is  $\text{C} + (2 \times \text{O}) = 44$  g/mol, while the ratio of  $\text{CO}_2$  to C is  $44/12 = 3.67$ . Therefore, to determine the weight of carbon dioxide sequestered in the tree, the Weight of carbon in the tree was multiplied by 3.67

$$\text{AGB (kg/tree)} = \text{Volume of tree (m}^3) \times \text{WD (kg/m}^3)$$

$$\text{AGB (kg/tree)} = \pi r^2 H (\text{m}^2) \times \text{WD (kg/ m}^3)$$

$$\text{AGB (kg/tree)} = (\text{DBH})^2/4\pi (\text{m}^2) \times \text{H (m)} \times \text{WD (kg/ m}^3) \text{----- Eq. (1)}$$

$$\text{BGB (kg/tree)} = 0.26 \times \text{AGB (kg/tree)} \text{----- Eq. (2)}$$

$$\text{Total Biomass (kg/tree)} = \text{AGB} + \text{BGB} \text{----- Eq. (3)}$$

$$\text{Total Carbon Stock (ton/tree)} = 0.5 \times \text{TB (ton/tree)} \text{----- Eq. (4)}$$

$$\text{CO}_2 \text{ Sequestered (ton/tree)} = 3.67 \times \text{TCS (ton/tree)} \text{----- Eq. (5)}$$

Where, r = radius of the tree (in m)

$$r = \text{DBH}/2\pi$$

H = Height of tree (m)

WD = Wood Density ( $\text{kg/m}^3$ )

## RESULTS AND DISCUSSION

In the present study, out of the 19 locations that were surveyed, Indhira Gandhi institute of child health care with 24 trees was estimated to have sequestered the highest amount of carbon (248.6556 ton) and Kavika, Mysore Road with 26 trees sequestered the lowest carbon (6.5780 ton). However, Central Silk Board, Hosur Road (85 trees), HSR Layout (59 trees) and Rail Wheel factory, Yelahanka (57 trees) were estimated to have sequestered 123.0244, 32.3957 and 102.5484 tons of carbon respectively. Hence correlation between number of trees and Carbon sequestered without the consideration of age factor would be incorrect. Due to unavailability of data, estimation of tree age was not made.

Perhaps GBH, as an indirect indicator of age could be used to relate to carbon sequestration. Higher the value of GBH more is the age of a tree. Despite the presence of high number of trees in these three locations (Central Silk Board, Hosur Road; HSR Layout and Rail Wheel factory, Yelahanka) Indhira Gandhi institute of child health care has the highest sequestered carbon which is predominantly



Table 1: location wise carbon sequestered estimation

Sl no.	Name of the Monitoring Station	combined Avg. GBH (m)	Combined Avg. Height (m)	combined Avg. C seq./tree	total no. Of trees	Total Carbon Sequestered (ton)
1	Indhira Gandhi institute of child health care	2.04	16.78	10.4	24	248.6556
2	City Railway Station	1.62	9.22	4.8	36	173.0659
3	UVCE, KR circle	1.2	8.18	4.8	35	166.8041
4	Central Silk Board, Hosur Road	1.06	10.56	1.4	85	123.0244
5	Saneguruvanahalli	1.36	2.88	3.1	38	117.7526
6	Rajeev Gandhi Child care Institute, NIMHANS	1.38	13.46	4.5	24	107.6519
7	Rail Wheel factory, Yelahanka	0.99	9.85	1.8	57	102.5484
8	AMCO, Mysore road	1.62	12.78	5.9	17	100.4530
9	Victoria hospital, KR Market	1.53	10.99	4.5	17	75.7087
10	Banaswadi Police Station	0.65	4.74	3.3	22	72.5807
11	ITPL, Whitefield	1.07	9.64	1.4	49	70.3238
12	TERI, Domlur road	1.27	7.21	1.5	29	43.8613
13	Urban Eco Park, Peenya	0.9	10.14	2.1	21	43.4643
14	Shalini grounds, Jayanagar	1.06	7.93	1.5	21	32.2347
15	Swan silk Pvt, ltd., Peenya	1.16	8.98	1.4	24	33.0711
16	HSR Layout	0.56	7.79	0.5	59	32.3957
17	Yeshwanthpur Police Station	1.17	6.73	1.2	22	26.6070
18	Veterinary College, Hebbal	0.7	12.22	1.1	17	18.0127
19	KAVIKA, Mysore road	0.49	6.85	0.3	26	6.5780

Table 2 : Location wise carbon sequestered estimation

Sl no.	Species	No.of locations found in	Avg. GBH (m)	Avg. Height (m)	Wood density (kg/cm <sup>3</sup> )	Avg. C seq./tree	No.of trees	Toatal C seq.
1	<i>Samanea saman</i>	11	2.29	14.15	523.7	9.5889	65	623.2779
2	<i>Peltophorum pterocarpus</i>	8	1.54	10.82	602.5	4.3192	51	220.2811
3	<i>Syzygium cumini</i>	3	1.15	5.04	760	23.6693	5	118.3467
4	<i>Delonix regia</i>	5	1.44	7.76	600	2.5617	36	92.2241
5	<i>Tabebuia spp</i>	8	0.64	8.7	736	1.1011	82	90.2929
6	<i>Pongamia</i>	9	1.1	7.64	619.8	1.3636	61	83.1802
7	<i>Mallingtonea hortensis</i>	2	0.88	16.24	600	1.5430	35	54.0002
8	<i>Ficus religiosa</i>	8	1.46	10.63	443	3.3484	16	53.5757
9	<i>Polyalthia longifolia</i>	7	0.87	10.94	563.5	1.1250	47	52.8792
10	<i>Spathodea companulata</i>	8	1.65	10.43	330.3	2.0678	24	49.6295
11	<i>Tamarindus indica</i>	2	1.14	7.77	990.2	8.3130	3	24.9393
12	<i>Sweitenia spp</i>	8	0.62	7.55	624.6	0.6701	31	20.7741
13	<i>Azadirachta indica</i>	1	1.43	7.5	727.5	2.2629	9	20.3662
14	<i>Bauhinia sps.</i>	5	0.8	7.5	720	0.8070	21	16.9478
15	<i>Terminalia arjuna</i>	2	0.45	4.28	805	2.9367	4	11.7467
16	<i>Dolichandrone platycalyx</i>	4	0.47	8.16	511.3	0.2190	48	10.5154
17	<i>Ficus benjamina</i>	3	1.24	7.23	499.3	2.3803	4	9.5212
18	<i>Cassia spectabilis</i>	3	0.58	4	480	1.3521	7	9.4650
19	<i>Broussonetia papyrifera</i>	2	0.53	1.9	390	0.9369	7	6.5583
20	<i>Thespesia populnea</i>	1	1.34	12.2	639.3	2.8404	2	5.6807
21	<i>Parkia biglandulosa</i>	1	1.04	9.8	490.3	1.0125	4	4.0502
22	<i>Jacaranda mimosifolia</i>	2	0.72	8.87	467.1	1.3467	3	4.0402
23	<i>Tectona grandis</i>	1	1.7	7	612.7	2.5139	1	2.5139
24	<i>Neolamarckia cadamba</i>	2	0.24	2.9	480	0.4149	6	2.4894
25	<i>Lagerstoemia indica</i>	3	0.44	5.31	625.9	0.1324	17	2.2521
26	<i>Artocarpus heterophyllus</i>	2	0.29	6.03	535.9	0.3784	4	1.5137
27	<i>Cordia sebestena</i>	1	0.46	5.4	700	0.1622	7	1.1356
28	<i>Terminalia catappa</i>	2	0.64	7.55	540.4	0.3534	2	0.7069
29	<i>Caesalpinia pulcherrima</i>	1	0.42	3.5	840	0.1052	5	0.5259
30	<i>Acacia auriculiformis</i>	1	0.72	8.3	581	0.5070	1	0.5070
31	<i>Ficus racemosa</i>	1	0.72	6.5	375.8	0.2568	1	0.2568
32	<i>Michelia champaka</i>	1	0.31	6	535	0.0626	4	0.2503
33	<i>Alstonia scholaris</i>	1	0.3	4.3	397.3	0.0312	8	0.2495
34	<i>Muntingia calabura</i>	1	0.46	4	300	0.0515	1	0.0515
35	<i>Ficus elastica</i>	1	0.2	7.8	607.1	0.0384	1	0.0384

**Table 3: Correlation with respect to location**

	<i>combined Avg. GBH (m)</i>	<i>Combined Avg. Height (m)</i>	<i>combined Avg. C seq. /tree</i>
<i>combined Avg. GBH (m)</i>	1	0.4946	0.8190
<i>Combined Avg. Height (m)</i>		1	0.5732
<i>combined Avg. C seq. /tree</i>			1

**Table 4: Regression statistics with respect to location**

<i>Regression Statistics</i>	
Multiple R	0.841555
R Square	0.708215
Adjusted R Square	0.671742
Standard Error	1.403381
Observations	19

**Table 5: Correlation with respect to tree species**

	<i>Avg. GBH (m)</i>	<i>Avg. Height (m)</i>	<i>Avg. C seq. /tree</i>
<i>Avg. GBH (m)</i>	1	0.5162965	0.892104078
<i>Avg. Height (m)</i>		1	0.566188655
<i>Avg. C seq. /tree</i>			1

**Table 6: Regression statistics with respect to tree species**

<i>Regression Statistics</i>	
Multiple R	0.900585
R Square	0.811053
Adjusted R Square	0.773264
Standard Error	1.202454
Observations	13

## CONCLUSION

Sequestering of CO<sub>2</sub> from the atmosphere by trees through photosynthesis is a natural, multi-beneficial and economically inexpensive method.

During the early 1980's, a massive tree plantation drive was carried out throughout the city (Neginhal, 2006) and most of the trees seen along the roadside of the city is an outcome of this drive. According to the study made by Ramachandra et al., 2014, there is one tree for every 7 persons and 32 to 55 trees per

person is needed in a region to mitigate respiratory CO<sub>2</sub> alone, implying that more trees are required to mitigate CO<sub>2</sub> released from numerous anthropogenic activities. According to the Karnataka State Remote Sensing Applications Centre, the total area under vegetation used to be around 12 % in 2000-01 but is drastically reduced now.(pradeep)

Younger trees grow faster hence better at sequestering carbon when compared to older trees. However, older trees with wide canopies provide other

facilities such as shade, cooling effect, habitat for birds and other tree-dwellers and so on., Roadside trees planted in the city were found to be supporting and attracting many birds, insects as most of the existing trees take turns in flowering throughout the year. In today's scenario finding land for a large scale tree plantation is challenging.

The authorities with the help and involvement of public, must try and recover green cover by planting more number of trees in available, barren spaces; along roadside where there are no trees and replace old/fallen trees. Existing trees must also be protected.

Pollution at lower strata is more than at higher strata as the former is prone to vehicular exhaust. Carbon can be sequestered by low lying vegetation cover (such as hedge plants, lawns and shrubs) more efficiently than high altitude trees. Hedge plants such as *Bougainvillea* and *Nerium* are known to be good sequesters.

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Aswath C- Principal Scientist, Laxman R H- Principal Scientist.

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