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Carbon flow in Delhi urban forest ecosystems

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ABSTRACT

There are more than 18,000 parks and gardens in National Capital Territory (NCT) spread in about 8000 ha in various locations throughout Delhi. These urban forests are recognized for their social, cultural recreational and aesthetic values apart from conserving the biodiversity of the region and improving local climate. As these green pockets are monitored, managed and protected strictly by Government agencies and possess moderate to high tree density hence has huge potential in contributing towards carbon sequestration. Estimate of carbon stocks and stock changes in tree biomass are necessary for reporting to UNFCCC and will be required for Kyoto Protocol reporting. Till date no data is available on the carbon stored by such green patches of utter importance in Delhi/NCR. Moreover, there is also a need to manage such areas from carbon sequestration point of view i.e. for short and long term carbon storage. In this modern world global warming and climate change has hit the centre stage and so tree-carbon accounting is gaining gradual attention among scientists and experts across the globe in recent times. In this backdrop carbon quantification of trees growing in parks of East Delhi was carried out. Thirty six parks (combined area 4.48 ha) were randomly selected for the study from Mayur Vihar-1 area which comes under east Delhi. 18 tree species including 2688 trees were recorded from 4.48 ha. The biomass and organic carbon of standing live trees was estimated by non destructive method. Stocking density came out to be 600.00 stems/ha. Above Ground Biomass came out to be 444.31 Tons while Below Ground Biomass was calculated as 66.65 Tons. Total Standing Biomass was calculated as 510.96 Tons. Total Organic carbon stored was 255.49 T. Data revealed that the urban forest patch considered for the study (4.48 ha) is a young forest (Av. DBH 21.31 cm) and thus has the ability to sequester more carbon in the coming years.

Keywords: Urban forest, Climate Changes carbon sequestration, UNFCCC, KP

INTRODUCTION

Many environmental functions of trees can be classified as ecosystem services because they benefit humans **[1]**. Urban trees in streets, gardens and parks-collectively the urban forest **[2]**- provide many ecosystem services to cities including offsetting carbon emissions through carbon storage and sequestration **[3]**. More than half of the world population lives in urban environment **[4]** and thus there is a growing interest and necessity in quantifying the ecosystem services of urban trees to develop a better understanding of the value of these services in cities and around the world **[5]**.

It is now evident that anthropogenic climate change is real and dangerous. Delhi is the most polluted city in the world and uncontrolled carbon emissions is posing serious questions to the developmental activities in this part of the world. The air quality is deteriorating which will has both short and long term implications on the overall health of the people in the city. Many efforts are being made to reduce atmospheric CO_2. The Kyoto Protocol, prepared by UNFCCC, stipulates Clean Development Mechanism (CDM) as its Joint Implementation (JI) whereby storage of carbon in various terrestrial sinks may be acceptable for insertion in national greenhouse gas inventories of each nation. Reducing GHG emissions including CO_2 can be achieved by controlling emissions and avoiding unadvisable land use changes. Carbon sequestration in growing trees is known to be a cost effective option for mitigation of global warming and global climate change. Estimation of carbon stocks and stock changes in tree biomass (above and below ground) are necessary for reporting to *United Nations Framework Convention on Climate Change* (UNFCCC) and will be required for *Kyoto Protocol* (KP) reporting **[6]**.

Significance of green pockets in urban ecosystems has been greatly acknowledged from time to time. Urban forests in the name of parks and gardens all across Delhi find a special place in the ecosystem dynamics of the city. To coordinate the management of parks/gardens in NCT, the Delhi State Government has formed a society namely Delhi Parks and Gardens Society registered under Societies Registration Act, 1860. This society functions under Department of Environment of Delhi Government.

There are more than 18000 parks and gardens in NCT spread in about 8000 ha in various locations throughout Delhi working towards environmental sanity. They play a vital role in mitigating CO_2 (an important GHG). As the tree grows and their biomass increase, they absorb carbon from the atmosphere and store it in plant tissues **[7]**, resulting in growth of different parts. The carbon is actively absorbed by the tree (in the form of CO_2) and is converted to biomass through photosynthesis using light energy from sun which is later transformed to chemical energy during the entire process. CO_2 is reduced to form sugars (biomass) and O_2 is released as a bi-product (photolysis of water). In terms of atmospheric carbon reduction, trees in urban areas offer the double benefit of direct carbon storage and stability of natural ecosystem with increased recycling of nutrient along with maintenance of climatic conditions by the biogeochemical processes **[8]**. Thus, policy makers has now started giving ample importance to manage and maintain the green pockets in the city for short term as well as long term carbon management. The agencies responsible for managing such places of utter importance are New Delhi Municipal Corporation (NDMC), Municipal Corporation of Delhi (MCD), Delhi Development Authority (DDA), Resident Welfare Associations (RWAs), etc.

Trees are important sinks for atmospheric carbon i.e. CO_2, since 50% of their standing biomass is carbon itself. Importance of forested areas in carbon sequestration is already accepted and well documented. But hardly any attempts have been made to study the potential of trees in carbon sequestration from urban areas. The main objective of this paper is to estimate sequestered carbon of different tree species in 36 parks of East Delhi, located at Mayur Vihar-1 (covering an area of approximately 4.48 ha) – moderate to high tree density and good management and monitoring practices predicts high carbon sequestration potential, contributing in reducing concentration of CO_2 in the atmosphere. The concept of carbon sequestration is first time reported in the present investigation.

MATERIALS AND METHODS

A) Study Area:

Delhi is located at 28°37’N 77°14’E/ 28.61°N 77.23°E and lies in north India. The city has a humid sub tropical climate. Temperature ranges from 5-40°C, annual mean temperature is 25°C. Delhi receives an annual rainfall ranging between 600-800 mm. The soil in this part of the city is mostly fertile and alluvial in nature. Vegetation of Delhi is thorny scrub which is peculiar to arid and semi-arid region.

B) Sampling strategy:

Thirty six parks (combined area 4.48 ha) were selected from Mayur Vihar-1, East Delhi area (where the first author lives). The parks exhibited wide range of sizes from a minimum of 0.03 ha up to a maximum of 0.48 ha. All these parks are monitored by MCD in association with RWAs. Random sampling method was used for sampling the above ground vegetation. Plot method was used, which is one of the most commonly used methods for all kinds of vegetation sampling. The method is versatile, cost-effective and applicable to baseline as well as project scenario. Plot Method is also among the methodologies approved by the CDM for afforestation and reforestation projects under the Kyoto Protocol. A total of 18 dominant species consisting of 2688 live and standing trees were sampled from an area of approximately 4.48 ha using (112) 20×20 m (0.04 ha) quadrates.

1) Diameter at Breast Height Measurement (DBH):
Biomass is an essential aspect of studies of carbon cycle **[9]**. There are two methods to calculate tree biomass, one is direct method and the other is indirect method **[10]**. Here indirect method for biomass estimation was used. Indirect methods are based on 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 **[11, 12].** Most of the research work revealed that AGB is strongly correlated with tree diameter **[13, 14]**. Also, it is accepted that simple model with only diameter as input is a good indicator of AGB **[15]**. Hence, in the present study we used allometric equation using tree diameter to estimate AGB (and BGB as well) following MacDicken **[16]**.

DBH $\geq$ 10 cm were considered as trees and measured. Initially GBH (cm) was taken which was later converted to corresponding DBH values. GBH of trees was measured directly by measuring tape. Average DBH per species was worked out for all 18 species separately (using dbh class) for mean biomass calculation (Table 1). This mean biomass was multiplied with the number of individuals of that particular specie to get the total biomass (Table 2).

2) Above ground biomass (AGB), belowground biomass (BGB) and Total Biomass (TB) of trees:
Mathematical equation used was:

- **$Y= 34.4703-8.0671D + 0.6589D^2$ ……………..(i)**
-

Where Y is the Above Ground Biomass (Kg) and D is the DBH (cm).
The above general equation is used for dry climates (annual rainfall<1500 mm), hence can be used for Delhi where the average annual rainfall ranges between 600-800 mm.
BGB is considered 15% of the AGB

- **BGB = AGB x (15/100)………………….(ii)**
-

Total Biomass is the sum of the above and below ground biomass **[17]**.

- **Total Biomass = Above ground Biomass + Below ground biomass…………(iii)**
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3) Carbon stock estimation:
Generally for any plant species 50% of its biomass as carbon **[18]**

- **Carbon Storage = Biomass x 50% OR Biomass/2**

RESULTS AND DISCUSSION

Total 18 species consisting of 2688 individuals were recorded from thirty six parks in Mayur Vihar-1, East Delhi covering an area of approximately 4.48 ha. Table 1 demonstrates total number of trees of each species and total number of trees present in the area. It also indicates the average DBH in cm. From the above statistics we can conclude the ecological significance of these tree species. As the diameter of the tree increases, its biomass and carbon storage capacity increases, also sequester more carbon and remove CO_2 from the atmosphere. List of species and their above ground, below ground and total biomass with carbon is given in table 2. The organic carbon sequestered in per species is also shown for comparison purpose. Total standing biomass of 2688 trees came out to be 510.96 Tons and total carbon stored was 255.49 Tons. *F. bengalensis* dominated the list having 105 trees and sequestered 24.62 Tons of carbon in its standing biomass followed by *A. indica* (23.49 T) and *B. ceiba* (21.59 T). Least carbon (3.63 T) was sequestered by *C. dichotoma*. The average DBH of 18 tree species was calculated as 21.31 cm which reflects a young forest therefore has a high tendency to sequester more carbon in the coming years i.e. has sufficient time to reach the climax stage. Regression and correlation of the data revealed that the AGB so obtained is strongly correlated with DBH i.e. AGB as a function of DBH showed high correlations (r^2 = 0.93). Thus, summing it up, it can be predicted that Delhi green cover provides benefits such as carbon sequestration and storage along with reduction in air pollution. Keeping this in mind, the need for evaluating and assessing the trees in parks and gardens in an urban ecosystem has become imperative. Urban forest plays a significant role in carbon mitigation and thus needs to be effectively monitored, managed, protected and extended to achieve sustainable development goals.

Table 1: Field data of trees from study area

S. No.	Scientific Name	Common/English Name	No. of Trees	Av. DBH (cm)
1.	*Azadirachta indica*	Neem	167	25.0
2.	*Alstonia scholaris*	Devil Tree	104	23.3
3.	*Bombax ceiba*	Semal	139	26.0
4.	*Cassia fistula*	Amaltash	174	21.7
5.	*Dalbergia sisso*	Shisham	235	16.5
6.	*Ficus religiosa*	Peepal	75	28.8
7.	*Polyalthia longifolia*	Ashok	220	20.5
8.	*Pongamia pinnata*	Karanj	142	21.6
9.	*Tamarindus indica*	Imli	176	23.0
10.	*Ficus bengalensis*	Bargad	105	30.7
11.	*Acacia auriculiformis*	Auri	152	14.3
12.	*Syzygium cumini*	Jamun	117	17.6
13.	*Bergera koenigii*	Meetha neem	124	16.5
14.	*Crateva adansonii*	Barna	132	22.8
15.	*Acacia nilotica*	Babool	137	24.0
16.	*Morus alba*	Sehtoot	139	15.9
17.	*Cordia dichotoma*	Lasora	165	12.7
18.	*Terminalia bellerica*	Baheda	185	22.6
			2688	

Table 2: Biomass conversion to Carbon stock in 18 different tree species

Scientific Name	AGB (kg)	BGB (kg)	TB (Kg)	C (kg)	C (Tons)
Azadirachta indica	40849.09	6127.36	46976.45	23488.23	23.49
Alstonia scholaris	21238.58	3185.79	24424.37	12212.19	12.21
Bombax ceiba	37549.75	5632.46	43182.21	21591.11	21.59
Cassia fistula	29524.96	4428.74	33953.7	16976.85	16.98
Dalbergia sisso	18975.94	2846.39	21822.33	10911.17	10.91
Ficus religiosa	26149.19	3922.38	30071.57	15035.79	15.04
Polyalthia longifolia	32119.45	4817.92	36937.37	18468.69	18.47
Pongamia pinnata	23804.50	3570.68	27375.18	13687.59	13.69
Tamarindus indica	34757.38	5213.61	39970.99	19985.50	19.99
Ficus bengalensis	42820.78	6423.12	49243.90	24621.95	24.62
Acacia auriculiformis	8185.08	1227.76	9412.84	4706.42	4.71
Syzygium cumini	11301.05	1695.16	12996.21	6498.11	6.50
Bergera koenigii	10012.84	1501.93	11514.77	5757.39	5.76
Crateva adansonii	25484.32	3822.65	29306.97	14653.49	14.65
Acacia nilotica	30192.92	4528.94	34721.86	17360.93	17.36
Morus alba	10116.41	1517.46	11633.87	5816.94	5.82
Cordia dichotoma	6318.20	947.73	7265.93	3632.97	3.63
Terminalia bellerica	34908.32	5236.25	40144.57	20072.29	20.07
	444308.80	**66646.33**	**510955.10**	**255477.60**	**255.49**

CONCLUSION

The authors are of the opinion that a complete carbon sequestration mapping for the entire city (along with NCR region) should be conducted, also incorporating trees located on either sides of roads and passages to get a more clear picture of the role played by such green areas in carbon offsetting.

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