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Assessing The Carbon Sequestration Potential of Various Parks in Bhopal City

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ABSTRACT:

Carbon sequestration, the process by which carbon dioxide (CO_2) is removed from the atmosphere and stored in terrestrial, aquatic, or geological reservoirs, is increasingly recognized as a critical strategy for mitigating climate change. This study investigated the carbon sequestration and storage capabilities of trees planted in the green spaces of Bhopal city. Given that large trees were the primary focus, urban gardens and green spaces possess significant potential to absorb carbon from the atmosphere and mitigate the effects of climate change in urban areas. From Bhopal city, nine green gardens were chosen in total. The purpose of this study was to evaluate various green spaces of Bhopal city and their capacity to sequester carbon for the purpose of better urban planning in the future. Using a non-destructive technique, the above ground biomass (AGB) and below ground biomass (BGB) were estimated. The results of the parks studied show that the Van Vihar with its huge area housing multiple varieties of trees, plants, shrubs and grasses is acting as major carbon sink for the city of Bhopal by sequestering total amount of 231547.6019 kg of carbon per species of tree. Even smaller parks like Mayur Park, Rose Garden and Titli Park are sequestering significant amount of CO_2 i.e.,18461.95272 kg,6869.636724kg, and 35977.83201 kg respectively.

1. INTRODUCTION

The increasing levels of atmospheric carbon dioxide (CO2) are widely acknowledged as a key factor driving the increasingly evident changes in global climate conditions. About 71% of energy related emissions is caused due to human activities in cities (Wang et. al 2021). Carbon sequestration is the process of removing carbon dioxide from the atmosphere by storing it as carbon. Soil, leaves, and forest trees all function as carbon sinks (Sedjo, 1999). One effective strategy for reducing greenhouse gas emissions and combating climate change is carbon sequestration.

Standing forests, understory vegetation, leaf and forest debris, and forest soils are important repositories of the world's terrestrial carbon (Ali et al., 2023). "Source" refers to a stock that releases carbon, and "sink" refers to a stock that absorbs carbon (Luyssaert et al., 2008).According to Green and Byrne (2004), carbon "fluxes" are the movements of carbon from one stock to another, such as the sequestration of carbon from the atmosphere into forests. Plants are able to sequester carbon dioxide from the atmosphere, allowing it to be stored for a very long time in terrestrial ecosystems. In terms of live biomass, plants store carbon for the duration of their lives (Gayathri et al., 2021). They are ornamental and valuable. Plants and trees serve as atmospheric carbon sinks since they contain 50% of their total biomass in carbon (Ravindranath et al., 1997). Carbon sequestration is the annual rate at which trees store carbon dioxide during one

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growth season (as above and below ground biomass). Tree sequestration is influenced by their growth rate and lifetime, which are influenced by their age, species, and surroundings. Trees are essential, and their ability to sequester carbon has been widely established and proven (Tiwari and Singh, 1987).

Trees play a vital role in India's carbon sequestration process, which is necessary to avert climate change. When trees grow, the carbon dioxide they absorb from the environment is transformed into organic matter and stored in their trunks, branches, and leaves (Sharma et al., 2021).The varied topography of India is home to a wide variety of tree species that provide this vital function. The active storage of carbon by iconic trees contributes significantly to the reduction of greenhouse gas emissions (Nandal et al., 2023). Some examples are the revered banyan, the common sal, and the towering teak. Furthermore, the nation's profusion of mango, neem, peepal, and jamun trees contributes to this natural carbon capture process, bolstering India's resolve. In addition to serving as recreational areas, Bhopal's parks serve as essential green spaces that allow residents and visitors to connect with nature and find tranquility amidst the hustle and bustle of the city. The visual attractiveness of these parks is enhanced by the mix of exotic and native trees and plants.

2. METHODOLOGY

The stock-change method, which estimates the amount of carbon sequestered as the net change in carbon stocks over time, works well for estimating net carbon flows for forests. The amount of living material, present in a component population at any time, may be expressed in terms of numbers or weight per unit area. Biomass is the standing crop expressed in terms of weight (i.e., organism mass) of the living matter present. The biomass of a tree includes above ground biomass which include all above ground living materials (stem, branches and leaves) (Marland&Marland, 1992). and below ground or root biomass which consist of coarse roots and stumps (Laclau, 2003). The radius of the trees was calculated using Girth at breast height (GBH). These measurements were then used to calculate the carbon stock which represents their carbon sequestration potential.

2.1 Study area:

The coordinates of Bhopal city are latitude 23.259933, longitude 77.412613. Its average elevation is 1,401 feet, or 500 meters. It is situated in the center of India, directly north of the Vindhya Mountain ranges' upper boundary. The Old City, New Bhopal and its outgrowth, and the BHEL campus are the three main zones into which the city of Bhopal can be broadly divided, each with their own set of features. Old Bhopal is recognized as the original settlement of the city and exhibits an unplanned growth pattern. Compared to the other two zones, there is significantly less urban green space in the old city. There are very few large green spaces that are intertwined with imposing structures or steep hills that are inaccessible for leisure. Development plans led to the creation of New Bhopal, where a wealth of green spaces can be found in the form of national parks, regional parks, city parks,

The goal of the study was to assess the trees planted in Bhopal's urban areas for their capacity to sequester carbon. The trees in these green areas improve the city's aesthetic appeal, reduce pollution, and supply clean air (Lee et al., 2015).Choosing tree species with consideration and sustainability could help improve the city's overall air quality (Hewitt et al., 2020).

Following nine parks having different tree species is selected for the study:

1. Birla Mandir Park: Saraca asoca, Mangifera indica, Eucalyptus globules, Azadirachta indica, Delonix regia.
2. Chinar Park: Cassia grandis, Dalbergia sissoo, Mangifera indica, Sterculia foetida, Azadirachta indica, Eucalyptus globules, Neolamarckia cadamba, Pithecellobium dulce, Alnus firma, Salix Caprea, Saraca asoca.
3. Kamla Park: Saraca asoca, Dypsis lutescens, Ficus religiosa, Ficus benjamina, Azadirachta indica, Serianthes grandiflora, Drypetes deplanchai, Betula utilis, Mangifera indica, Ficus benghalensis, Syzygium cumini.
4. Mayur Park: Saraca asoca, Azadirachta indica, Dypsis lutescens, Mangifera indica, Neolamarckia cadamba, Putranjiva roxburghii, Magnolia champak, Cassia fistula, Ficus benjamina, Ficus benghalensis.
5. Rose Garden: Eucalyptus globules, Acacia nilotica, Mangifera indica, Phyllanthus emblica, Neolamarckia cadamba, Bambusa vulgaris, Lagerstroemia speciosa, Moringa oleifera, Dypsis lutescens.

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6. Sair Sapata Park: Eucalyptus globules, Dalbergia sissoo, Vachellia nilotica, Dypsis lutescens, Azadirachta indica, Salix babylonica, Ficus benghalensis, Delonix regia.
7. Shaurya Smarak Park: Eucalyptus globulus , Acacia nilotica , Mangifera indica , Phyllanthus emblica , Neolamarckia cadamba, Bambusa vulgaris , Syzygium cumini , Holoptelea integrifolia , Cassia fistula , Azadirachta indica , Dypsis lutescens.
8. Titli Park: Pongamia pinnata, Vachellia nilotica, Butea monosperma.
9. Vann Vihar: Azadirachta indica, Schleichera oleosa, Mangifera indica, Bambusa arundinacea, Crateva religiosa, Ficus racemosa, Vachellia nilotica, Dalbergia sissoo, Acacia leucophela, Eucalyptus globules, Phyllanthus emblica, Prosopis cineraria, Butea monosperma, Adina cordifolia, Holoptelea integrifolia, Pongamia pinnata, Cassia fistula, Tamarindus indica, Pterospermum acerifolium, Pithecellobium dulce, Madhuca Indica, Shorea robusta, Syzygium cumini, Tectona grandis, Ficus benghalensis, Terminalia elliptica, Peltophorum pterocarpum, Ziziphus jujube, Elaeodendron glaucum, Pterocarpus marsupium, Lannea grandis, Mitragyna parvifolia, Lagerstroemia parviflora, Terminalia belliric, Bixa orellana**.**

2.2 Sampling and Method

In larger parks, the number of trees was determined by park authorities through data collection; in smaller parks, tree counts were conducted by hand. Urban trees total biomass, total carbon stored, and CO_2 removed were measured and compared using allometric model/volume equations.

Every tree was measured if the count was less than or equal to ten. To make things simpler, a random sampling procedure was applied to the species of trees that had more than ten in a single park. This involved measuring ten percent of representative trees and providing a 95% confidence interval for the measurements (Brown, 2007).

1. Measurement of Girth at breast height (GBH) and tree height:

The biomass of the tree was estimated on the basis of Girth at breast height (GBH) and tree height. GBH can be determined approximately 1.3 meter above the ground. The GBH of trees having the diameter greater than 10 cm were measured directly by the measuring tape. The tree height measured by the Theodolite instrument.

2. Above ground biomass (AGB) of trees:

The above ground biomass of the tree includes whole shoot, branches, flowers, leaves and fruits. It is calculated using the following formula (Potadar Vishnu R et. al, 2017).

$$AGB\ (kg) = \text{volume of tree}\ (m^3) \times \text{wood density}\ kg/m^3$$

$$V = \pi r^2 H$$

Where H = Height of the tree in meter,

V= volume of the cylindrical shaped tree in m^3,
r = radius of the tree in meter, Radius of the tree is calculated from GBH of tree.

Height was measured with the help of the instrument Theodolite. The wood densities were obtained from the website www.worldagroforestycentre.org. The standard average density of 0.6 gm/cm^3 was applied wherever the density value is not available for tree species (A.N. Djomoa et. al., 2010).

3. Estimation of the Below Ground Biomass (BGB):

The Below Ground Biomass (BGB) includes all biomass of live roots excluding fine roots having < 2 mm diameter. The below ground biomass was calculated by multiplying AGB by 0.26 factors as the root: shoot ratio. BGB is calculated by following formula .

$$BGB\ (kg/tree) = AGB\ (kg/tree) \times 0.26$$

4. Estimation of Total Biomass (TB):

Total biomass is calculated by adding Above Ground Biomass and Below Ground Biomass.

$$TB = AGB + BGB\ (kg/tree).$$

5. Carbon Content Estimation:

Usually, 50% of a plant's biomass is considered as its carbon content.

We calculated Carbon content by the following formula

$$\text{Carbon content} = \text{Total Biomass} \times 50\ \%$$

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6. Estimation of Sequestered Carbon dioxide in the tree:

The weight of CO_2 sequestered was calculate by finding the weight of carbon in CO_2, i.e.,

C + 2 X O = 43.99915

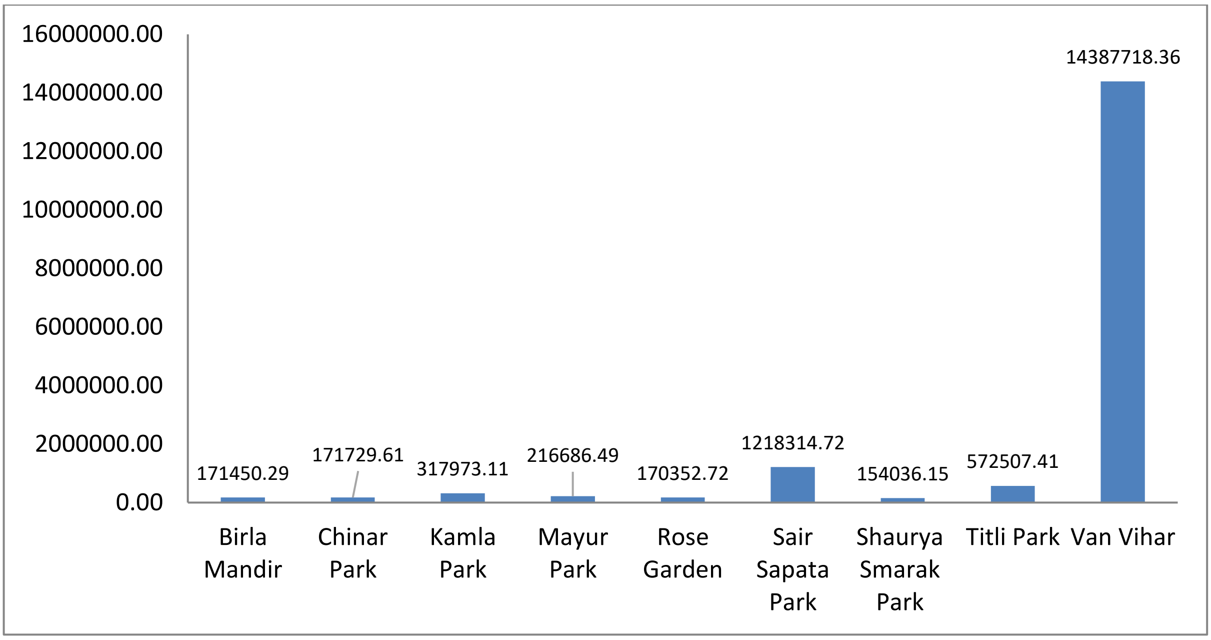
The ratio of CO_2 to C is: 43.99915/12.001118 = 3.6663. Hence, to find out the weight of CO_2 sequestered by a tree we multiply the weight of carbon content with 3.663.

3. RESULT AND DISCUSSION

The urban parks in Bhopal play a crucial role in mitigating pollution, with Van Vihar standing out as a notable contributor. Its expansive area and numerous trees make it a significant carbon sink, sequestering substantial amounts of CO_2. Nevertheless, even smaller parks such as Titli Park and Rose Garden exhibit notable CO_2 sequestration capabilities. This suggests that beyond the sheer number of trees, the selection of tree species is a crucial factor in enhancing CO_2 absorption. The data presented in Table 1 and Graph 1, illustrating the carbon sequestration capacity of various parks in Bhopal. The collective efforts of these parks result in the sequestration of a noteworthy 17,380.77 tons of CO_2, contributing significantly to the improvement of air quality in Bhopal and fostering a cleaner and more breathable environment.

Table 1 Total CO_2 Sequestered by urban parks of Bhopal

S.No.	Name of Parks	Total Area (Approx.) in Acres	Volume (m^3)	Biomass (kg/tree)	Total Carbon Sequesterd (in kg)
1	**Birla Mandir**	7.5	6.09	4914.27	171450.3
2	**Chinar Park**	32	6.8	5442.48	171729.6
3	**Kamla Park**	7.5	63.78	38726.7	317973.1
4	**Mayur Park**	3.19	15.23	10080.22	216686.5
5	**Rose Garden**	3.2	4.75	3750.84	170352.7
6	**Sair Sapata Park**	24.56	59.98	46524.74	1218315
7	**Shaurya Smarak Park**	18.75	4.24	3770.86	154036.1
8	**Titli Park**	7.4	17.48	19643.92	572507.4
9	**Van Vihar**	1100	146.44	126425.1	14387718
	TOTAL	1204.1	324.79	259279.13	17380768.7



Graph 1. Carbon sequestration (in kg) by all parks in Bhopal

Van Vihar, characterized by its expansive area and diverse array of trees, plants, shrubs, and grasses, functions as a significant carbon sink for the city of Bhopal. It demonstrates substantial carbon sequestration, accumulating a total of 14,387,718 kilograms of carbon per species of tree. Notably, smaller parks such as Mayur Park, Rose Garden, and Titli Park also play a meaningful role in CO_2 sequestration, with respective quantities of 216,686.5 kilograms, 170,352.7 kilograms, and 572,507.4 kilograms. These findings underscore the collective impact of both large and small urban parks in mitigating carbon emissions and contributing to the overall environmental well-being of Bhopal.

The cumulative above-ground biomass across the nine parks under study, covering a total area of 1204.1 acres, was determined to be 259,279.13 kilograms. As per the data in Table 1, which outlines the carbon sequestration estimates, the total carbon stored in the trees within these parks amounts to 17,380,768.7 kilograms. Van Vihar Park emerges as the leading carbon storage entity, housing a maximum of 14,387,718 kilograms of carbon, followed by Sair Sapata Park with a carbon storage of 1218315 kilograms. In comparison, study reports a higher carbon storage of 337,000 tons (33.22 tons/ha) in the urban forests of Shenyang (Liu and Li, 2012).The relatively lower carbon values in the trees of the current study area can be attributed to their lower biomass.

4 CONCLUSION

The current study undertook an assessment of both above- and below-ground biomass of trees within accessible urban parks in select areas of Bhopal city. A broader survey of emissions in Bhopal indicates an annual release of 1.65 million tons of CO2, along with other pollutants such as SO2 (Sulphur dioxide), CO (Carbon monoxide), among others. The recorded urban average ambient PM2.5 concentration stands at 49.9 ± 6.7 µg/m3, approximately five times higher than the WHO recommendation ("City - Bhopal, India -," n.d.). The trees in Bhopal's urban parks collectively sequester 17,380.7687 tons of CO_2, signifying a substantial role in pollution mitigation by functioning as effective carbon sinks.

In conclusion, the strategic selection of tree species with high CO_2 sequestration capabilities for the development of parks, even those with limited space, can significantly contribute to mitigating carbon dioxide pollution in areas characterized by high population density, increased transportation activities, and industrial emissions. This approach holds the potential to enhance air quality and address environmental challenges in urban settings.

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