



Original article

Carbon sequestration potential of trees from urban green spaces of Kolhapur city, Maharashtra, India

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ABSTRACT

This study was an investigation into the carbon storage and sequestration of trees grown in the green spaces of Kolhapur city, Maharashtra. Urban gardens and green spaces, mainly considering big trees, have a great potential to sequester carbon from the atmosphere and to mitigate the impacts of climate change in cities. Total ten green pockets (gardens) were selected from Kolhapur city. This study was a sustainability initiative to inventory tree species from the green pockets and to assess their carbon sequestration potential for improved urban planning in the future. The above ground biomass (AGB) and below ground biomass (BGB) were estimated by a non destructive method. This included the measurement of tree height and diameter. A total of 29 species of trees were recorded during the study with a storage potential of 688.77 tons of carbon dioxide. *Polyalthia longifolia* was found to sequester maximum carbon dioxide (CO₂) followed by *Albizia saman* and *Mangifera indica*. This research highlights the role of urban forests or green spaces and gardens, not only as ornamental and aesthetic plantations but also for mitigating the impacts of climate change at a local level. Well planned urban spaces and urban trees have a major role as green vegetation cover which can act as a carbon sink with high potential which will help in policy making and decision making in the future.

KEY WORDS: Above Ground Biomass; Below Ground Biomass; urban green spaces; urban trees, carbon restoration

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1. Introduction

Cities are generally places of rapid economic expansion and development in any country. The rapid increase of urbanization and industrialization has an impact on the amount of green space in cities which leads to decrease in the vegetation cover. Change in lifestyle, developmental activities, and urbanization are affecting the vegetation cover of Kolhapur city in Western Maharashtra, India.

Urban areas contribute close to half of India's gross domestic product today, but rapid urbanization is a major driver of global change, driving land use change, habitat loss, biodiversity decline, climate change, and causing pollution both within and outside the city (SATTERTHWAITE, 2010). The waste products from factories and industries are responsible for the accumulation of various toxic pollutants, including greenhouse gases (GHGs), in the atmosphere which are one of the reasons

responsible for loss of local biodiversity in the region. This accumulation of human enhanced GHGs also leads to changing temperature, harsh climatic conditions, global warming and climate change. A report published by International Council of Local Environmental Initiatives (ICLEI), South Asia, has stated that average per capita carbon emissions are higher in the metropolitan cities of India, being 1.19 tons per capita, as compared to only 0.90 tons per capita in the non-metropolitan cities (SHARMA ET AL., (2021). Any infrastructural activities including industrial and urban and transportation cause the emission of large concentrations of GHGs into the atmosphere, among which CO₂ plays a major role in absorbing outgoing radiation and contributes to about half of the greenhouse effect which leads to global warming and resultant climate change. The concentration of CO₂ in atmosphere has increased from 278 ppm, during the pre-industrial period (TAK ET AL., 2020) and globally averaged concentrations for CO₂ reached a new high of 413.2 ppm in 2020 (GREENHOUSE GAS BULLETIN, 2021). Increasing carbon emissions is of major concern and was addressed in the Kyoto Protocol and United Nations Framework Convention on Climate Change (UNFCCC). According to the INDIAN INFRASTRUCTURE REPORT (2010), reduced energy demand, altered energy use, or increased rates of CO₂ removal by trees through carbon sequestration can reduce atmospheric carbon dioxide concentrations.

UGLE (2010), mentioned that the terms urban forest and urban green spaces include trees in gardens, parks, and alongside streets, roads, canals, etc and these spaces provide a variety of ecosystem services such as improving air quality. The research done by SINGH (2018), states that urban green spaces buffer noise pollution, are sites of biodiversity conservation, mitigate the Urban Heat Island effect, regulate local climate, stabilization of soil, ground water recharge, prevention of soil erosion and carbon sequestration by SHAH (2017) as well. Carbon sequestration is a natural process for the removal of carbon from the atmosphere into stores in the biosphere (CHAVAN & RASAL, 2010). The CO₂ in the atmosphere is absorbed by carbon sinks and stored as carbon. Trees act as sinks for CO₂ by fixing carbon during photosynthesis and storing excess carbon as biomass (NOWAK, 2002). More the photosynthesis

process done, lead to further absorbing of atmospheric CO₂ being transformed into biomass. It reduces atmospheric carbon and sequesters it in above and below ground plant tissues which also enrich the essential carbon related element for plant growth. The carbon pools of terrestrial ecosystem are biomass, above-ground biomass, below-ground biomass, dead wood, and litter and soil organic matter. The vegetation and soil of green spaces cannot only sequester carbon, directly contributing to reduction in atmospheric CO₂ concentration, but also affect the carbon balance indirectly, through their effect on the urban energy balance and thus on CO₂ emissions related to energy use (CHURKINA, 2016).

Trees have been planted and cultivated in towns and cities all over the world since the dawn of civilization. Hence, the landscapes in urban areas with vegetation can be terrestrial carbon sinks for urban ecosystems. As the developing countries are trending towards fast urbanization, these green spaces including urban trees can be latent mitigation sinks of atmospheric, as well as anthropogenic CO₂ by terrestrial carbon sequestration. Trees from urban regions currently store carbon, which can be released back into the atmosphere after the death of the tree, and capture carbon as they grow (POTDAR ET AL., 2017). Trees from urban areas, also influence the air temperatures and reducing the traditional energy use, which consequently alter carbon release from numerous urban sources (ABDOLLAHI ET AL., 2000). Thus, urban trees potentially influence climate at the local level, its related carbon cycle, and total energy use and which leads to minimizing the climate change effect (ABDOLLAHI ET AL., 2000; WILBY ET AL., 2006; GILL ET AL., 2007; NOWAK, 2010; LAL ET AL., 2012).

Terrestrial vegetation and soil currently absorb 40% of global carbon dioxide (CO₂) emissions from human activity (ADAM, 2001). There is growing concern about climate change, and problems concerned with this have led to research quantifying the overall effects of trees on atmospheric carbon dioxide (CO₂) within urban area (MCPHERSON, 1998; JO, 2002; NOWAK ET AL., 2002; ESCOBEDO ET AL., 2010). HARIPRIYA (2000) and CHHABARA ET AL., (2002) studied that trees growing stock based estimation of biomass and carbon stock is the reliable and valuable source for the estimation of

carbon sequestration potential. The Kyoto protocol from the climate convention recognized that drawing CO₂ from the air and storing it as biomass is the only practical way to mitigate of the gas from the atmosphere (BHADWAL ET AL., 2002). The estimation of tree carbon sequestration is dependent on species, mortality and growth characteristics, as well as their overall condition. In terms of reducing atmospheric carbon, trees in urban areas give a double advantage by directly storing carbon and reducing CO₂ emissions from urban areas, stabilizing natural ecosystems and preserving climatic conditions through the biogeochemical process. The well-planned sustainable management of urban trees with the objective of carbon sequestration, while paying attention to the protection of biodiversity is the need of current time to protect our Mother Earth by capturing emitted CO₂ with the help of natural and low cost method.

This study focused on the carbon storage and carbon sequestration potential of native and dominant woody trees from the green spaces of Kolhapur City, Maharashtra for sustainable planning and management of the urban green spaces. This study highlights the need for finding of ecological unit like big trees with high carbon sink capacity as the sustainable mitigation strategy to terrestrial carbon sequestration to tackle human induced global warming risk from emission of greenhouse gases (GHGs). Planting native tree species in public gardens can increase their ability to absorb atmospheric CO₂ in terms of storing more carbon than that of exotic species, with an emphasis on native solution.

2. Methodology

2.1. Study area

Kolhapur city is one of the historic and culturally significant cities of Maharashtra, India, lying along the banks of the River Panchganga. Kolhapur is located 574 meters above mean sea level and is spread across an area of 66.82 km². The city is situated between 16°46' and 16°39' North and

74°11' and 74°17' East. Kolhapur ranges across the Deccan plateau in the rain shadow region of the Sahyadri mountain range which is present at the southernmost tip of Maharashtra state, India. The city experiences three distinct seasons in the year summer, monsoon and winter. Its elevation above mean sea level and its leeward position in relation to the Western Ghats generate a moderate and healthy climate. The average temperature is about 27°C with a minimum of 15°C and a maximum of 40°C. Three quarters of the annual rainfall of 1025 mm occurs between June and September which is about 65 days each year. The relative humidity of the atmosphere is about 55%. The city is governed by Kolhapur Municipal Corporation (KMC). All the green spaces i.e., gardens, are managed by the KMC governance except for 3 gardens. For this study, ten gardens were selected by stratified random sampling method in which city is divided into five wards. Based on the major areas occupied by the gardens of the city, study site were selected for the estimation of carbon storage and carbon sequestration potential of woody trees (Fig. 1).

2.2. Measurement of tree height and diameter at breast height (DBH)

To estimate the biomass of different trees in the gardens, a non-destructive method was used. The biomass of each tree was based on the tree height and its diameter at breast height (DBH). The DBH was determined by measuring tree Girth means circumference at Breast Height (GBH), approximately 4 feet i.e. 1.3 meters, above ground. The GBH of tree was divided by the π value to calculate DBH. The GBH of trees with a diameter greater than 10 cm were measured directly using a measuring tape (HANGARGE ET AL., 2012) and height was measured by stick method (AF TREE-MEASURING GUIDELINES HANDBOOK, 2014). In this method to Measure the height of a tree using a yardstick, starting at F and moving back until an inch covers F. Estimate the tree's tip, subtract the second reading, and multiply by F to find the tree's height (Fig. 2).

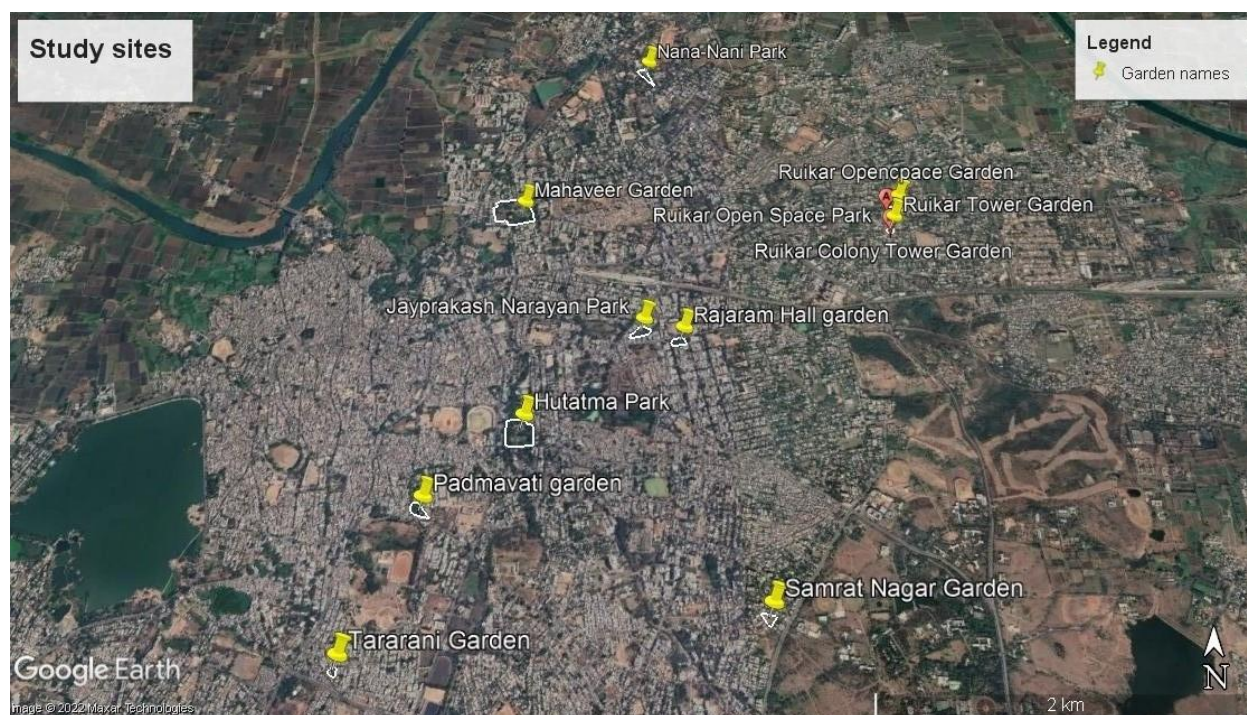


Fig. 1. Map of the study sites showing the gardens of Kolhapur, Maharashtra (Source: Google Earth)

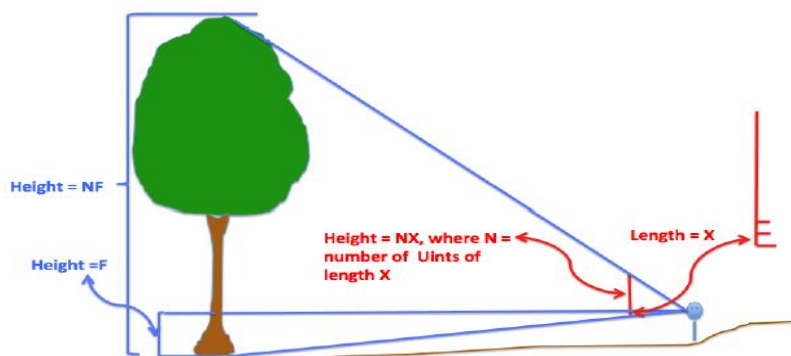


Fig. 2: Measurement of tree height (Source: American Forest Tree Measuring Guidelines handbook, 2014)

2.2.1. Estimation of biomass, carbon stock and sequestered CO₂

To estimate the biomass of trees a non – destructive method was used. Total biomass includes above and below ground biomass known as AGB and BGB and it was calculated using the volume of the tree (BANDANA GUPTA ET AL., 2014). The wood densities were obtained from wood density database of world agroforestry centre; where the wood density of tree species was unavailable, the standard average value 0.6gm/cm³ were taken (RAVINDRANATH & OSTWALD, 2008).

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

$$\text{Volume } V = \pi r^2 h$$

where, V = Volume of cylindrical shaped tree in m³
 r = Radius of tree in meters
 h = Height of tree in meters

All biomass from live roots is considered was below ground biomass with the exception of roots with a diameter of less than 2 mm. The below ground biomass was calculated by multiplying AGB by a factor of 0.26 as the root: shoot ratio method by POTDARE ET AL., (2017). BGB was calculated

using method proposed by MACDIKEN (1997), HANGARGE ET AL. (2012), POTDAR ET AL. (2016).

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

In addition, total biomass was calculated as,

$$\text{Total Biomass (kg)} = \text{above ground biomass (AGB)} + \text{below ground biomass (BGB)}$$

WESTLAKE (1963), observed that there is 47% carbon present in dry biomass, while IPCC (1995) reported that the carbon present in biomass is 45% (IPCC, 1995). Generally, for any species of plant 50% of its biomass is considered to be carbon (PEARSON ET AL., 2005). Therefore,

$$\begin{aligned} \text{Carbon storage} &= \text{Biomass} \times 50\% \text{ or Carbon} \\ \text{stock} &= \text{Biomass} / 2 \end{aligned}$$

Two atom of oxygen and one carbon atom make up the molecule carbon dioxide (CO₂). The ratio is 43.99/12.00 i.e., 3.66, hence to calculate the weight of carbon dioxide sequestered by the tree the carbon stock is multiplied by 3.66.

3. Results and discussion

This study was carried out in the of Kolhapur city, Maharashtra region to assess carbon sequestration potential of trees in selected green pockets by stratified random method with non-destructive approach. The observations and findings were used to analyze the potential and role of trees in green spaces for reducing atmospheric CO₂. This study estimated carbon sequestration in randomly selected green spaces of Kolhapur containing 638 trees belonging to 29 species (Table 1).

The total biomass was 377.28 tons and total carbon storage by trees was 188.64 tons. The total carbon sequestration of trees was 692.31 tons.

Cassia siamea was the dominant native tree species in the green spaces followed by *Pongamia*

pinnata and *Mangifera indica*. As in a survey performed in Delhi by the Ministry of Environment, Forest and Climate Change, GOI; *Ficus religiosa*, *Syzygium cumini*, *Azadirachta indica*, *Mangifera Indica*, *Tamarindus indica* are the native tree species found useful to combating pollution (MoEFCC, 2018) and they also have ecological value in the environment. All these species were reported in the study area. *Polyalthia longifolia* is a dominant exotic tree species then *Hyophorbe lagenicaulis*, *Delonix regia* and *Spathodea campanulata* within the study area. These exotic species are used as ornamental trees and contribute the beautification of green spaces in the city. *Delonix regia*, *Spathodea campanulata*, *Albizia saman*, *Grevillea robusta* are mostly considered to be avenue trees and have also been planted road sides in the city. A total 638 woody trees were counted in the study area and the ratio of native trees to exotics in the population is approximately 1:2.16. A total of 29 tree species were enumerated and the ratio of native to exotic tree species is 14:15 i.e. 1:1 approximately in the study area. The use of a greater variety of native indigenous species in reforestation may improve the resilience of urban ecosystems, decrease sensitivity to pest and diseases, and increase functional diversity (BENAYAS ET AL., 2009; HOOPER ET AL., 2005; RODRIGUES ET AL., 2009).

Approximately 68% of the total trees counted were exotic species while the remaining 32 % were native species. A total of 436 exotic trees were enumerated during the study. Among them *Polyalthia longifolia* (248) was the most dominant tree species followed by *Hyophorbe lagenicaulis* (24) and *Delonix regia* and *Spathodea campanulata* each with 22. A total of 202 native trees were enumerated during the study of which *Cassia siamea* (52) was dominant species followed by *Pongamia pinnata* (24) and *Mangifera indica* (20) (Fig. 3).

Table 1. CO₂ sequestrated by trees from green pockets of Kolhapur city, Maharashtra, India

Sr. No.	Scientific Name	Common Name	Native/ Exotic	Avg Height m $\pm$ S.D.	Avg GBH m $\pm$ S.D.	Avg Volume m ³ $\pm$ S.E.	Avg AGB kg	Avg BGB kg	Avg TB kg	Avg Carbon stock kg	Avg CO ₂ kg	Total CO ₂ sequestrate d ton	Tree Count
1	<i>Terminalia catappa</i>	Badam	Native	9.17 $\pm$ 3.68	0.80 $\pm$ 0.43	0.74 $\pm$ 0.22	244.4	63.54	307.94	153.97	563.54	11.3	20
2	<i>Plumeria alba</i>	Chafa	Exotic	5.44 $\pm$ 2.49	0.81 $\pm$ 0.49	0.50 $\pm$ 0.27	224	58.24	282.24	141.12	516.5	11.3	7
3	<i>Pongamia pinnata</i>	Karanj	Native	4.99 $\pm$ 1.72	0.49 $\pm$ 0.24	0.68 $\pm$ 0.05	54.81	14.25	69.06	34.53	126.38	3.04	24
4	<i>Azadirachta indica</i>	Neem	Native	9.66 $\pm$ 3.54	1.08 $\pm$ 0.53	1.19 $\pm$ 0.23	621	161.46	782.46	391.23	1431.9	24.41	17
5	<i>Eucalyptus obliqua</i>	Nilgiri	Exotic	6.91 $\pm$ 1.26	1.09 $\pm$ 0.19	0.69 $\pm$ 0.14	430.95	112.05	543	271.5	993.68	5.98	6
6	<i>Ficus racemosa</i>	Umber	Native	8.99 $\pm$ 3.49	1.09 $\pm$ 0.48	1.21 $\pm$ 0.46	268.8	69.89	338.69	169.34	619.8	4.97	8
7	<i>Polyalthia longifolia</i>	Ashok	Exotic	10.89 $\pm$ 3.00	0.91 $\pm$ 0.37	0.88 $\pm$ 0.05	424.8	110.45	535.25	267.62	979.5	243.58	248
8	<i>Callistemon citrinus</i>	Bottle Brush	Exotic	9.75 $\pm$ 4.31	1.14 $\pm$ 0.49	1.32 $\pm$ 0.36	454.5	118.17	572.67	286.34	1047.99	13.66	13
9	<i>Cassia siamea</i>	Kassod	Native	9.94 $\pm$ 4.47	1.21 $\pm$ 0.63	1.84 $\pm$ 0.30	801.55	208.4	1009.95	504.98	1848.21	96.37	52
10	<i>Muntingia calabura</i>	Cherry	Exotic	4.00 $\pm$ 2.31	0.45 $\pm$ 0.16	0.07 $\pm$ 0.01	18	4.68	22.68	11.34	41.5	0.71	17
11	<i>Cocos nucifera L.</i>	Coconut	Exotic	11.05 $\pm$ 6.08	0.91 $\pm$ 0.33	0.91 $\pm$ 0.22	360	93.6	453.6	226.8	830.09	13.32	16
12	<i>Delonix regia</i>	Gulmohar	Exotic	7.94 $\pm$ 2.61	1.09 $\pm$ 0.74	1.24 $\pm$ 0.34	516.75	134.36	651.11	325.55	1191.52	26.28	22
13	<i>Spathodea campanulata</i>	Pichkari	Exotic	9.23 $\pm$ 3.26	0.88 $\pm$ 0.64	1.05 $\pm$ 0.44	142.5	37.05	179.55	89.78	328.58	7.25	22
14	<i>Sesbania bispinosa</i>	Shevari	Native	8.17 $\pm$ 2.21	0.62 $\pm$ 0.37	0.35 $\pm$ 0.09	107.5	27.95	135.45	67.73	247.87	4.72	19
15	<i>Ficus benghalensis</i>	Vad	Native	6.62 $\pm$ 3.89	1.31 $\pm$ 1.68	4.39 $\pm$ 3.94	351	91.26	442.26	221.13	809.34	5.68	7
16	<i>Hyophorbe lagenicaulis</i>	Bottle Palm	Exotic	10.12 $\pm$ 5.28	1.16 $\pm$ 0.44	1.53 $\pm$ 0.26	490.5	127.53	618.03	309.02	1130.99	31.75	28
17	<i>Tamarindus indica</i>	Chinch	Native	12.57 $\pm$ 2.47	0.98 $\pm$ 0.67	1.46 $\pm$ 0.84	720	187.2	907.2	453.6	1660.18	8.32	5
18	<i>Syzygium cumini</i>	Jambhul	Native	12.13 $\pm$ 3.57	1.43 $\pm$ 0.67	2.66 $\pm$ 0.63	1386	360.36	1746.36	873.18	3195.84	48.07	15

19	<i>Mangifera indica</i>	Mango	Native	11.69 ± 3.02	1.52 ± 0.52	2.65 ± 0.51	1177	306.02	1483.02	741.51	2713.93	54.43	20
20	<i>Albizia saman</i>	Rain tree	Exotic	11.44 ± 4.59	1.83 ± 0.82	4.41 ± 1.38	1586	412.36	1998.36	999.18	3657	55	15
21	<i>Moringa oleifera</i>	Shevaga	Native	5.67 ± 2.22	0.88 ± 0.35	0.48 ± 0.24	94.32	24.52	118.84	59.42	217.48	1.09	5
22	<i>Acacia auriculiformis</i>	Australia n Babhul	Exotic	6.97 ± 2.13	1.06 ± 0.48	0.86 ± 0.34	421.6	109.62	531.22	265.61	972.13	6.82	7
23	<i>Ficus religiosa</i>	Pimpal	Native	6.83 ± 2.01	0.69 ± 0.49	0.44 ± 0.31	101.4	26.36	127.76	63.88	233.81	1.17	5
24	<i>Casuarina equisetifolia</i>	Suru	Exotic	7.48 ± 1.27	0.86 ± 0.22	0.47 ± 0.09	365.2	94.95	460.15	230.08	842.08	9.29	11
25	<i>Ficus elastica</i>	Rubber	Native	6.10 ± 0.01	0.67 ± 0.09	0.66 ± 0.03	132	34.32	166.32	83.16	304.37	0.92	3
26	<i>Pithecellobium dulce</i>	Vilayati Chinch	Exotic	3.35 ± 1.10	0.37 ± 0.16	0.04 ± 0.02	25.6	6.66	32.26	16.13	59.03	0.18	3
27	<i>Saraca asoca</i>	Sitecha Ashok	Native	4.42 ± 0.22	0.71 ± 0.04	0.18 ± 0.02	144	37.44	181.44	90.72	332.04	0.67	2
28	<i>Grevillea robusta</i>	Silver Oak	Exotic	8.53 ± 1.74	1.01 ± 0.47	0.83 ± 0.24	325.68	84.68	410.36	205.18	750.95	3.01	4
29	<i>Gliricidia sepium</i>	Undirmar i	Exotic	4.46 ± 1.83	0.81 ± 0.44	0.38 ± 0.10	170.2	44.25	214.45	107.23	392.45	6.69	17
Total							12160. 06	3161.62	15321.6 8	7660.84	28038.6 7	692.31	638

*S.E. = Standard error, S.D. = Standard deviation, Avg=Average.

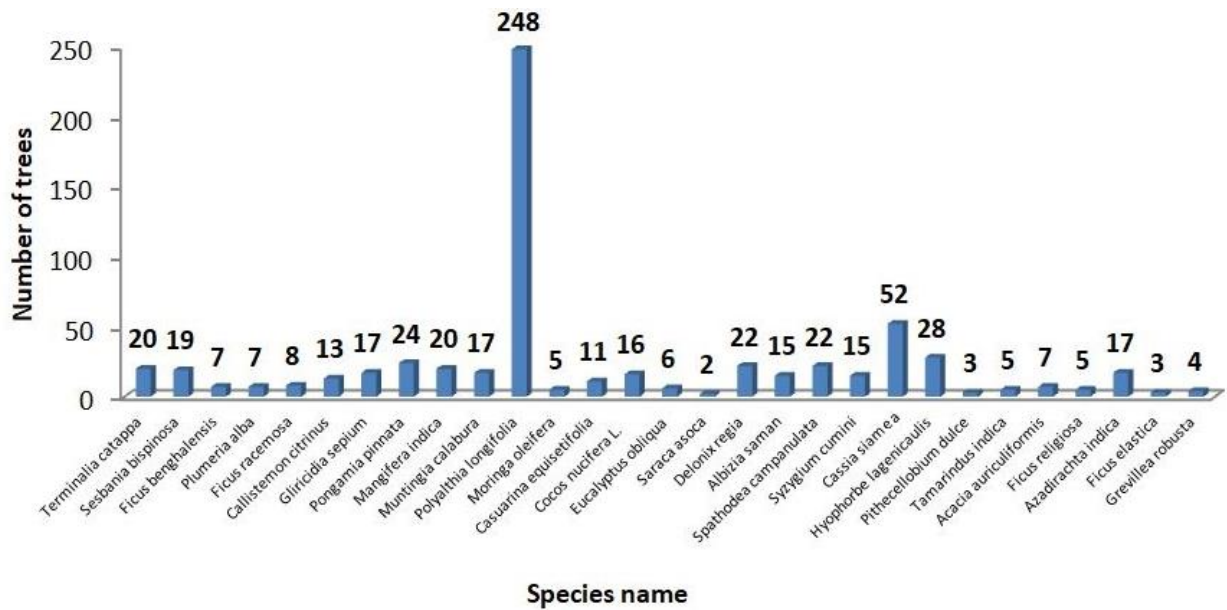


Fig. 3. Tree species distribution in selected gardens of Kolhapur city

Table 1 shows a range of average heights in meters with varying levels of variability. Species like *Ficus elastica* (6.10 ± 0.01) and *Saraca asoca* (4.42 ± 0.22) with minimum SD (*Standard Deviation*) indicate a relatively narrow range of heights, while others e.g. *Cocos nucifera L* (11.05 ± 6.08) and *Hyophorbe lagenicaulis* (10.12 ± 5.28) have a maximum SD, suggesting a wider range of heights. The species *Ficus benghalensis* (1.31 ± 1.68), *Albizia saman* (1.83 ± 0.82) and *Delonix regia* (1.09 ± 0.74) have maximum SD hence show more variability in GBH, while the species *Saraca asoca* (0.71 ± 0.04) and *Ficus elastica* (0.67 ± 0.09) which have minimum SD have a more consistent GBH. The average girth at breast height (GBH) is an important metric to consider for analyzing the tree's overall size and health. Larger GBH values indicate mature and well-developed trees. Such trees might be preferred for their stability and longevity. This can be useful for various ecological and environmental studies, tree management, and conservation efforts for carbon sequestration. The average volume of different tree species along with the SE (*Standard error*), represents the variability in the observations. The tree species have a low SE, indicating low variability and high confidence in the average volume, while others have a larger SE, indicating higher variability and less confidence in the average volume estimation. The volume of tree can be used to compare the sizes of different

tree species and study their ecological significance and potential impact on the environment.

The research found that, *Albizia saman* has the highest average carbon stock i.e. 999.18 kg C/tree followed by *Syzygium cumini* (873.18 kg C/tree) and *Mangifera indica* (741.51 kg C/tree) (Fig. 4). The highest average AGB was recorded in *Albizia saman* (1586 kg) followed by *Syzygium cumini* (1386 kg) and *Mangifera indica* (1177 kg) while lowest average AGB has recorded in *Muntingia calabura* (18 kg). The highest average BGB was recorded in *Albizia saman* (412.36 kg) followed by *Syzygium cumini* (360.36 kg) and *Mangifera indica* (306.02 kg). The lowest average BGB was recorded in *Muntingia calabura* (4.68 kg). *Albizia saman* (1998.36 kg) recorded maximum total biomass among all 29 tree species followed by *Syzygium cumini* (1746.36 kg) and *Mangifera indica* (1483.02 kg). *Muntingia calabura* (22.68 kg) recorded the lowest total biomass during the research (Fig. 5).

We discovered that above ground biomass is more strongly correlated with DBH (CLARK ET AL., 2001). Hence, during this study *Albizia saman* had the highest average DBH of 0.58 m which gave the highest above ground biomass among all other species. Also, it is acknowledged by many experts that simple models with only diameters as input is one of the best estimators of AGB (DJOMOA ET AL. 2010). The maximum DBH records the highest carbon stock and shows a positive correlation (Fig. 6).

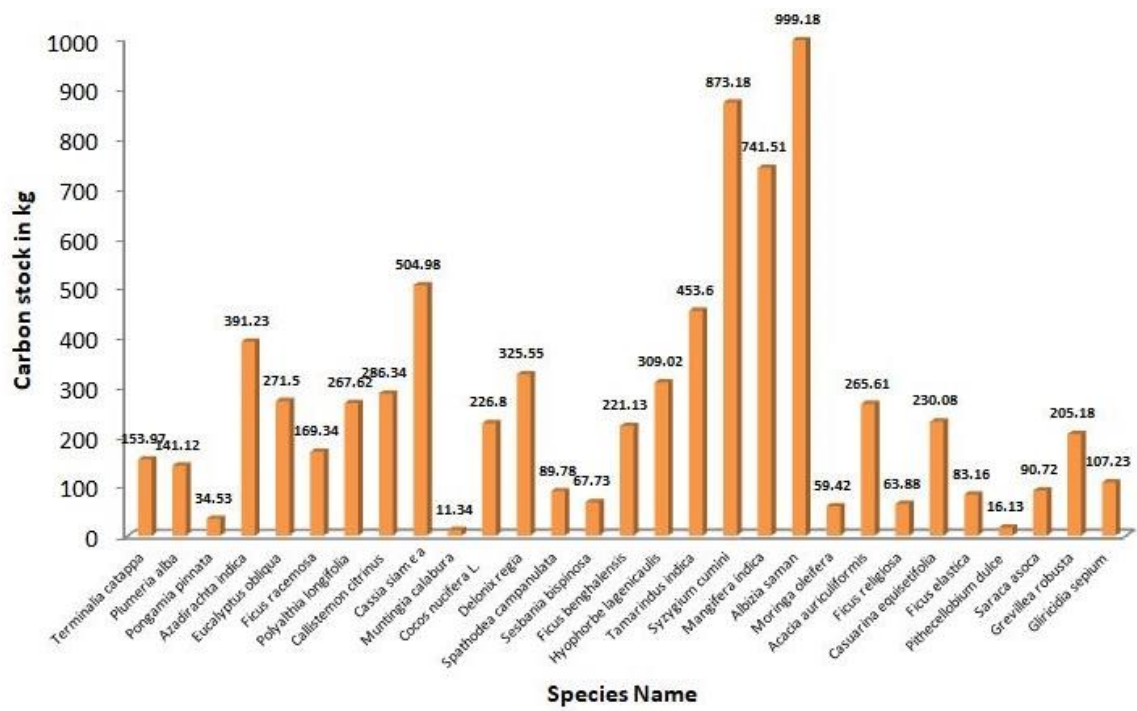


Fig. 4. Species wise average carbon stock distribution in selected gardens of Kolhapur

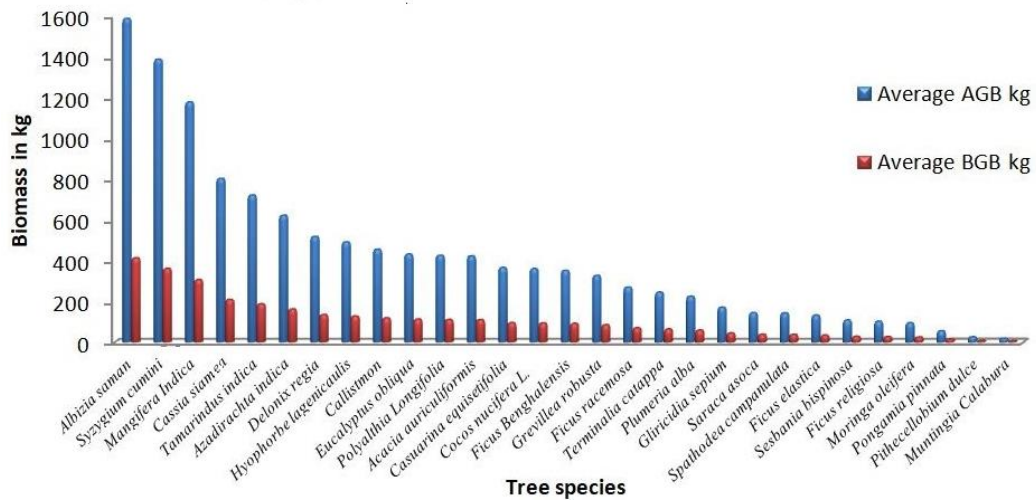


Fig. 5. Species wise distribution of AGB and BGB in selected gardens of Kolhapur

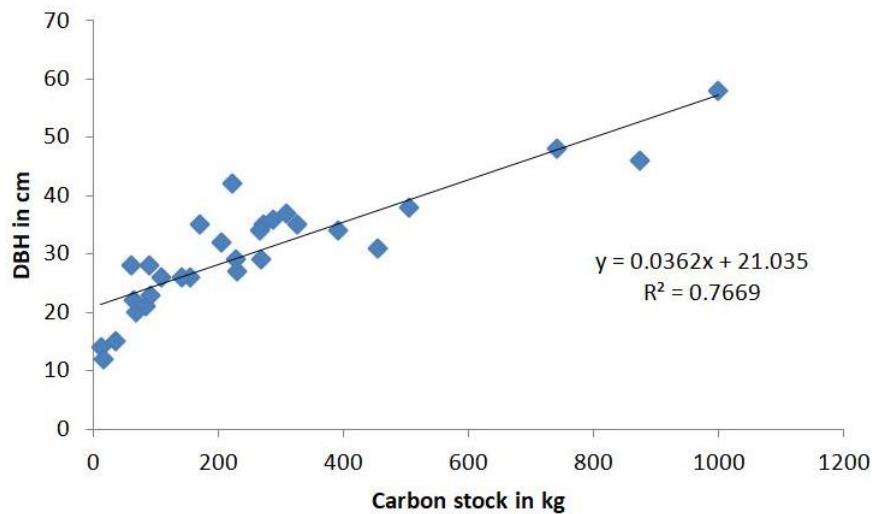


Fig. 6. Relation between tree DBH and carbon stock

According to studies (GIBBS ET AL., 2007; VASHUM & JAYAKUMAR, 2012), tropical urban forests are carbon-rich ecosystems that contribute equal to 55% of total terrestrial carbon sink out of which above ground biomass accounts for the highest carbon pool in these ecosystems. *Polyalthia longifolia* sequestered the highest CO₂ (242.94 tons) followed by *Cassia siamea* (96.11 tons) and *Albizia saman* (54.85 tons). *Pithecellobium dulce* recorded the lowest CO₂ sequestration at 0.18 tons. A study carried out by MACDIKEN (1997) revealed that large healthy trees with a diameter of more than 77 cm sequester approximately 90 times more carbon compared with small healthy tree species which have a diameter of less than 8 cm. Larger trees also preserve approximately 1000 times more carbon than smaller trees (MACDIKEN, 1997; DJOMOA ET AL., 2010). Similar consistent results were observed in the study by POTDAR ET AL. (2017) in Aurangabad city where 853 trees sequester 565.30 tons of CO₂ and by HANGARGE ET AL. (2012) at Somjaichi Rai, Bor, Pune which is also an urban green space in Maharashtra. The 4000 trees in Somjaichi Rai sequestered 1055.283 tons in Maharashtra. Carbon sequestration rates vary by tree species, soil type, regional climate, topography and management practice (EPA, 2010). As the urban areas are responsible for or causing discharge maximum amount of emissions of carbon, tree creates an impact on carbon emissions through changing in climates at micro level, albedo, use of energy, and maintenance of emission which require to be added with tree storage and capture estimates to improve a more complete role of urban trees of urban area on climate change (DJOMOA ET AL., 2010). In order to facilitate future urban designs that may enhance the environmental and social benefits of urban trees and lessen climate change effect. It is imperative to comprehend the relationship that exists between people, the environment and urban trees in the urban ecosystem. According to ANBARASHAN ET AL., 2020, in mixed species plantings had higher values of carbon sequestration than mono plantations.

4. Conclusion

This study was an inventory of the trees and their carbon storage capacity from gardens and green spaces of Kolhapur; Maharashtra, India. Trees from urban areas play a vital role in reduction in the level of atmospheric carbon dioxide. In this study 29 tree species were recorded with 638 individuals. The study revealed that trees from green spaces have a higher potential for carbon sequestration. We used a non-destructive method to calculate carbon stock and the carbon sequestration

potential of tree species. Only for the beautification purpose of green spaces is exotic species in garden areas are increasing without considering carbon sequestration potential. A total of 692.31 tons of carbon was sequestered in ten gardens of Kolhapur. The carbon sequestration potential of native tree species was 508.74 tons whereas exotic species was 191.24 tons. The ratio of native to non-native species in the population is 1:2.16 which shows the high potential of native trees for carbon sequestration. Additionally, it has been found that, the success of plantations is more strongly influenced by local climate. The development in height and girth of the crown is mainly determined during growth in the monsoon (rainy) season, while minimal growth occurs during dry seasons. Mixed species of trees are planted in gardens since they are typically used for recreation with an eye towards aesthetics. This study highlights the value of urban trees not only for beauty and aesthetic purposes but also for their carbon sequestration potential in order to combat climate change at the local level. These results will be helpful for the sustainable management of Kolhapur, and for many other cities in Maharashtra, and the rest of India. This will also highlight the value of the carbon sinks in urban areas for sustainable future.

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